# U.S. Virgin Islands Energy Road Map: Analysis

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**NOTICE**

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# Acknowledgments

# List of Acronyms

| | |
|---|---|
| AC | alternating current |
| ARRA | American Recovery and Reinvestment Act of 2010 |
| BAU | business as usual |
| COE | cost of energy |
| CREST | Cost of Renewable Energy Spreadsheet Tool |
| CSP | concentrating solar power |
| DC | direct current |
| DHW | domestic hot water |
| DNI | direct normal irradiance |
| DOE | U.S. Department of Energy |
| DOI | U.S. Department of Interior |
| ECM | energy conservation measure |
| EDIN | Energy Development in Island Nations |
| EIA | U.S. Energy Information Administration |
| ESCO | energy service company |
| FIT | feed-in tariff |
| GSHP | ground source heat pump |
| HRSG | heat recovery steam generator |
| IECC | International Energy Conservation Code |
| KEA | Kodiak Electric Association |
| LEAC | levelized energy adjustment clause |
| LCOE | levelized cost of energy |
| LFG | landfill gas |
| LMOP | Landfill Methane Outreach Program |
| MED | multiple-effect distillation |
| MSW | municipal solid waste |
| NREL | National Renewable Energy Laboratory |
| OTEC | ocean thermal energy conversion |
| PREPA | Puerto Rico Electric Power Authority |
| PSC | USVI Public Services Commission |
| PV | photovoltaic |
| RDF | refuse-derived fuel |
| RES | renewable energy standard |
| RO | reverse osmosis |
| SF | solar fraction |
| SWH | solar water heating |
| tpd | tons per day |
| tpy | tons per year |
| USD | U.S. dollars |
| USVI | U.S. Virgin Islands |
| VIEO | Virgin Islands Energy Office |
| WAPA | USVI Water and Power Authority |

# Executive Summary

With high energy costs, isolated grids, and abundant renewable energy resources, island communities around the world are exploring alternatives to fossil fuels. Many small island states have set ambitious targets to reduce oil consumption—the primary fossil fuel consumed on islands. The U.S. Virgin Islands (USVI) has emerged as a leader in the effort to reduce oil imports and stabilize electricity costs via the deployment of energy efficiency and renewable energy technology. In 2010, a partnership among the USVI, the U.S. Department of Energy (DOE) who funded this report, and the U.S. Department of the Interior (DOI) was formed under the guidance of DOE's Energy Development in Island Nations (EDIN) initiative. This partnership is tasked with developing and implementing a plan to achieve a 60% reduction in business-as-usual (BAU) fossil fuel demand by 2025 (60x25).

This report lays out the strategy envisioned by the stakeholders in the USVI, DOE, and DOI to achieve this ambitious goal within the electricity sector (the full 60x25 goal also includes fossil fuel consumption in the transportation sector). The results presented here do not identify or quantify all power system or rate impacts. Instead, this work and supporting analysis provides a framework within which decisions can begin to be made, a concrete vision of what the future might hold, and a guide to determine what questions should follow.

## Methodology

The path forward articulated here was developed through four primary efforts:

- A review of existing initiatives and activities that are currently focused on decreasing oil consumption in the power sector

- A review and analysis of energy efficiency potential within specific sectors of the USVI economy

- A screening for technical and market potential of renewable technologies

- The development of a model that allows basic assessments of the relative impact and cost effectiveness of each efficiency and renewable energy opportunity.

This analysis combined the review of ongoing activities with assessments of energy efficiency potential and the results of the renewable energy technology screening to develop three potential future energy scenarios where the USVI achieves its 60x25 goal. The three scenarios have been labeled as the *High Renewable Scenario*, the *Base Case*, and the *High Efficiency Scenario*. These scenarios are intended to represent a reasonable profile of what the USVI energy mix could look like in 2025. Each scenario contains a slightly different mix of end-user energy efficiency (e.g., more efficient lighting and appliances) and renewable energy, with the same set of supply-side efficiency improvements (i.e., improved efficiency in the production and distribution of electricity and desalinated water) common to all three scenarios. The high renewable and high efficiency scenarios are intended to represent the possible extremes associated with deployment of commercially available technology. The base case is a blend or mix of these two more extreme scenarios.

The scenarios laid out here are not intended to prescribe the path to the 60x25 goal. The scenarios are designed serve as a guide moving forward. The continued evolution of technology

and the development of a more complete understanding of costs and benefits in the USVI are expected to influence the ultimate deployment of renewable energy and energy efficiency technology. Results presented here should be viewed in this context and followed by more detailed economic and power system studies.

## Current Initiatives

An array of current activities is expected to provide reductions in power sector oil consumption. At the utility level, initiatives include:

- Plans for a 16.5 MW waste-to-energy plant

- Upgrades to existing generation and transmission and distribution infrastructure to increase efficiency and allow improved operational practices

- Plans to acquire utility-scale photovoltaic (PV) generation

- A technical study of a proposed St. Thomas-to-Puerto Rico interconnection

- Plans to shift water production from multiple effect distillation (a thermal process requiring fossil fuel inputs) to reverse osmosis (a membrane technology requiring less primary energy input).

On the private sector and consumer side, various distributed generation projects have also been initiated, with some already completed.

## Efficiency Opportunities

Preliminary assessments from an industry consultant (e.g., VIEA 2010) indicated significant energy efficiency opportunities among large commercial and industrial consumers as well as in the government sector. Modeling of end-user efficiency has also identified a diverse set of opportunities in the residential sector. Reductions in end-use consumption on the order of 20%–40% have been estimated across end-user types. On the supply-side, estimates based on the USVI Water and Power Authority's (WAPA's) current fuel consumption and operations practices suggest that supply-side efficiency could result in a 22% increase in overall power system production efficiency. Estimates of transmission and distribution system upgrades have the potential to reduce technical distribution losses by 2%.

## Renewable Energy Opportunities

The detailed screening of renewable energy technologies conducted in this study suggests considerable resource and technical potential across the USVI. From those technologies deemed to be economically viable, landfill gas, waste-to-energy, and biomass power are among the lowest-cost options for the USVI. As dispatchable resources, they also integrate well with small power systems. Power generation from these three resources figures prominently in all future scenarios where the USVI achieves its 60x25 goal. However, these power generation alternatives are resource limited. In contrast, wind power (which is also among the lowest-cost renewable energy technologies), solar PV, and solar water heating (SWH) are resource abundant in the USVI. Due to potential land-use impacts and possible siting challenges, utility-scale wind capacity in the three scenarios noted above ranges from 12 MW to 33 MW. As the highest-cost renewable energy technology considered in the road map, solar PV capacity ranges from only 6 MW to 13 MW, with the majority of this being utility-scale PV installations. Residential

penetration of SWH is estimated to be between 40% and 50% based on favorable economics, resulting from its ability to offset retail electricity consumption and relatively high penetration levels (30%–35%) observed in other island settings (e.g., Barbados) (Langniss and Ince 2004).

## Expected Impacts and Fuel Cost Savings

A 60% reduction in BAU electricity sector fossil fuel consumption is achieved by 2025 in each of the three scenarios examined. The expected rate of reduction in fossil fuel consumption is consistent between scenarios with the overall trend shown in Figure ES-1. This figure also illustrates the annual and cumulative fuel cost savings assuming a constant real (2010) fuel price of $1.91/gal. With this assumption, the 60x25 goal would save a cumulative total of more than $1.5 billion. Fuel cost savings are estimated to exceed the initial capital investment costs required to implement the 60x25 goal by the latter half of this decade (Figure ES-1).
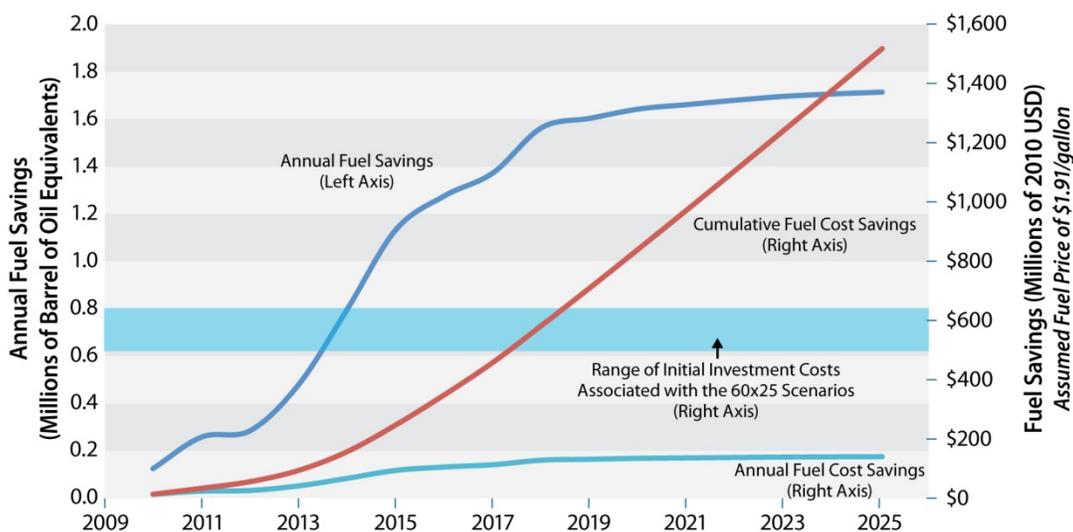


**Figure ES-1. Expected fuel savings in barrel of oil equivalents, cost savings at $1.91/gal, and capital expenditures required to achieve 60x25**

Note: All dollar values are reported as constant 2010 USD.

## Differences among the Scenarios

While the overall impact on fossil fuel consumption (i.e., 60% reduction) is comparable between individual scenarios, each case differs around a few critical variables. Figure ES-2 illustrates the respective percentage of conventional fossil fuel generation, renewable energy generation, and energy efficiency used to serve the BAU 2025 fossil fuel demand across each scenario. Clearly, renewable energy and energy efficiency improvements become a critical part of meeting expected future demand for energy services in the USVI. Much of the efficiency improvements across all three scenarios are anticipated to come from improvements in the efficiency of water and power production.
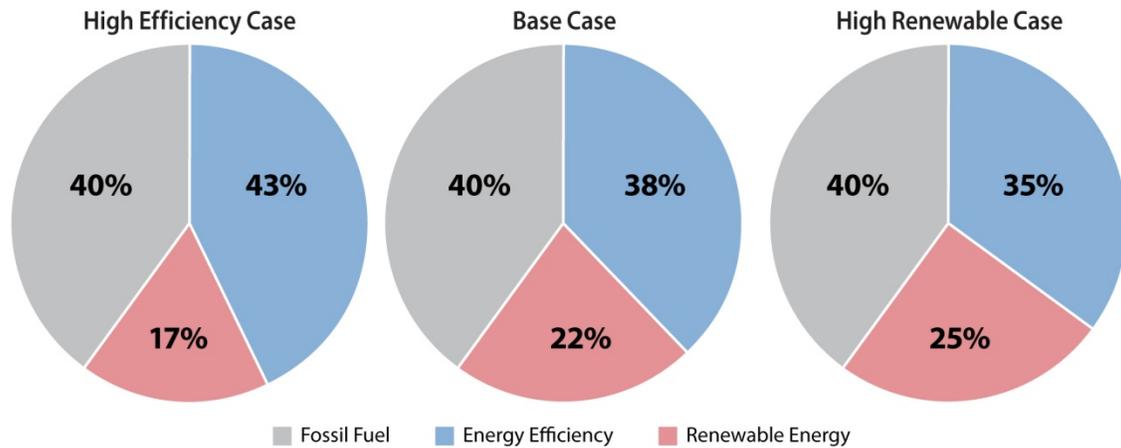
**Figure ES-2. Percentage of conventional fossil fuel generation, renewable energy generation, and energy efficiency used to serve the expected, business as usual 2025 fossil fuel demand across scenarios**

Because of the reliance on different types of technology to achieve the goals, initial investment costs also vary between scenarios. The high renewables scenario is the most costly at $635 million (constant 2010 USD).[1] It also relies on the largest deployment of utility-scale renewable energy generation technology. The base case is estimated to cost about $565 million. The high efficiency case is estimated to cost $495 million. The increased cost of the high renewables scenario is the result of increased reliance on utility-scale renewable generation technology. However, increased reliance on utility-scale generation in the high renewables scenario makes for simpler implementation and has the potential for reduced transaction costs relative to the high efficiency scenario. Ease of implementation and lower transaction costs could become significant if deploying large amounts of end-user efficiency ultimately requires large additional expenditures in outreach and technical support in order to mobilize the local population to adopt energy efficiency improvements.

Penetration of variable output renewables also changes among the scenarios. This issue is of particular importance in grid operations for small island power systems. Results from this analysis suggest variable generation could constitute 10% to 20% of WAPA's generation mix. Such levels of variable output generation have been successfully managed in a variety of large and small power systems around the world. However, grid integration and reliability studies will be required to better understand the potential impacts and any potential additional cost that might be associated with deploying this level of variable output renewables.[2]

## Conclusions

Reducing fossil fuel consumption 60% from BAU by 2025 in the USVI is ambitious and will require aggressive deployment of energy efficiency and renewable energy technologies. However, investments in energy efficiency and renewables could pay for themselves before the end of this decade and support 400 new jobs by 2025 (Shirley and Kammen 2010, Text Box 3), while also generating reductions in greenhouse gas and other emissions.

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[1] All dollar values are reported in constant (i.e., non-discounted) 2010 USD.
[2] Integrating renewable energy into the USVI grid is explored in somewhat greater detail by Burman et al. 2011.

Many steps have already been taken to move the USVI toward its goal, and initial progress has been impressive. To maintain this momentum, however, a number of important next steps across an array of fronts are likely to be necessary (e.g., detailed resource assessment, detailed analysis of specific efficiency opportunities, project-specific cost-of-energy analysis, and power systems studies to better understand the system impacts of variable output generation). In addition, achieving 60x25 is likely to require sustained investment of human and financial resources and a coordinated effort among the utility sector, government agencies, private businesses, and USVI residents. New policy measures may also be needed to facilitate and encourage deployment of renewable energy and energy efficiency technologies.

Nevertheless, this report illustrates that the desired transformation is technically and economically attainable using renewable energy and efficiency technologies that are commercially available today. Through the EDIN-USVI effort, a broad group of federal and local stakeholders have identified a set of pathways that could transform the energy economy in the USVI.

The approach adopted for this effort can be extended to other island communities that face similar challenges of high energy costs and heavy dependence on foreign oil. By identifying existing resources, analyzing how these assets might be leveraged to accomplish more, and identifying a concrete set of actions that can achieve ambitious goals, other island states can also gain a firm understanding of the actions necessary to reduce dependence on imported oil.

# Table of Contents

# List of Figures

# List of Tables

# 1  Introduction

Developing and advanced economies rely on secure, affordable energy for economic growth and prosperity. The United Nations Development Program has identified energy as a fundamental key to eliminating poverty and achieving its Millennium Development Goals (UNDP 2011). Island communities similarly require access to affordable, secure sources of energy for social, economic, and environmental development. However, island communities face a unique set of challenges associated with access to and development of energy. They typically have few conventional energy resources (i.e., oil, natural gas, and coal), and their remoteness and relatively small size lead to diseconomies of scale (Weisser 2004). Such features also apply to "islanded" power systems that may exist in extreme remote (e.g., Alaska) or rural settings (e.g., in the developing world).

The absence of indigenous resources, coupled with small power systems, has favored the deployment of diesel or oil-powered electricity generation on islands. As part of a global market, oil is a relatively easy fuel to acquire, and by utilizing oil for both power generation and transportation, some efficiency in market size is gained. Oil-fired generation also permits the relatively rapid ramp rates necessary to manage the greater variability in load that often results in a small power system. However, as prices have climbed, dependence on oil has created significant challenges. High prices are exacerbated for islands by market size and location (i.e., often small and remote from major global markets); evidence suggests that in some cases island states may pay 200%–300% of the prevailing global market rate for fuel imports (Weisser 2004). Moreover, oil price volatility is a source of instability and uncertainty in business and economic planning. When oil prices spike, recession, reallocation of funds that might otherwise go to infrastructure or development programs, trade imbalances (with associated impacts on the ability to acquire and service debt), and extreme debt burdens are only a few of the economic consequences (Munasinghe and Mayer 1993).

Renewable energy technologies and energy efficiency technologies offer two potential solutions to the energy dilemma island communities face, and the contained system that islands constitute makes them ideal test beds for high penetration renewables deployment. As such, island communities can provide unique opportunities to demonstrate the feasibility of moving to an advanced energy economy with far greater fuel diversity than exists elsewhere and offer a glimpse of what the future might hold for the rest of the world.

Throughout the world, island communities are exploring alternatives to fossil fuels, and many have set ambitious targets to reduce fossil fuel consumption. Two examples include Kodiak Island, Alaska, and Hawaii. In 2009, Kodiak Island installed three General Electric 1.5 MW wind turbines and now generates about 9% of its power from wind (KEA 2011). The Hawaii Clean Energy Initiative is a coordinated effort between the State of Hawaii and the U.S. Department of Energy (DOE) focusing on achieving the state's ambitious 70% by 2030 clean energy goal (30% efficiency, 40% renewables).

Along with Kodiak Island and Hawaii, the U.S. Virgin Islands (USVI) has emerged as a leader in the effort to reduce oil imports and stabilize electricity costs via the deployment of energy efficiency and renewable energy technology. In 2010, a partnership between the USVI, DOE who funded this report, and the U.S. Department of Interior (DOI) was formed under the

guidance of DOE's Energy Development in Island Nations (EDIN) initiative. During the signing of a Memorandum of Understanding between these three organizations, USVI Governor John de Jongh, Jr., announced his goal:

> "The USVI will lead the Caribbean to a clean energy future. We will lead by example and reduce our fossil fuel imports by 60% from business as usual by 2025."
>
> *Governor John P. de Jongh, Jr., February 16, 2010, opening remarks at the signing of the Memorandum of Understanding between the USVI, DOE, and DOI*

The USVI, DOE, and DOI are working together to achieve this ambitious goal. Fundamental to this effort is the development of a strategy or road map detailing the steps the USVI can take to accomplish 60x25 (60% by 2025). This report lays out the strategy envisioned by the stakeholders in the USVI, DOE, and DOI to reduce USVI electricity sector and water production[3] fossil fuel use by 60% over the next 15 years.[4] This work is necessary because decisions made today will determine the future of energy use in the USVI for decades to come. In addition, a comprehensive planning effort helps to define targets and demonstrates what needs to be accomplished within the time period of the goal. In documenting the planning process used in the USVI and its outcomes, it is hoped that other island communities and nations (large and small) can learn from the experience and resolve of the USVI. Eventually, lessons learned on the island of St. Thomas could be applied to the island of Manhattan.

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[3] Freshwater resources in the USVI are produced by seawater desalination. The desalination process is a relatively energy-intensive enterprise but is necessary due to minimal domestic freshwater resources.

[4] The 60x25 goal also includes transportation fossil fuel consumption; however, the analysis of the transportation sector was outside the scope of this report.

## 2 USVI Background

The USVI consists of three primary islands—St. Thomas, St. Croix, and St. John—and a handful of surrounding islands. The islands are located in the Caribbean Sea approximately 50 mi east of Puerto Rico. The islands in the north, St. Thomas and St. John, are separated from St. Croix by about 40 mi of ocean and a deep sea trench, which exceeds 2 km in depth.



**Figure 1. Map of the U.S. Virgin Islands**
Map provided courtesy of the CIA (2011)

The climate is tropical with relative humidity averaging from 67% to 85% but moderated by easterly trade winds (Table 1). In total, the islands consist of just over 130 mi$^2$ and have nearly 120 mi of coastline (CIA 2011). The islands are relatively mountainous with only about 5% of total land area designated as arable and limited amounts of flat land (CIA 2011). Apart from rainfall, little to no freshwater is available (CIA 2011). Due to their location in the Caribbean, hurricanes are a threat, and multiple hurricanes in the past 25 years have damaged electrical infrastructure (WAPA 2010).

**Table 1. Monthly High and Low Temperatures on St. Thomas and St. Croix (°F)**

| | St. Thomas | | St. Croix | |
|---|---|---|---|---|
| | Maximum | Minimum | Maximum | Minimum |
| January | 85 | 72 | 84 | 72 |
| February | 85 | 72 | 84 | 72 |
| March | 86 | 73 | 85 | 72 |
| April | 87 | 74 | 86 | 74 |
| May | 88 | 76 | 87 | 76 |
| June | 89 | 78 | 88 | 78 |
| July | 90 | 78 | 89 | 78 |
| August | 90 | 78 | 90 | 78 |
| September | 90 | 77 | 89 | 77 |
| October | 89 | 76 | 89 | 76 |
| November | 87 | 75 | 87 | 74 |
| December | 86 | 73 | 85 | 73 |

Source: VINow 2011

The aggregate population of the islands is estimated to be approximately 109,000 (CIA 2011). About 42% of the population is between the ages of 25 and 54 (U.S. Census 2000).[5] Median household income, adjusted for inflation, is estimated to be approximately $32,000—well below the current U.S. average of about $50,000 (U.S. Census 2000; U.S. Census 2010).[6] The poverty rate is relatively high in the USVI. U.S. Census data (2000) indicate approximately 29% of families and 33% of individuals live below the poverty line. This can be compared with a 2009 poverty rate of approximately 14% for the United States (U.S. Census 2010).

The USVI observed a period of steady economic growth throughout much of the previous decade. Between 2003 and 2007, the U.S. Bureau of Economic Analysis data indicate gross domestic product per capita grew at an average annual rate of 2%. Between 2001 and 2008, employment grew approximately 6.5% (VIBER 2011). However, in 2008, economic growth stalled and employment has nearly returned to 2001 levels (VIBER 2011). Tourism is the primary economic driver, making up an estimated 80% of the territory's economic activity. Behind tourism, manufacturing is the second largest source of economic activity. The manufacturing sector includes oil refining, rum distillation, textiles, and electronics (CIA 2011).

## 2.1 Utility Sector Overview

Similar to many island communities, the USVI is 100% dependent on imported fuel oil for electricity (WAPA 2010). Retail electricity rates in 2011 have ranged from $0.33/kWh to as high as $0.49/kWh[7] and were as high as $0.52/kWh following the oil price spikes of 2008 (VI PSC

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[5] Although 2010 census data were collected in the USVI, these data were not yet available at the time of this report.
[6] Median household income in 2000 was reported to be $24,700 (U.S. Census 2000). Inflation adjustment applied here is based on national U.S. consumer price indices.
[7] Average commercial rate for Q3.

2011).[8] The electricity generation and distribution systems in the USVI are owned, operated, and maintained by the Virgin Islands Water and Power Authority (WAPA).[9] Created in 1964, WAPA operates as an independent public utility and is overseen by nine board members. WAPA is regulated by the USVI Public Service Commission (PSC). The WAPA board is responsible for operations-related activities including budgeting, purchasing, and system planning. The PSC primarily oversees utility rate cases and participates in power-sector-related rulemaking; it is also sometimes tasked with policy implementation and enforcement.

WAPA generation assets are primarily located on St. Thomas and St. Croix and consist of steam turbines operating on No. 6 fuel oil, combustion turbines operating on No. 2 fuel oil, and a limited amount of internal combustion (diesel) generation.[10] Capacity is derived primarily from combustion turbines (72%) and steam turbines (28%). Total installed capacity is 191 MW on St. Thomas and 117 MW on St. Croix (RW Beck 2010). Existing generators date from 1967 through 2004, as detailed in Table 2 (RW Beck 2010).

**Table 2. Power Generating Station for St.Thomas/St. John and St. Croix**

| St. Thomas/St. John – Randolph Harley Generation Station | | | |
|---|---|---|---|
| Technology | Fuel Type | Capacity (MW) | In-Service Date |
| Reciprocating Engine Generator | No. 2 Oil | 2.5 | 1985 |
| Fired Boiler STG* | No. 6 Oil | 18.5 | 1968 |
| Simple Cycle CTG | No. 2 Oil | 12.5 | 1970 |
| Simple Cycle CTG | No. 2 Oil | 12.5 | 1972 |
| Fired Boiler STG* | No. 6 Oil | 36.9 | 1973 |
| Combined Cycle CTG/HRSG* | No. 2 Oil | 20.9** | 1981 |
| Combined Cycle CTG/HRSG* | No. 2 Oil | 23.5** | 1993 |
| Simple Cycle CTG | No. 2 Oil | 24.0 | 2001 |
| Simple Cycle CTG | No. 2 Oil | 39.5 | 2004 |
| **Total** | | **146.4** | |
| St. Croix – Estate Richmond Generating Station | | | |
| Fired Boiler STG* | No. 6 Oil | 10.0 | 1967 |
| Fired Boiler STG* | No. 6 Oil | 19.1 | 1970 |
| Combined Cycle CTG/HRSG* | No. 2 Oil | 20.9** | 1981 |
| Combined Cycle CTG/HRSG* | No. 2 Oil | 21.9** | 1988 |
| Simple Cycle CTG | No. 2 Oil | 22.5 | 1994 |
| Simple Cycle CTG | No. 2 Oil | 22.5 | 1994 |
| **Total** | | **74.1** | |

*Fired boilers and HRSGs deliver steam to steam headers and four MED production units
**Capacity shows CTG output only
*Source: R.W. Beck 2010*

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[8] Commercial rates peaked at an average $0.52/kWh and residential rates peaked at 0.50/kWh in 2008. Residential rates in 2011 have been as high as $0.46/kWh.
[9] Street lighting is also owned, maintained, and operated by WAPA.
[10] A limited amount of back-up generation is also located on St. John.

Due to use of low and high pressure steam for desalination, coupled with outmoded controls and non-standardized operations procedures, WAPA's generation fleet operates at a relatively inefficient heat rate—greater than 15,000 BTU/kWh (WAPA 2011). This can be compared with the heat rate for Guam, an island in the South Pacific that also relies on No. 6 and No. 2 fuel oil and had a system average heat rate of 9,720 BTU/kWh, or Hawaii, whose heat rate has been estimated at 10,500 BTU/kWh (Baring-Gould et al. 2011). To enhance the efficiency of existing generation assets, WAPA installed waste heat recovery steam generators (HRSGs) in St. Thomas in 1997 and St. Croix in 2010. WAPA intends to upgrade the St. Thomas HRSGs to capture increased efficiency but has not yet established a timeframe to complete these upgrades.

St. Thomas and St. John are part of one interconnected power system, peaking at approximately 80 MW; the minimum load on the St. Thomas/St. John grid is about 50 MW. The island of St. Croix constitutes the second power system in the USVI. This system peaks at about 50 MW and has a minimum load of 35 MW (WAPA 2010). Although the topography of the ocean floor has prevented the direct interconnection of these two grid systems to date, studies are underway to examine the possibility of connecting both island systems with Puerto Rico (see Text Box 2 in Section 3).

Based on the relatively small size of the two grids, the USVI grid infrastructure consists primarily of sub-transmission lines (25–115 kV). At present, the two grid systems operate at 24.9 kV and 34.5 kV for St. Thomas and St. Croix, respectively. St. Croix is currently in the process of upgrading parts of its system to operate at 69 kV (WAPA 2010). Underwater cables interconnect St. Thomas with St. John and some of the immediate surrounding islands. The distribution systems are typically operated at 13.8 kV (WAPA 2010). Total losses (technical and non-technical) in fiscal year 2009 were estimated at more than 13% on St. Croix, while losses on the St. Thomas/St. John system were estimated at 6% (WAPA 2010).[11]

In addition to power generation, WAPA is responsible for production of desalinated water. Four multiple-effect distillation (MED) units are located on St. Thomas, and four are on St. Croix. Currently the MED desalination units operate by extracting steam from the steam turbines. An estimated 10% of the energy from steam boilers is used to desalinate water (WAPA 2011a). As part of a planned transition to reverse osmosis (RO) desalination, a pilot RO facility has been installed on St. Croix and is operated under contract to WAPA. This system provides about half the total potable water required for St. Croix. WAPA plans to deploy additional RO units in the future, but again no explicit timeframe has been established. Historically, WAPA relied on large water catchment basins as a source of water; however, these basins have deteriorated with age and are no longer in use.

Oil for power generation and desalination is supplied by the HOVENSA oil refinery, a partnership of the Hess Oil Virgin Islands Corporation and Petroleos de Venezuela, located on St. Croix.[12] Fuel from HOVENSA is typically below U.S. market prices due to its location on St. Croix as well as contractual agreements between the USVI government and HOVENSA (WAPA 2010). The modestly reduced fuel price for WAPA from HOVENSA, as well as the

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[11] Technical losses include, for example, line losses; non-technical losses include losses due to thievery.

[12] One of the largest oil refineries in the western hemisphere, HOVENSA, maintains its own independent power and freshwater supply and is not considered an energy consumer in this analysis.

presence of a major oil refinery in the USVI, alleviates the isolation that many islands experience when acquiring oil. However, WAPA and USVI consumers are still subject to the price volatility of the market and are not sheltered from increasing oil prices over time. The historical blended fuel price for WAPA and the fuel price component of the typical USVI electricity bill [i.e., the levelized energy adjustment clause (LEAC)] are shown in Figure 2. Clearly, higher oil prices lead to higher electricity prices. In addition to the LEAC, utility rates are made up by a standard customer charge, energy charge, and a payment in lieu of tax surcharge (VI PSC 2011). However, these variables remain fixed between rate cases. In 2008, LEAC averaged 75%–85% of the average residential retail power bill (VI PSC 2011).
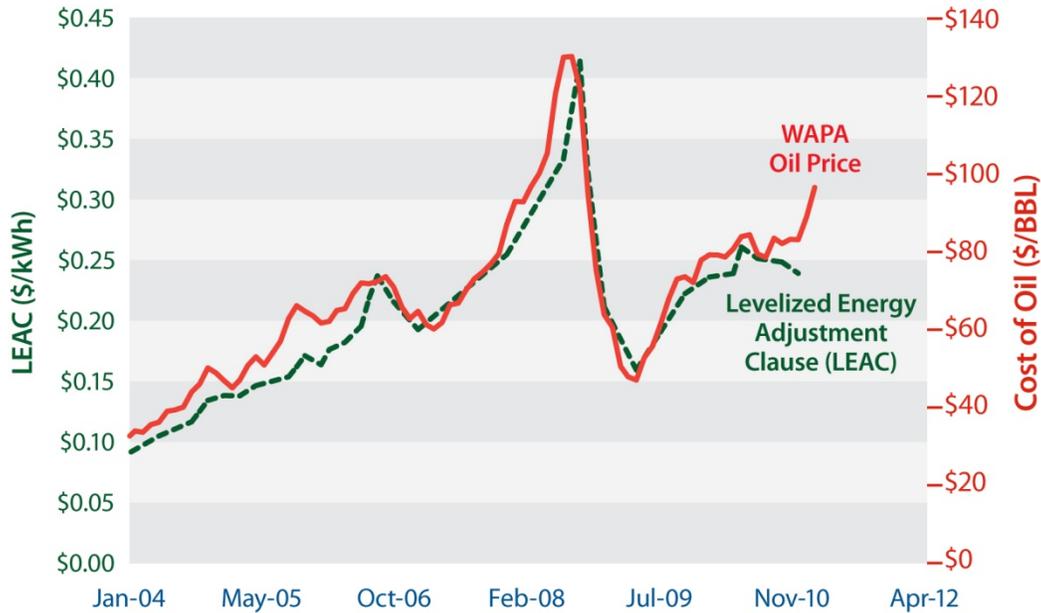


**Figure 2. Historical blended Virgin Islands Water and Power Authority fuel price and levelized energy adjustment clause**

Source: WAPA 2011a
Note: LEAC may not always precisely track the volatility of the oil price. Differences may result from principal and interest payments on fuel-related indebtedness, fuel hedging costs, and historical true-ups that may result from volatility that occurs between LEAC adjustments (WAPA 2011b).

## 2.2 Electricity Consumption in the USVI

For the period 2005 to 2009, WAPA retail customers increased modestly to about 54,000. Retail sales also increased through 2007 before falling in 2008 and 2009 (Figure 3). Decreased consumption observed in 2008 and 2009 is believed to have been a function of price elasticity as the oil price spikes of 2008 resulted in electricity rates on the order of $0.50/kWh for the USVI consumers. Barring widespread deployment of energy efficiency or distributed power capacity, consumption is expected to recover and trend upwards again in the coming years (WAPA 2010; RW Beck 2010).
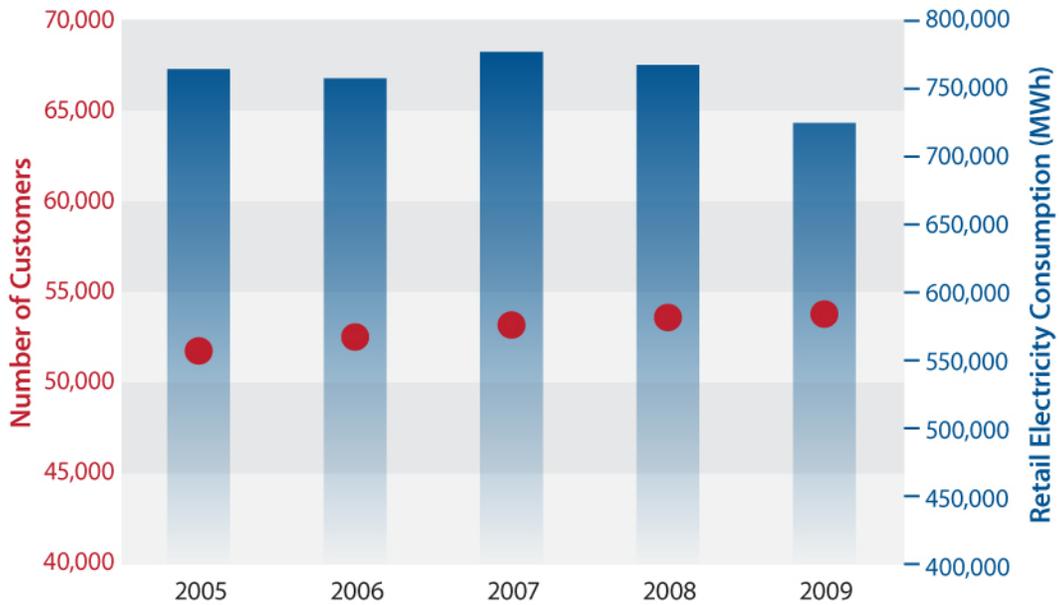
**Figure 3. Recent trends in WAPA customers and sales**

Source: WAPA 2010

Historically, the largest single electricity consumer in the USVI has been the government. In 2009 the government sector was estimated to constitute about 14% of WAPA revenues (WAPA 2010). Outside of the government, the largest individual consumers consist of hotels serving the tourism industry, retail centers, and industrial users (WAPA 2010). By sector, residential loads constitute the greatest share of retail sales, followed by large commercial and industrial users, government, and the small commercial sector (Figure 4). Public services including street and highway lighting constitute approximately 2% of WAPA's retail sales (WAPA 2010; VIEA 2010).
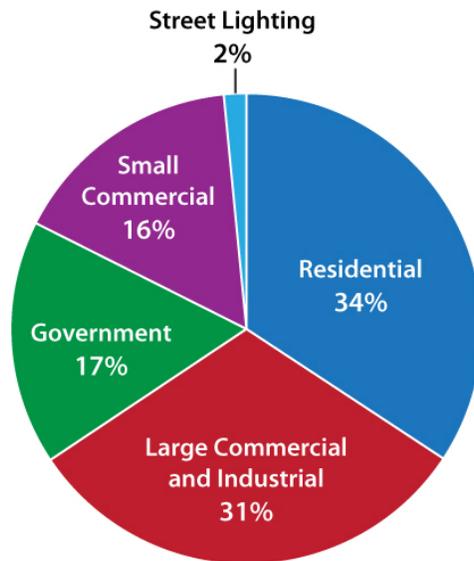


**Figure 4. Retail electricity consumption by sector**

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Energy intensity by sector ranges from 470 kWh/month for residential customers to approximately 1,200 kWh/month for small commercial users. Usage ranges from 21,000 kWh/month to 180,000 kWh/month for large commercial and industrial consumers. Total per capita electricity consumption, including WAPA losses and water production, is estimated to be the equivalent of 8,000 kWh/person/year (WAPA 2010).

## 2.3 Current Policy

### 2.3.1 Act 7075

There has been growing recognition that reduced fuel imports, increased fuel diversity, and greater energy independence are important to the long-term economic strength of the USVI. The territory has engaged this issue in various ways. At the territorial legislative level, Senator Louis Patrick Hill introduced and the legislature passed Act 7075 in 2009 (VI Senate 2009).[13] This major energy bill was signed into law by Governor de Jongh in July 2009 (VI Governor 2009). It includes an array of provisions affecting energy policy throughout the USVI. Most importantly, it seeks to promote an organized transition to renewable energy as well as the widespread deployment of energy efficiency technology, efficient transportation, and solar water heating (SWH) systems. Act 7075 focuses on building knowledge through resource assessment, utility planning, and workforce training. It also authorizes the provision of incentives for solar and wind energy, authorizes net metering, and seeks to reduce institutional and regulatory barriers to deployment of renewable energy technology. SWH is mandated for all new construction and government buildings, and a territory-wide renewable energy standard (RES) has been established.[14]

### 2.3.2 Virgin Islands Energy Office Policies and Recovery Act Programs

Along with Act 7075, the Virgin Islands Energy Office (VIEO) (i.e., the governor's energy office) has been working to identify a comprehensive set of strategies and actions that the USVI can take to reduce fossil fuel imports, reduce energy costs, increase efficiency, and promote clean energy. Building on its long-term programs, the VIEO has also leveraged more than $32 million in American Recovery and Reinvestment Act (ARRA) funds to support a diverse portfolio of rebates, grants, and a revolving-loan program for distributed energy efficiency and renewable energy technology (VIEO 2011) (Table 3). A nearly 80% boost in discretionary grant program funding in 2010 enabled the VIEO to award nearly $1 million to local schools, churches, community foundations, youth organizations, and other non-profits for energy efficiency and renewable energy projects aimed at reducing their energy use and lowering their utility bills (EDIN-USVI 2011). Grant recipients are investing in a variety of energy efficiency and renewable energy technologies, including wind, solar photovoltaics (PV), SWH, LED lighting, compact fluorescent lighting, day-lighting, solar outdoor lighting, insulating radiant barriers, and high-efficiency air-conditioning (VIEO 2011). VIEO has also undertaken efforts to collect improved wind and solar resource data and identify opportunities to reduce fuel consumption and increase efficiency in the transportation sector.

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[13] The USVI has a unicameral legislature consisting of a 15-member senate.

[14] The RES established in Act 7075 requires 30% of peak generating capacity to be from renewable energy technologies by 2025 and includes language that requires a continued increase in renewable energy capacity until more than 50% is from renewable energy technology. The RES is currently being implemented by VIEO and PSC in conjunction with WAPA.

**Table 3. American Recovery and Reinvestment Act of 2009: USVI Funding by Program**

| Program | Description | Funds Allocated (Millions $) |
|---|---|---|
| State Energy Program | Enhance existing funding for energy efficiency and renewable energy programs. | $20.7 |
| Weatherization Assistance Program | Augment existing weatherization efforts in the islands, targeting low income families; expected to weatherize nearly 450 homes. | $1.8 |
| Energy Efficiency Community Block Grant | Develop, promote, implement, and manage local energy efficiency programs. | $9.6 |
| Energy Efficiency Appliance Rebate Grant | Consumer rebates for ENERGY STAR® appliances, reducing energy use and saving money for families. | $0.1 |
| Total | | $32.2 |

Act 7075 and the various short- and long-term programs of the VIEO have resulted in major steps forward for the USVI. These activities represent the beginning of a transition away from petroleum-based power generation and toward a clean, efficient, and renewable energy future. ARRA-funded VIEO activities have also supported a burgeoning renewable energy economy by attracting private sector business investment, helping to train a USVI energy workforce, and increasing consumer familiarity with new technology. However, it remains to be seen whether this momentum can be maintained as ARRA funding diminishes. Continued policy and program development are likely to remain important.

## 2.4    New Policy Opportunities

New policy opportunities currently being discussed in the USVI include some form of decoupling, which refers to breaking the link between utility revenues and consumer consumption (i.e., utility revenues are determined by costs as opposed to retail sales), reduction or elimination of tariffs on imported energy efficiency and renewable energy equipment, the adoption of a tropical building code, review and refinement of the territory's interconnection standards for distributed generation, and consideration of a possible feed-in tariff (FIT), which would provide a fixed payment and guaranteed interconnection for all eligible distributed renewable energy.

In principle, decoupling would eliminate the utility incentive to sell more electricity in order to recover fixed costs. It could also be designed to allow the utility to engage directly in promotion of energy efficiency either via outreach, education, and financing or even potentially as an energy service company (ESCO).[15] If decoupling were implemented, detailed third-party auditing of expenditures and revenues with periodic "true-ups" would likely be necessary. Moreover, decoupling policies typically need to be structured with care if they are to continue to incentivize the utility to increase supply-side and operational efficiency. Nevertheless, decoupling may be important for the long-term viability of WAPA, as energy efficiency and distributed generation could potentially reduce demand for conventional utility-scale generation.

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[15] ESCOs provide energy consulting and management services. Often they invest in cost-saving efficiency technologies, and then as energy consumption diminishes, they rely on consumer savings to earn a return on their investments while passing a portion of the cost savings on to the consumer.

Import tariff reductions on renewable energy equipment (e.g., solar water heaters or solar PV modules) and FITs could provide greater economic incentives to pursue renewable energy technologies and ultimately increase private sector interest in clean energy projects. Reducing or eliminating tariffs would be expected to result in an incremental cost reduction for clean energy technologies but might also reduce government revenues. In contrast, a FIT operates by providing a guaranteed payment for all renewable power generation and is typically open access with interconnection guaranteed, within predetermined limits. A well-designed FIT could also provide enhanced market certainty and stability. At the same time, FIT cost containment and capacity limits are likely to be necessary in the USVI where budgets and the ability of the grid to take on high penetrations of renewable energy are limited. In addition, regular review and updates of island-specific technology and project cost estimates would likely be necessary to minimize the risk of developers extracting excessive profits from a particular FIT payment scheme.

An enforced tropical building code would help increase the use of technology and design standards that are in line with state-of-the-art knowledge regarding energy efficiency in the specific climatic conditions of the USVI. Refined interconnection standards could clarify required rules and regulations, ultimately facilitating the interconnection process while also ensuring that distributed renewable projects pay their requisite share of WAPA fixed costs and are not cross-subsidized by the remaining WAPA customer base.

## 2.5   Policy Challenges

To stimulate widespread, significant deployment of clean energy technologies, a robust, comprehensive set of energy policies is often required. Such a suite of policies will typically include measures that address economic, financing, regulatory, environmental, permitting and siting, and other barriers. Ongoing policy discussions today are focused on many of these topics. However, without a truly comprehensive policy suite, individual barriers may stall widespread deployment of efficiency and renewables, even when many of the other policy elements are in place. For example, insufficient interconnection standards can halt distributed generation renewables even when such projects are economically viable (Rose 2010). Similarly, utility-scale renewable energy projects can be delayed and result in higher costs because of inadequate siting and permitting policies, which may result simply because standards and protocols for new or emerging energy technologies have not yet been established.

The challenge for policymakers, advocates, and government in the USVI today is to work to continue to develop the territory's policy portfolio to remove persistent barriers. Addressing policy at all levels, including economics and financing, standards and regulation, permitting and siting, among others, will likely be necessary if the USVI is to achieve their desired reductions in oil-based power generation. The following specific policy challenges provide some examples of the need for continued policy development at multiple levels. These examples are not comprehensive but are intended to highlight a few of the barriers that persist today.

One of the most significant remaining challenges is in clarifying and implementing existing legislation. This challenge is particularly critical with respect to the RES that was established in Act 7075. For more than two years USVI regulators, WAPA, and the government have struggled to reach consensus on an RES policy that meets the requirements of the statute while also matching the needs and priorities of WAPA and consumers. To date, the substantive issues have

focused on how to achieve the goal of moving toward renewable energy without generating negative impacts for consumers. Minimizing administrative costs, defining eligible resources, managing and tracking compliance, and clarifying the legislative language are also concerns. Without clear rules and direction, project development activities and potential investments that could reduce USVI oil consumption are on hold as investors wait for final guidance to determine actual market demand and project feasibility.

Increased clarity around other critical policies would also be valuable to facilitate project development. At present, there is significant uncertainty around the legality of distributed generation third-party financing models used elsewhere in the United States (for additional information on third-party financing, see Text Box 1). This issue is of particular concern in the USVI because many consumers lack the ability to self-finance capital-intensive distributed generation projects. At the same time, the high retail electricity rates in the USVI suggest that behind-the-meter (i.e., systems that offset retail electricity consumption) distributed generation could prove to be an economically attractive alternative to conventional oil-fired power generation. Opening the USVI to third-party financing, which eliminates initial cost barriers, could significantly improve the ability of USVI residents to adopt distributed generation technologies. Such trends have been observed throughout the industry (Kollins et al. 2009) and in California where the emergence of third-party financing has opened up new market segments for solar PV among younger, middle income consumers (Hoen et al. 2011).

Resolving the persistent challenges associated with interconnection and net metering and establishing fair consumer charges for net-metered customers is also an important first step. Without greater clarity among third-

**Text Box 1. Third-Party Financing Overview**

Third-party financing provides the opportunity to expand the market for distributed generation renewable energy projects. Markets may see their potential grow because third-party financing reduces or eliminates the up-front cost burden of these projects.

In practice, external investors provide the up-front capital necessary to develop or install an RES. Then, either by leasing the equipment or selling the energy the system produces at a set cost over the life of the project, investors are able to recover their costs and obtain a given rate of return. In turn, the consumer is able to capitalize on the benefits associated with renewable energy, including fixed electricity prices, rates that are sometimes competitive with the prevailing retail rates, reduced emissions, and decreased dependence on fossil fuels or other conventional generation resources.

Third-party financing does not necessarily displace or offset the need for continued utility service and does not require that third-party financiers be regulated as a utility (Kollins et al. 2009). Utilities themselves could in principle act as the third-party financier (Kollins et al. 2009).

In the case of lease agreements, customers pay to use the equipment that has been installed on their home or business to offset a portion of their regular electricity consumption. In theory, customers continue to receive utility bills and are required to pay all necessary charges, including potentially standby, demand, or other service charges associated with net metering (Kollins et al. 2009). Third-party power purchase agreements can be designed to function similarly to lease agreements but reduce consumer risk by only charging consumers for the energy produced by the system. Depending on specific design features and legal or regulatory requirements, customers with third-party power purchase agreements could theoretically remain utility customers and be required to pay all requisite charges (Kollins et al. 2009).

party financing schemes and interconnection standards, successfully developing a robust distributed generation sector is likely to remain a challenge, and the resource potential of distributed generation may be left untapped.

Siting and permitting policy barriers also present challenges to new renewable energy projects. Current barriers affect permits for resource data collection efforts as well as siting of actual projects. Today, permits must be acquired from a handful of government entities, each operating independently and including, in some cases, Coastal Zone Management, the Department of Planning and Natural Resources, and the local government. In many cases, specific environmental protection standards and potential mitigation strategies as well as basic insurance and contractual requirements have not yet been established. The absence of clear policies on these types of issues is likely to result in delays and greater costs as indecision by government agencies and regulators, or in some cases litigation, extends development lead times. Absence of clarity around siting and permitting requirements has already resulted in significant delays (more than 12 months) in the installation of meteorological towers for wind and solar resource data collection that are critical to financing utility-scale wind projects and conducting analysis of potential grid and operational impacts from deployment of variable output wind and solar energy.

Decision-making processes that are based on a single or multiple non-representative metrics can also present barriers to renewable energy projects. When such processes are embedded in formalized procedures, policy solutions may be necessary. For example, WAPA generation investments rely on the ability of an alternative to compete with current "avoided costs"—largely, the assumed fuel cost looking forward. In the USVI, however, an emphasis on avoided costs can result in suboptimal outcomes because minor errors in future fuel price estimates, which are highly uncertain, can dramatically skew the perceived economic viability of potential alternative generation resources. Policy can help to resolve these types of challenges by requiring decision-making processes that are multi-faceted and take into consideration an array of metrics. Identifying such single variable decision-making processes can be difficult, as such conditions are not always immediately obvious. Nevertheless, when brought to light, it is important to recognize their impact and adjust formal procedures to better reflect the full array of values held by stakeholders.

Additional challenges discussed here emphasize the importance of policy consistency and reliability to grow long-term market confidence and provide the requisite decision-making tools for policymakers. Inconsistent policy (i.e., policies requiring frequent renewal or extensions) or policy that results in inconsistent levels of funding for technology deployment has a tendency to induce boom-and-bust cycles. Such cycles can actually discourage long-term investment and local workforce training and development. If such policies and funding are tied to data collection and analysis efforts, they can also result in knowledge gaps that leave policymakers poorly informed when new policy is proposed. By designing policy to be in place for multiple years, investors and businesses can adapt and develop business models for their given situation. Businesses are also more likely to invest in and train local capacity to support their work when the market is perceived to provide a consistent, sustainable level of local demand (Lantz et al. 2010). Consistent data collection and analysis also helps to provide continuous local market intelligence and offers a more robust understanding of market conditions, which are critical factors for policymakers seeking to address persistent barriers or emerging market conditions.

# 3 Developing a Strategic Energy Road Map for the USVI

The primary goal of this effort was to develop a road map detailing the path forward to achieve the USVI's 60x25 goal.[16] In conducting such an analysis for island communities, many of the issues observed in the continental United States are magnified. Factors including available land, topography, and grid integration are of greater importance in an island setting. In addition, social or environmental barriers to a specific technology may eliminate its potential when there are a limited number of sites for development.

The results presented here do not identify or quantify all power system or rate impacts.[17] In addition, they are not intended to be prescriptive. Instead, this work and supporting analysis provide a framework within which decisions can begin to be made, a vision of what the future might hold, and a guide to determine what questions should follow.

## 3.1 Methodology

This effort began by surveying historical energy trends and projections. The research involved a survey of current conventional-, renewable-, and efficiency-related activities that could alter the extension of past trends into the future. These two tasks assisted in clarifying the scope of the 60x25 goal, quantifying current energy use, and providing insight into the technologies and policy initiatives with the potential to have the greatest impact in the USVI. A detailed renewable energy technology screening and basic assessment of energy efficiency potential were also conducted to assess the relative feasibility of specific renewable or efficiency alternatives. A simple spreadsheet model was then constructed to evaluate the potential impact of proposed initiatives and renewable energy technologies and to identify where expanding or developing new initiatives might assist in meeting the targeted goal. The model includes high-level capital expenditures associated with the portfolio of initiatives necessary to achieve the USVI goal and allowed basic calculations of cost effectiveness in terms of barrel of oil equivalents of initial investment. Two additional model sensitivities were developed to illustrate the range of possible outcomes that may be applicable to the USVI.

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[16] The goal also entails energy consumed for transportation; however, the exclusive focus of this report is on electricity and water generation.

[17] It is not a techno-economic energy cost analysis. Additional technology-specific cost analysis is available in the companion transmission and distribution report (Burman et al. 2011).

**Figure 5. Steps to establishing the USVI energy road map**

## 3.2 Estimating Business as Usual

A business-as-usual (BAU) case was established to determine the baseline from which the 60% reduction was estimated. The BAU case was developed after reviewing the historical market and consumption data as well as high-level market projections. The estimate was ultimately grounded in long-term utility planning trends (e.g., RW Beck 2010). A 1.5% annual increase in electricity consumption for St. Thomas and St. John and a 0.5% annual increase in electricity consumption for St. Croix were assumed. As these trends are generally associated with overall changes in economic growth and consumption, it was assumed that projections for electricity use were also generally representative of the expected increase in demand for potable water. The starting point for the BAU case is in 2009 in conjunction with the commencement of the USVI, DOE, DOI, and National Renewable Energy Laboratory (NREL) joint EDIN initiative.

## 3.3 Survey of Activities and Initiatives

A survey and review of ongoing and proposed initiatives was utilized to understand potential opportunities that could be leveraged into larger initiatives to prevent the creation of duplicative efforts and to build from preexisting knowledge. Ongoing and proposed initiatives were compiled from semi-structured interviews with stakeholders from the University of the Virgin Islands, WAPA staff, VIEO staff, the governor's policy advisors, private-sector entrepreneurs, environmental advocacy groups, and others.

## 3.4 Energy Efficiency Potential

Estimation of the efficiency potential focused on both supply-side and end-user efficiency. Review of WAPA production and input data were used to understand the operational limitations and overall efficiency of power and water production in the USVI. Results were compared with typical estimates from similar power systems.

End-user efficiency opportunities were initially identified through preliminary estimates from selected energy audits by industry consultants (e.g., VIEA 2010). Modeling of representative buildings was conducted to identify specific residential energy efficiency opportunities. Modeling was conducted by NREL and built upon the prior work of researchers from Harvard University (e.g., Holms and Kao 2010). Opportunities for the residential sector elicited through

modeling efforts were added to those identified by the industry consultants in the commercial, industrial, and government sectors.

## 3.5   Renewable Energy Potential

To determine what renewable energy technologies were applicable to the USVI and the possible extent of development for each specific technology, a basic feasibility screening was conducted. The feasibility screening attempted to cover the following issues:

1. *Resource availability.* To what extent is this resource available in the USVI?

2. *Technology maturity.* Is the technology in commercial use? What is the estimated installed capacity in the United States and globally? How long has this technology been commercially available? If it is not commercially available, what are the barriers to commercialization and the expected timeline?

3. *Economic viability.* Based on current technology, what is the range of estimated cost of energy ($/kWh)?[18]

4. *Land constraints.* What are the land requirements? Are there limitations with respect to slope and shading?

Resources were generally eliminated from consideration where there was little or no resource potential or when technologies were determined not to have reached commercial status.

## 3.6   Defining the Road Map

A model that captures the outcomes of the current initiatives and the analysis of technical potential was developed to determine the specific level of new capacity and efficiency improvements necessary to achieve the stated 60x25 goal. This tool allows for the creation of multiple scenarios with varying mixes of energy efficiency and renewable energy technologies, changes in the deployment timeline, and changes in initial investment cost to be constructed. Individual renewable or efficiency opportunities can be compared against one another in terms of their overall ability to contribute to the USVI energy goal of 60x25 and their relative cost effectiveness. One important caveat is that cost effectiveness is measured primarily by comparing initial investment costs and overall ability to contribute to the 60x25 goal, rather than on a lifetime cost-of–energy (COE) basis. This resulted from limited COE data for projects in the USVI and the region. Of course, technology deployment levels considered in the road map were informed by detailed knowledge of typical COE estimates for individual technologies in other contexts and through detailed discussions with an array of USVI stakeholders (e.g., utility representatives, regulators, non-governmental organizations, business representatives, and members of the public). However, this external insight is not explicitly factored into the analytical results (detailed discussions, including typical COE estimates, are included in the technology descriptions in Section 5.2 and Appendix A). With the exception of the waste-to-energy and biomass plants, the significant majority of all costs associated with renewables and efficiency improvements are their initial capital costs, so the simple comparison between technologies based on initial installation costs begins to illustrate some of the relative tradeoffs. However, before significant investment decisions are made, detailed COE and system integration

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[18] Cost-of-energy (COE) ranges estimated here are high-level approximations only; detailed COE estimates are planned for future work.

impact studies are necessary. This work was beyond the scope of this study (for additional detail on the strengths and weaknesses of this approach, see Section 3.8).

Inputs into the model include the array of ongoing and proposed initiatives (or their expected impact), the approximate technology capital or investment cost, and the likely timeframe to implementation. Particularly uncertain variables (e.g., costs and expected deployment) are summarized on their respective inputs page, which provides users the ability to easily manipulate these variables and to understand how changes impact the analysis results. All energy inputs and the expected changes in oil consumption are converted to British thermal units and subsequently to barrels of oil equivalent to determine their impact on fossil fuel consumption. British thermal units and barrels of oil equivalent estimates are designed to be inclusive of existing production inefficiencies and require energy inputs by using representative system heat rates. Such a system perspective allows assessment of actual USVI energy inputs, which are the ultimate subject of the stated 60x25 goal.[19]

Overall fossil fuel reduction strategies included in the model target supply and distribution efficiency, end-user efficiency, and renewable energy deployment. Where specific projects are in planning or under development, technology deployment or program implementation is coordinated with the specific timelines identified for each of these projects. For distributed renewable generation as well as implementation of energy efficiency, a linear deployment pattern is generally assumed; in some cases, deployment in the early years is initiated at a slower rate to allow time to increase local workforce and business capacity.

## 3.7 Sensitivities to Inform Planning

There are, in reality, multiple solutions to the stated goal. This analysis identifies three specific scenarios intended to capture the likely range of activities necessary to achieve the respective goal. The primary scenario is the *base case scenario*, which reflects the most likely scenario to achieve the desired fossil fuel reductions based on today's best available information regarding realistic potential among the array of possible fossil fuel reduction opportunities as judged by the collaborative EDIN team. The *high energy efficiency scenario* assumes higher penetrations of energy efficiency technology are achievable across the various types of end users. The *high renewable energy scenario* assumes lower penetrations of energy efficiency and relies on increased deployment of utility-scale renewable energy technologies to reach the 60x25 target.

Due to the relatively large potential for supply-side efficiency upgrades to reduce fossil fuel consumption and their relatively modest cost, supply-side efficiency improvements are common to all three deployment scenarios. In addition, all scenarios assume the same level of BAU growth in consumption. Variable inputs developed for each scenario are grounded in the analysis of resource potential and realistic levels of deployment as determined by NREL in conversation with USVI stakeholders. Inputs specific to each scenario are included in the results section.

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[19] British thermal unit estimates were converted to barrels of oil equivalent by assuming 5.8 million British thermal units per barrel of oil (IRS 2011). This is approximately the energy released by burning one barrel (42 gallons or 159 liters) of crude oil.

**Text Box 2. The Potential for Interconnection with Puerto Rico**

This road map is focused on indigenous production of renewable energy in the USVI coupled with supply- and demand-side efficiency measures. However, interconnecting the two island systems or potentially interconnecting with Puerto Rico's Electric Power Authority (PREPA) are two additional possibilities that could fundamentally alter the energy future of the USVI. The former option is unlikely in the near future due to the ocean depth between St. Thomas and St. Croix and the current state-of-the-art underwater cable technology. The latter alternative, interconnecting with Puerto Rico, is a viable near-term alternative, and it is possible that a cable connecting the USVI to Puerto Rico will be placed in service by 2025.



Note: Concept demonstration, actual cable routes may be different.
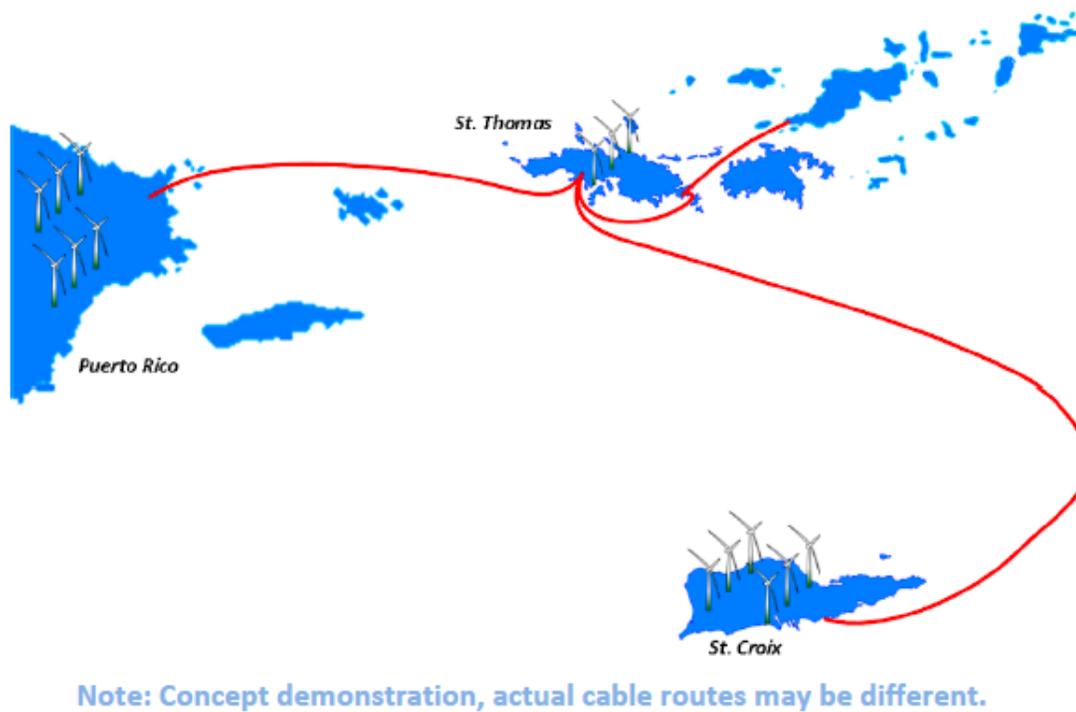
**Figure 6. Conceptual interconnection between the USVI, Puerto Rico, and the British Virgin Islands**

Illustration by NREL

The substantially larger population, land area, and electric power system (over 4,000 MW) in Puerto Rico provides PREPA with much greater flexibility in terms of electric power fuel sources and the ability to develop alternative generation. PREPA reports that only about 68% of its energy production is from oil, while 15% is from coal, 15% from natural gas, and 2% from hydroelectric resources (PREPA 2011). The combined effect of a larger system and greater fuel diversity is lower prices. By interconnecting with Puerto Rico and realizing the economies of scale associated with PREPA's much larger electric power system, the USVI might also be able to achieve lower electricity prices. Moreover, the opportunity to purchase lower-cost, non-oil-based power generation from Puerto Rico or to build renewables on Puerto Rico for import into the USVI are also potential issues that could impact the realization of the scenarios studied here. By connecting USVI's grids to a much larger, more stable grid, WAPA also has the opportunity to deploy a higher percentage of renewable energy without affecting power quality or system stability. However, as PREPA is still heavily reliant on oil-fired generation (68%), the incentive to increase energy efficiency and pursue renewable energy deployment in the USVI is expected to persist even if an interconnection with PREPA is realized.

## 3.8 Methodological Strengths and Limitations

The methodology adopted here takes a pragmatic and comprehensive look at the full portfolio of ongoing and potential initiatives and organizes them within the current context. It also offers the ability to envision what a complete portfolio of activities necessary to achieve the stated goals looks like. In this regard it is very much a "what if" approach that allows policymakers or stakeholders the ability to pose an array of scenarios and quickly identify how a specific high-level change will impact the overall mix of energy and what initial investment costs are required to achieve a given level of deployment. The flexibility of the tool also allows new information to be taken into account as it becomes available.

The usefulness of this tool, however, should be kept in context. In assuming that current activities and some related extension of those activities is the most rational step forward, this approach may overlook other opportunities, such as the advent of new technologies or significant cost reductions among existing technologies. In addition, the model only provides data on initial investment costs or capital expenditures, and there is no direct assessment of power system impacts. Figure 7 illustrates the spectrum of analytical tools that are likely to be necessary to achieve higher levels of analytical and power system understanding necessary to achieve the USVI 60x25 goal. In brief, Figure 7 indicates how this analysis, as a high-level scoping and planning effort, is to be followed by more detailed economic and technical studies.
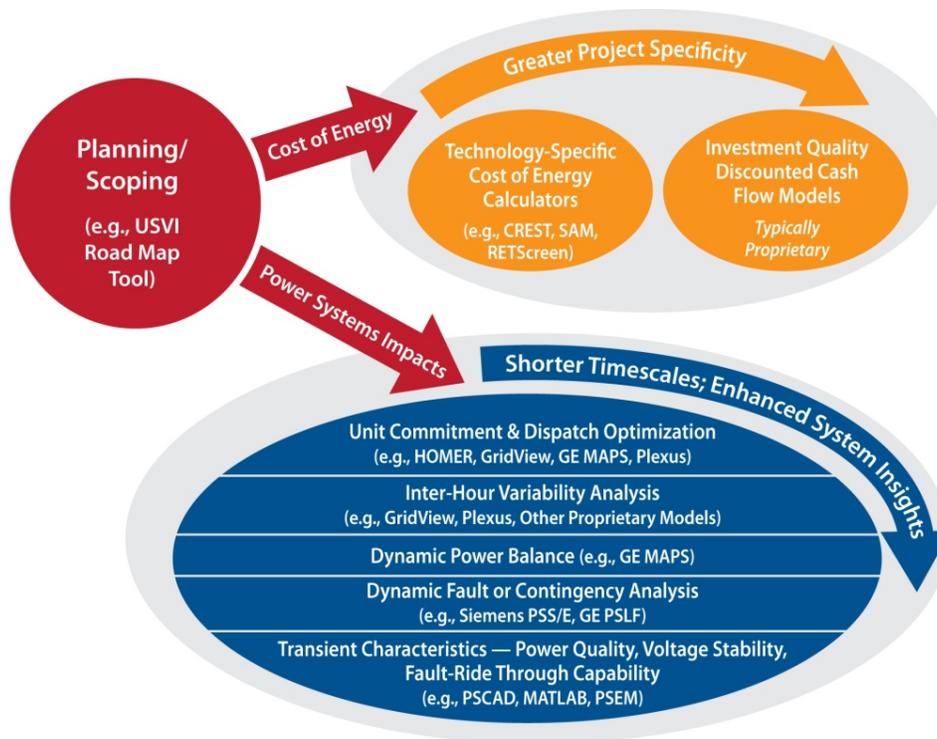
**Figure 7. Analytical planning and optimization tools**

Illustration by NREL

More specifically, detailed economic analyses (beyond those in Appendix A) are required to inform future decisions as requests for proposals are issued and individual projects are brought forth. In addition, the initial comparisons of investment costs and relative energy contributions should be followed directly by a comparison of each technology's island-specific cost of energy.[20] Conducting a complete COE estimate will provide greater insight into cost differences of delivered energy (or energy savings) among competing technologies. This is particularly critical when comparing capital-intensive renewable or efficiency technologies with other alternatives that may have lower initial costs but also significant and ongoing fuel costs, but it is also necessary when judging competing proposals for new renewable technologies such as wind and solar.[21] Moreover, as the cost of energy for various technologies may be highly site or project specific, sophisticated discounted cash flow models should be used to better understand project-specific COE and the relative value for ratepayers prior to acting on specific investment opportunities. Because technology and project costs change over time, particularly for emerging renewable and efficiency technologies, and this approach does not capture the effects of technological breakthrough or significant reductions in cost among the various technologies, economic analysis should be updated regularly and used to continue to inform power sector decision making into the future.

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[20] Island-specific analysis is important because individual island characteristics such as ports or transportation infrastructure may make otherwise viable opportunities unfeasible. Moreover, relatively remote access can increase the difficulty of securing qualified and available labor to complete projects. Such conditions can greatly impact island costs, and hence, island-specific pricing.

[21] Additional economic analysis on the relative cost differences between wind and solar PV is included in Burman et al. (2011).

Detailed power system analysis is also necessary as significant amounts of new variable-output renewable resources are considered. System integration and grid studies, in line with those highlighted in Figure 7, can assist in identifying the specific operational and infrastructure changes and system costs associated with integrating new generation into the USVI grid systems. Such studies are not necessary for each new project, but a series of studies that evaluates the impacts of moving to penetrations of variable output generation (e.g., 20% to 30%) may be warranted.

These caveats suggest that a well-informed user, familiar with the likely tradeoffs among technologies, is in the best position to conduct this type of initial high-level planning. Moreover, while the results presented in Sections 4 and 5 illustrate a path forward and can guide initial efforts in this space, they should be viewed as dynamic and subject to modification and adaptation as new information and improved understandings are gained.

# 4 Electricity Consumption and Opportunities for Fossil Fuel Reductions

This section presents the analysis of the BAU projection and opportunities determined likely to contribute to the overall 60x25 goal.

## 4.1 Business as Usual

In the absence of any action, power sector (electricity generation and desalination) oil consumption is projected to grow by almost a half million barrels of oil per year from nearly 2.6 million barrels per year to about 3.0 million barrels per year (Figure 8). Assuming fuel prices were fixed at early 2011 costs of $1.91/gal (WAPA 2011), WAPA's fuel costs would grow from about $200 million (constant 2010 USD)[22] per year today to more than $230 million per year in 2025.
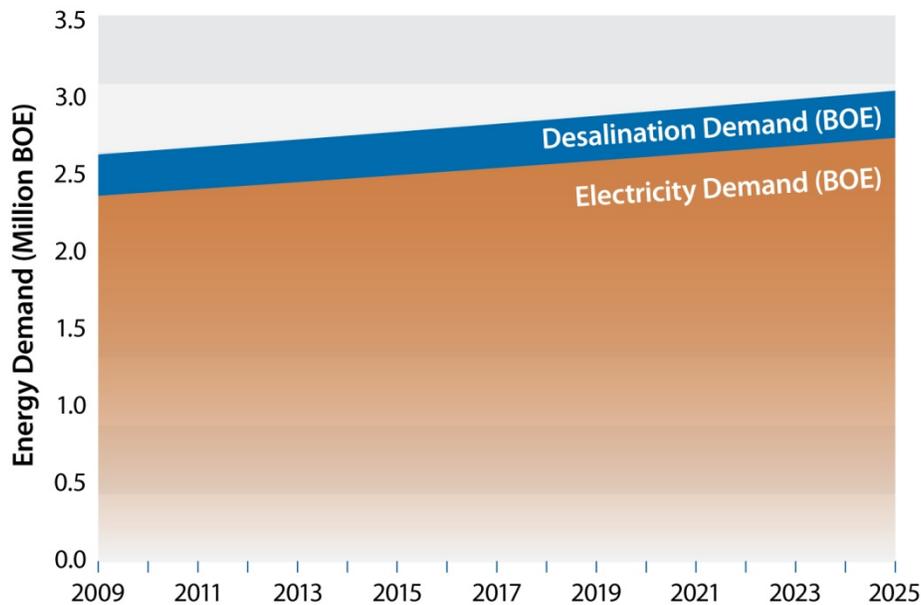


**Figure 8. Projected business-as-usual retail energy demand for the USVI, 2009–2025**

## 4.2 Current and Proposed Activities

In response to sustained high electricity prices, along with significant price volatility, a number of activities intended to reduce power sector oil consumption have been initiated or proposed. At the utility level, initiatives include:

1. Plans for a 16.5 MW waste-to-energy plant

2. Upgrades to existing generation and transmission and distribution infrastructure to increase efficiency and allow improved operational practices

3. Plans to acquire utility-scale PV generation

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[22] All dollars are reported in constant (i.e., non-discounted) 2010 USD.

4. A technical study of the proposed St. Thomas-to-Puerto Rico interconnection

5. Plans to shift water production from MED (a thermal process requiring fossil fuel inputs) to RO (a membrane technology requiring less electricity).

Significant action has been taken on each of these fronts in the last 18 months and includes the installation of the HRSGs on the existing generation in St. Croix, the completion of a 451 kW PV system at the Cyril E. King Airport, the installation of a pilot RO facility on St. Croix, and a number of energy efficiency improvements in the USVI school system.

On the private sector and consumer side, various distributed generation (SWH, solar PV, and wind) projects have also been initiated, with some already completed. These activities have been supported in part by ARRA funds distributed through VIEO. Preliminary assessments from an industry consultant (e.g., VIEA 2010) also indicated significant energy efficiency opportunities among large commercial and industrial consumers as well as in the government sector.

One trend that suggests possible increases in energy consumption from water desalination is associated with use of water catchment systems. Historical water catchment and cistern requirements have been relaxed for homes that have convenient access to WAPA's portable water piping system or are in densely populated localities (Ottley 2011). Given the high cost and energy intensity of water desalination, a move away from water catchment could result in increased fossil fuel use and greater utility costs for consumers. Continued use or expansion of water catchment facilities provides additional opportunities to drive down water consumption and the associated fossil fuel usage.

With the possible exception of water catchment, the current activities suggest a great deal of momentum and have already resulted in completed projects that will reduce USVI fossil fuel consumption. Such action must be sustained and new projects moved forward in order to ultimately achieve the USVI goals. Nevertheless, the impact of activities completed over the past 18 months has already begun to shift the USVI from its BAU projection (Figure 8).

## 4.3  Energy Efficiency Potential

This analysis indicates that energy efficiency presents a valuable opportunity to reduce USVI oil consumption. Supply-side efficiency improvements could dramatically reduce oil consumption and are particularly critical to meeting the 60x25 goal. End-user efficiency, although a less significant contributor to the overall goal, is among the best energy-related investments individuals and businesses can make (Figure 12).

Estimates based on WAPA's current fuel consumption and operations practices suggest that supply-side efficiency could result in a 22% increase in overall power system production efficiency. Transmission and distribution system upgrades are estimated to be capable of reducing technical distribution losses by 2%, further increasing the efficiency of the electricity and water supply. Transmission and distribution upgrades are estimated to cost approximately $40 million (WAPA 2010).

End-user efficiency has been identified to provide a wide swath of opportunities across the islands, specifically in new and existing building stock. Reductions in end-use consumption on

the order of 20%–40% have been estimated across end-user types. Additional detail on residential end-user efficiency opportunities can be found in Appendix B.

## 4.4   Renewable Energy Potential

The detailed screening of renewable energy technologies conducted as part of this effort suggests considerable resource and technical potential across the islands. However, there are some renewable energy technologies for which there is no viable resource, and there are some technologies that, despite notable resource potential, have not reached an adequate level of commercialization to be considered as realistic alternatives within the next 15 years. Table 4 summarizes the list of technologies reviewed and highlights the critical variables. For additional information on each specific technology, including cost estimates and relevant considerations for the USVI, see Appendix A.

**Table 4. Renewable Energy Technology Screening Results**

| Technology | Resource Potential in USVI | Technical Maturity | Approximate Cost of Delivered Energy* | Estimated USVI (Island-Specific) Installation Cost | Land Use Impact | Included In Road Map |
|---|---|---|---|---|---|---|
| Biomass Power | Medium | Commercial | $0.13 - $0.18 /kWh | $8,500/kW | High | Yes |
| Concentrating Solar Power | Low | | | | | No |
| Geothermal Power | None | | | | | No |
| Landfill Gas | Medium | Commercial | $0.18 - $0.27/kWh | $1,715/kW | Low (existing landfills) | Yes |
| Marine and Hydro-kinetic Power | Uncertain, likely low | R&D/ prototype | | | | No |
| Ocean Thermal Energy Conversion | High | R&D/ prototype | | | | No |
| Solar Photovoltaics | High | Commercial | $0.19 - $0.36 /kWh | $6,000/kW (utility) $8,000/kW (residential) | Medium (5-8 acres per MW) | Yes |
| Solar Hot Water** | High | Commercial | $0.15 - $0.20 /kWh | $4,000/system (4-person household) | Low (typically rooftops) | Yes |
| Waste-to-Energy | Medium | Commercial | $0.08 - $0.16 /kWh | $8,200 - $8,500/kW | Low | Yes |
| Land-Based Wind Power | High | Commercial | $0.10 - $0.20 /kWh | $3,600/kW (utility) $4,000/kW (residential) | Medium (~2 acres per MW)*** | Yes |
| Offshore Wind Power | High | No commercial facilities in North America | $0.20 - $0.30 /kWh | >$4,250/kW | Low | No |

*COE estimates are for general, high-level cost comparisons only and may or may not ultimately be representative of the cost of delivered energy from projects in the USVI. As such, these values were used only as a general screening tool to assess basic competitiveness. Conventional oil-fired generation existing on the islands today is estimated to produce electricity at about $0.15/kWh (RW Beck 2011).

**Estimated COE is based system costs and energy consumption offset by use of a SWH

***Land removed from service (required for turbines, access roads, related infrastructure) is approximately 2 acres per MW; however, due to turbine spacing requirements, the total footprint of a project may be on the order of 30–45 acres per MW (Denholm et al. 2009).

Note: Sources for data shown here include Clean Power Research 2010; Denholm et al. 2009; EIA 2010; EPA 2011; IPCC 2011; JIS 2010; and KEA 2011; some data were generated with internal NREL modeling. For additional detail, see Section 5.2 and Appendix A.

Note: If the resource potential was low or if there was no resource potential, the technology was not considered any further.

The primary renewable energy technologies determined to provide near-term opportunities to reduce oil consumption by the initial screening exercise include waste-to-energy, landfill gas (LFG), biomass, solar PV, SWH, and land-based wind power. With no known geothermal power potential in the USVI and very low concentrating solar power (CSP) potential, due to a relatively

low level of direct normal irradiance (DNI),[23] these technologies were not considered in the USVI road map. Offshore wind was also excluded, as it has not yet been commercially deployed in North America. Ocean thermal energy technology (OTEC) and marine hydrokinetic technology were excluded, as they exist only in the prototype demonstration stage and are not expected to achieve widespread commercial deployment by 2025.

LFG, waste-to-energy, and biomass power were identified among the lowest cost renewable energy resources in the USVI. As dispatchable resources, they also integrate well with the small power systems. Power generation from these three resources figures prominently in all future scenarios where the USVI achieves its 60x25 goal. However, these power generation alternatives are also resource or fuel limited. Based on preliminary analysis and discussions with project developers currently operating in the USVI, the estimated total capacity for these three resources combined is approximately 25 MW.

In contrast, wind, solar PV, and SWH are resource abundant. They also have a relatively large land-use footprint, and with respect to solar PV, may result in incrementally higher costs. Due to potential land-use impacts and possible siting challenges, installed wind capacity in the three scenarios noted above ranges from 12 MW to 33 MW (a nominal amount of small wind capacity is also included). Such estimates are based on the ability to site between 10 and 20 turbines greater than 1 MW in capacity. Should 1 MW or lower-capacity wind turbines be utilized, it may be more difficult to achieve the installed wind power capacity estimated at the higher end of the range.

The relatively high cost of solar PV is expected to be its primary limiting factor. At present, solar PV is the highest-cost renewable energy technology considered in the road map (Appendix A). As a result, solar PV capacity ranges from only 6 MW to 13 MW, with the majority of this being utility scale, as opposed to distributed, PV installations. Looking into the future, should recent cost reductions observed over the past few years continue, PV deployment at both the utility scale and the residential scale may ultimately be more substantial. Nevertheless, higher levels of deployment are not likely until further cost reductions are realized.

Although SWH is higher in cost than wind power, it is still viewed as a viable resource, especially since it is capable of directly offsetting retail electricity consumption. SWH has been deployed at relatively high levels (30%–35%) on other Caribbean islands (e.g., Barbados) (Langniss and Ince 2004), and arguably, a concerted effort could result in penetrations at this level in the USVI. Residential penetration of SWH is estimated to be between 40% and 50% in the sensitivities explored to meet the 60x25 USVI goal.

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[23] In contrast to solar PV and SWH, which can utilize diffuse solar radiation, the high temperature fluids necessary for CSP generating are best achieved with large amounts of direct solar irradiation.

**Text Box 3. The Economic Development Opportunity of Green Jobs**

Dr. Daniel Kammen and Rebekah Shirley of the University of California-Berkeley's (UC-Berkeley's) Renewable and Appropriate Energy Laboratory have been working with the EDIN-USVI teams to estimate the number of green jobs that could be created as the USVI strives to achieve 60x25. A "green job" is loosely defined as one that pays reasonable wages that can support a family, provides a real career path and upward mobility, and reduces waste or pollution or provides some other form of benefit to the environment (Walsh 2008).

The UC-Berkeley team modified their Green Jobs Calculator (http://rael.berkeley.edu/greenjobs) that is based on the continental United States and Europe to apply to the Caribbean islands in general and the USVI in particular. The Green Jobs Calculator estimated both direct and indirect jobs related to the deployment of energy efficiency and renewable energy technologies (Wei et al. 2010). For the purpose of this work, direct employment includes jobs created in the design, manufacturing, delivery, construction/installation, project management, and operation and maintenance of the different components of the technology under consideration. Indirect employment refers to the "supplier effect" of upstream and downstream suppliers.

The analysis conducted by Shirley and Kammen is not strictly based on the scenarios described here. However, the overall mix of renewables and efficiency deployment modeled by Shirley and Kammen is comparable. As such, the general magnitude of impact is expected to be representative of the jobs supported by investments associated with the three scenarios outlined in this road map.

A conservative estimate of the potential for new, green jobs is 400 jobs by 2025. Over half of these jobs would be created in the realm of energy efficiency. Of the renewable energy jobs, solar PV installations represent approximately half (Shirley and Kammen 2011). In total, these jobs represent 3,492 job-years by 2025 and 5,928 job-years by 2030.

**Table 5. Direct and Indirect Green Jobs in the USVI**

| New Jobs Versus BAU in: | 2025 | 2030 |
|---|---|---|
| Direct Jobs | 208 | 329 |
| Indirect Jobs | 187 | 296 |
| Total Jobs | 395 | 625 |
| Cumulative Job-Years | 3,492 | 5,928 |
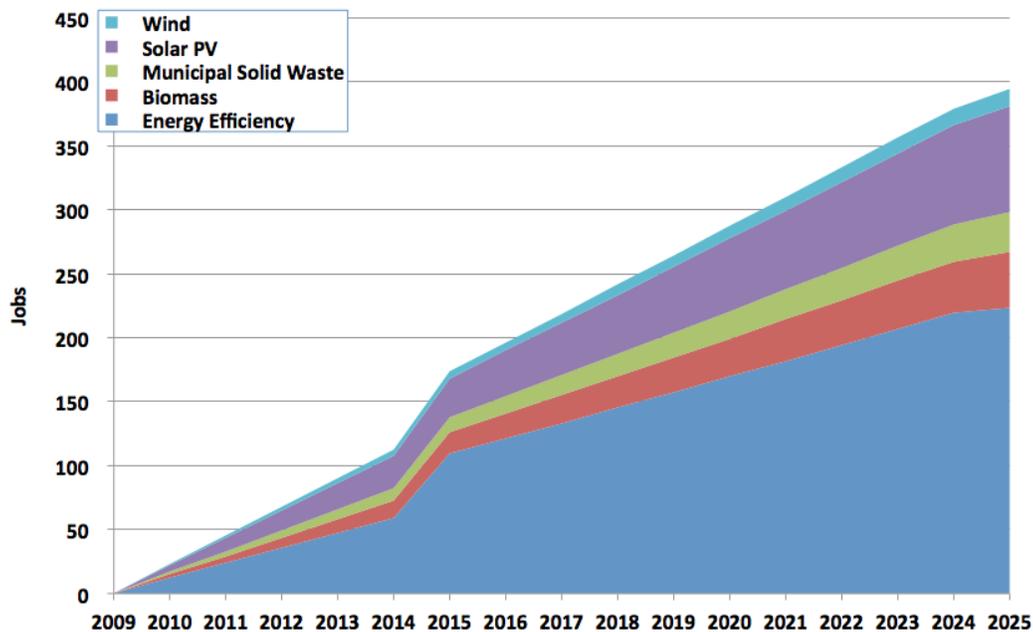


**Figure 9. Green jobs in the USVI by sector**

Source: Shirley and Kammen 2010

# 5  Three Future Scenarios

Reducing oil consumption 60% from BAU by 2025 is ambitious and will require aggressive deployment of energy efficiency and renewable energy technologies. The mix of energy efficiency, renewable energy, and fossil fuel required in each scenario to meet the expected demand for energy is described in this section.

## 5.1  Base Case

This scenario has been constructed as the most likely pathway to the 60x25 goal moving forward. Building on recently completed efforts, it contains an aggressive, but balanced, mix of renewable energy deployment, supply-side efficiency, and end-user efficiency (Figure 10). Supply-side efficiency improvements and, to a lesser extent, renewable energy installations are already being incorporated into the current USVI energy mix. End-user and larger-scale renewable energy efforts are expected to ramp up over time.
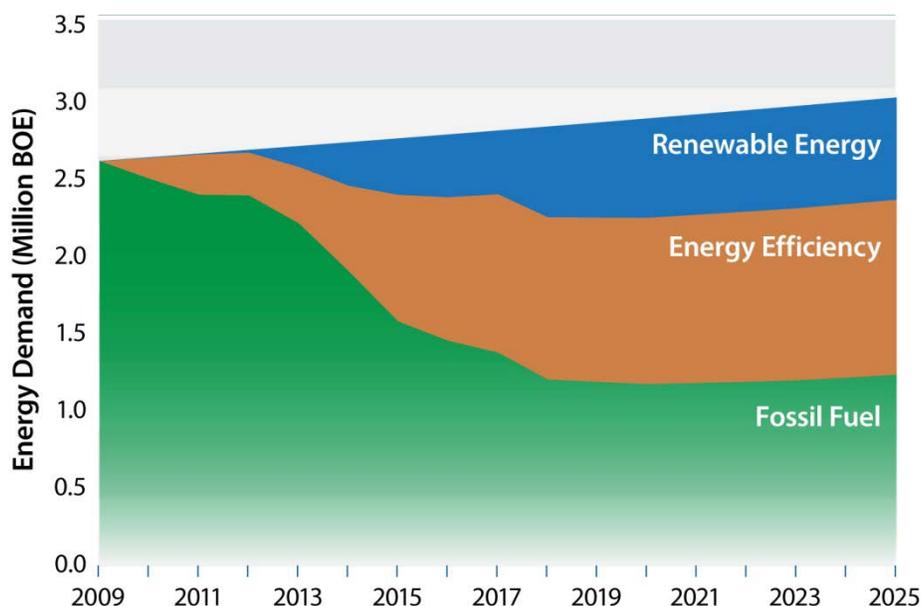


**Figure 10. Base case energy mix in the USVI, 2009–2025**

In this scenario, roughly 43% of the USVI goal is expected to be met by improvements in supply-side efficiency. This entails the continued implementation and completion of activities to improve power and water production efficiency already started on St. Croix, significant upgrades to existing generation assets on St. Thomas, and the addition of RO water desalination units on St. Thomas. Such efforts are fundamental to reducing fossil fuel consumption. In addition, about 40% of the overall goal is to be met by deployment of new utility-scale power generation. A 16.5 MW waste-to-energy capacity and 22 MW of utility-scale wind are most critical to new renewable energy deployment, but 3 MW of biomass, 9 MW of solar PV, and 5 MW of LFG are also important.[24] The largest distributed renewable energy technology contributing to the goal is

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[24] Considering the resource, landfill gas contribution to the USVI goal is relatively substantial. The estimate of 5 MW of capacity is based upon an assumed average of 970 scfm of landfill gas production from 2011 through 2030 at the Bovoni Landfill on St. Thomas and comparable production from the Anguilla Landfill on St. Croix. Annual

SWH systems, which are expected to have a relatively high penetration of 40%. End-user energy efficiency constitutes about 13% of the total goal. Despite its share of the overall goal, the relatively low cost of implementing end-use efficiency suggests that these opportunities will be among the first to be pursued and realized. Table 6 summarizes the expected impact of each specific opportunity on the 2025 power sector energy mix as well as the requisite deployed capacity.

**Table 6. Opportunities and Estimated Impacts from Renewables and Efficiency in the Base Case**

| Technology/Area of Focus | Action Required | Share of Overall Goal |
|---|---|---|
| **Supply-Side Efficiency** | | |
| Generation | Install state-of-the art heat recovery and operational practices | 28% |
| Desalinization | Install state-of-the art RO technology | 12% |
| Transmission and Distribution | Substation and distribution upgrades | 3% |
| *Subtotal* | | **43%** |
| **End-User Efficiency** | | |
| Government (Water & Power) | Reduce 75% of consumption by 25% | 5% |
| Residential (Power Only) | Reduce 25% of consumption by 25% | 3% |
| Large C&I (Water & Power) | Reduce 25% of consumption by 25% | 3% |
| Small Commercial (Power Only) | Reduce 25% of consumption by 25% | 2% |
| *Subtotal* | | **13%** |
| **Utility-Scale Renewables** | | |
| Waste-to-Energy | 16.5 MW | 16% |
| Wind | 22.5 MW | 12% |
| Landfill Gas | 5 MW | 6% |
| Biomass | 3 MW | 4% |
| Solar Photovoltaics | 9 MW | 2% |
| *Subtotal* | | **40%** |
| **Distributed Renewables** | | |
| Solar Hot Water | 40% penetration on residences | 4% |
| Solar Photovoltaics | 1 MW | >1% |
| Small Wind | 0.5 MW | >1% |
| *Subtotal* | | **4%** |
| **Total** | | **100%*** |

*Totals may not sum due to rounding

production estimates at the Bovoni Landfill were carried out by an external consultant (Maguire Group 2007) and converted to an overall average by internal NREL analysis. Estimates of potential capacity supported by the approximate fuel production at both landfill sites were conducted by using the U.S. EPA Landfill Methane Outreach Program: Interactive Conversion Tool. For more information on the U.S. EPA tool and landfill gas resources, see EPA (2011).

In terms of costs, the estimated COE shown in Table 4 should be the primary source used to inform prioritization of activities moving forward, as it reflects a more complete estimate capturing both installation and fuel costs. However, also of interest may be the initial investment costs. To implement the full portfolio of capital and infrastructure improvements associated with this scenario, it is estimated to cost about $565 million. Not surprisingly, many of the more costly investment opportunities are also the larger contributors to the 2025 energy mix. An estimated $140 million is required for waste-to-energy generation, and about $80 million each is estimated to be necessary for the improvements to the electricity generation fleet and the development of utility-scale wind capacity. SWH totals about $70 million and solar PV (utility-scale and distributed) is estimated to be about $62 million.

To assess the relative return on initial investment, one can compare estimated initial installation costs with the specific share of energy savings or production from a given technology in 2025. This allows one to assess high-level cost effectiveness as well as the relative technical opportunity provided by a particular technology or efficiency alternative. Figure 11 illustrates the result of such a comparison for the opportunities constituting the base case; the width of each bar on the x-axis is indicative of the contribution to the 2025 energy goal while the height of the bar is indicative of reduction in fossil fuel associated with every million dollars of initial investment. Figure 11 illustrates that although end-use efficiency provides a relatively small contribution to the overall goal, it is the most cost-effective opportunity (even without factoring potential fuel or operation and maintenance costs associated with the other power generation alternatives). Similarly, improvements to supply-side energy efficiency can be obtained at modest cost but offer significant potential savings in the 2025 base case energy mix. Of the various opportunities, renewables, particularly wind and waste-to-energy, are more expensive but also offer the potential for significant reductions in fossil fuel use.
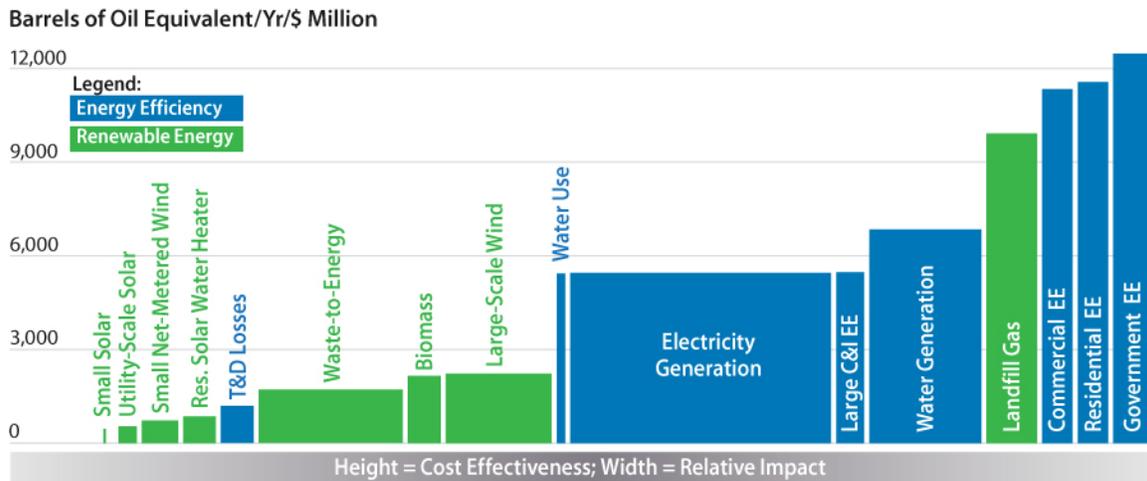


Note: Initial investment costs do not include fuel costs and should not be construed as reflective of actual cost of energy.

**Figure 11. Initial investment cost coupled with the relative contribution to the 60x25 fossil fuel reduction goal**

### 5.1.1 Technical Potential and Other Considerations of Technology Utilized in the Base Case

Many of the renewable energy and energy efficiency technologies deployed to achieve 60% by 2025 will not be obvious to the casual observer—an energy efficient home looks much like a non-efficient home. However, some of the renewable energy technologies will be more obvious. Two technologies in particular, wind and solar, will come to define some of the landscape of the USVI if they are to be broadly deployed. If the USVI achieves the 60x25 goal, residents and visitors will see concrete proof, in wind farms and solar roofs, that they live on or are visiting a "green island." The following sections provide additional discussion of technical, economic, and landscape and other considerations associated with the specific technologies incorporated in the base case scenario. Additional detail on a broad array of renewable energy technologies is found in Appendix A.

#### 5.1.1.1 Supply-Side Efficiency Potential

Review of WAPA fuel consumption and production data reveal that the WAPA generation fleet currently operates at relatively low efficiency—approximately 15,000 BTU/kWh (WAPA 2011). This is in part because of the thermal energy required when operating the island's MED desalination process. However, significant opportunities for increased efficiency in the production of electricity and potable water do exist. Operating generation units in combined cycle mode to utilize waste heat to increase electricity production is one of the larger opportunities to reduce fossil fuel use. The most efficient combined cycle operations can be achieved with modern HRSG technology similar to those recently installed on two steam units on St. Croix. The total cost to install this system on St. Croix and make comparable upgrades to older HRSGs on St. Thomas was estimated at approximately $80 million (WAPA 2010).[25] Improved operational strategies could further increase the efficiency of existing generation assets. In total, the resulting estimated reduction in fuel consumption from these improvements is about 22%/kWh generated by existing WAPA assets. Such improvements could be gained with little or no apparent change to the USVI landscape; however, they do not reduce the territory's overall dependence on fossil fuel.

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[25] This includes those installations that have already taken place on St. Croix.

**Figure 12. Heat recovery steam generators on St. Croix**
NREL PIX 18598

Energy use in water desalination was determined to be another large opportunity for reducing oil consumption. Historically, water in the USVI has been desalinated by use of MED. However, RO technology is expected to greatly reduce energy inputs required for desalination. Although the USVI is unlikely to revert back to large-scale water catchment facilities, broader use of small-scale water catchment systems represents an even lower energy intensity source of fresh water, and the precedent exists for its implementation in the USVI.

Presently, MED water production in the USVI is estimated to require between 0.49 MMBtu/kGal and 0.90 MMBtu/kGal. A pilot RO facility recently installed in St. Croix is estimated to require just 0.16 MMBtu/kGal.[26] Although some efficiency improvements for MED might be achieved with operational changes, RO is still a lower-energy-intensity technology (Figure 13). Assuming an annual MED energy requirement of 0.78 MMBtu/kGal (WAPA 2010), shifting to RO could reduce energy inputs into water production by nearly 80%. Estimated cost for shifting all water production to RO technology is approximately $28 million (OAS 2010). Moving to RO is expected to result in minimal changes to the infrastructure landscape of the USVI.

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[26] This pilot facility is capable of producing roughly 25% of USVI desalinated water requirements.
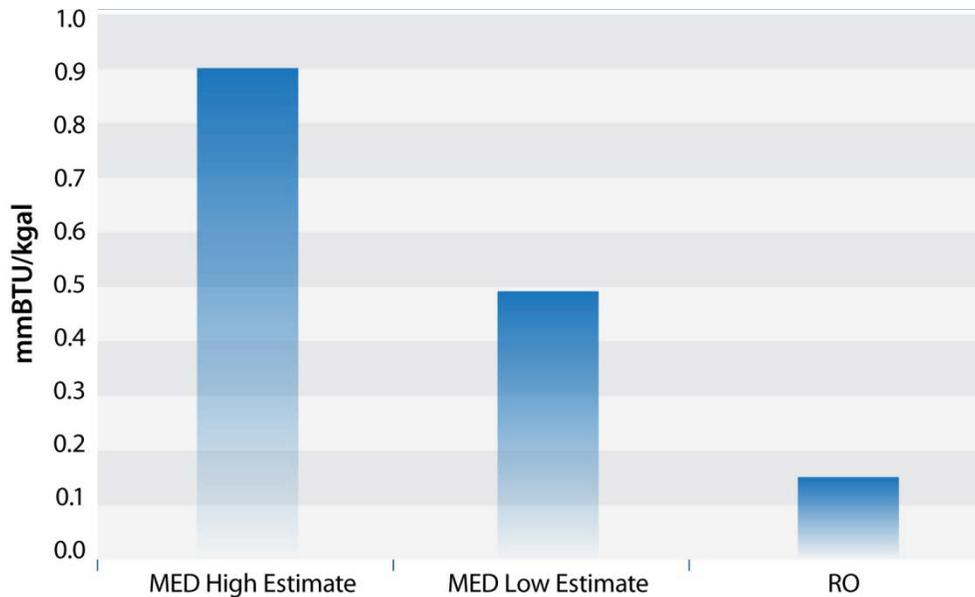
**Figure 13. Energy use for desalination—MED versus RO**

Source: WAPA 2010

### 5.1.1.2 End-User Efficiency Potential

End-user efficiency targets both electricity consumption and water use. It is only in the recent past that the USVI has begun to seriously evaluate the potential for end-use efficiency gains. As a result, detailed data on the potential of this opportunity is limited. Preliminary estimates suggest that a 25% reduction in end-user electricity consumption across the residential, commercial, government, and large commercial and industrial sectors is achievable (VIEA 2010). These estimates are of comparable magnitude to those suggested for the continental United States (e.g., Mckinsey 2009). A similar 25% reduction in the use of desalinated water is estimated for government and large commercial and industrial users (VIEA 2010). In formulating the energy road map, it was assumed that these levels of efficiency improvement are feasible in 25%–50% of the building units in each sector. As much as 75% of government sector electricity and water consumption is estimated to be capable of being reduced by approximately 20%–30%. Achieving these relatively high levels of penetration in efficiency among end users in the base case and other scenarios is justified because of the particularly high electricity costs in the USVI. Nevertheless, doing so will require significant education and outreach efforts and potentially new supporting policy as well.

To better understand and quantify the potential value of individual end-user energy conservation measures (ECMs), NREL and researchers at Harvard University (e.g., Holms and Kao 2010), in coordination with VIEO, have begun collecting data on actual energy use and modeling representative building structures with state-of-the-art efficiency measures employed. The most recent iteration of the modeling efforts details three specific residential housing types commonly found in the USVI.[27] The first is a typical medium-income, 900 ft$^2$ home with three bedrooms, one bathroom, a kitchen, and a living area (Figure 14). This representative housing unit was

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[27] A high-level overview of this work is provided here; for a detailed description of methods and inputs, see Appendix B.

modeled both with and without air-conditioning. In combination with two 900 ft$^2$ units, modeling was also done on larger "vacation homes" (Figure 14). Such homes are common in attractive tourism destinations like the USVI. As modeled, these houses consist of 3,000 ft$^2$ with four bedrooms, three bathrooms, a kitchen, and two living areas. Vacation or resort-type homes were assumed to be fully air-conditioned.
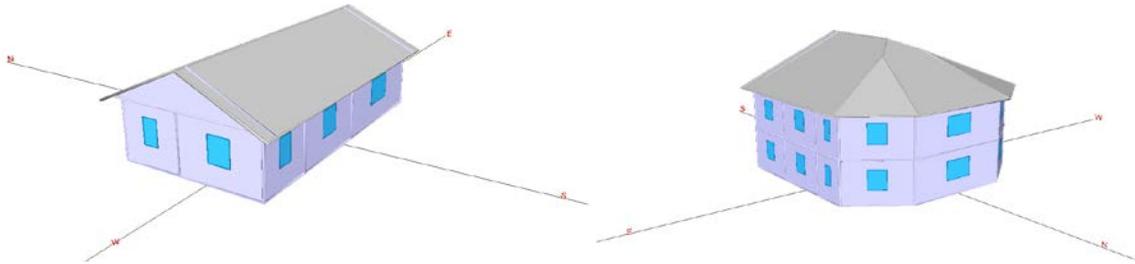


**Figure 14. Building types considered in preliminary efficiency modeling**

Illustration by NREL

For the 900 ft$^2$ homes without air-conditioning, three primary energy efficiency improvements considered were targeted lighting, refrigerators, and domestic hot water. By using standard lighting assumptions, lighting energy requirements are estimated to be reduced by 30%–50%. In evaluating upgrades to new ENERGY STAR® refrigerators, efficiency was expected to improve by approximately 30%. SWH is estimated to be capable of offsetting 80%–90% of electricity that would otherwise go to heating water. Excluding SWH in homes without air-conditioning, an approximately 18% reduction in energy use is observed. In homes with air-conditioning, an array of additional efficiency opportunities are possible, including increasing actual air-conditioner efficiency, adding roof and wall insulation, adopting high-emissivity cool roofs, improving window glazing, and adding external shading. Considering the full portfolio of energy efficiency improvement opportunities, a fully air-conditioned 900 ft$^2$ home could see a 35% reduction in end-use consumption (25% excluding SWH) (Figure 15), and a fully air-conditioned 3,000 ft$^2$ residence could expect a nearly 40% reduction in energy use (31% excluding SWH). For the average residential consumer using about 500 kWh per month, a 20%–30% reduction in energy consumption would result in $30 to $65 in electricity bill savings per month at typical 2011 electricity rates.
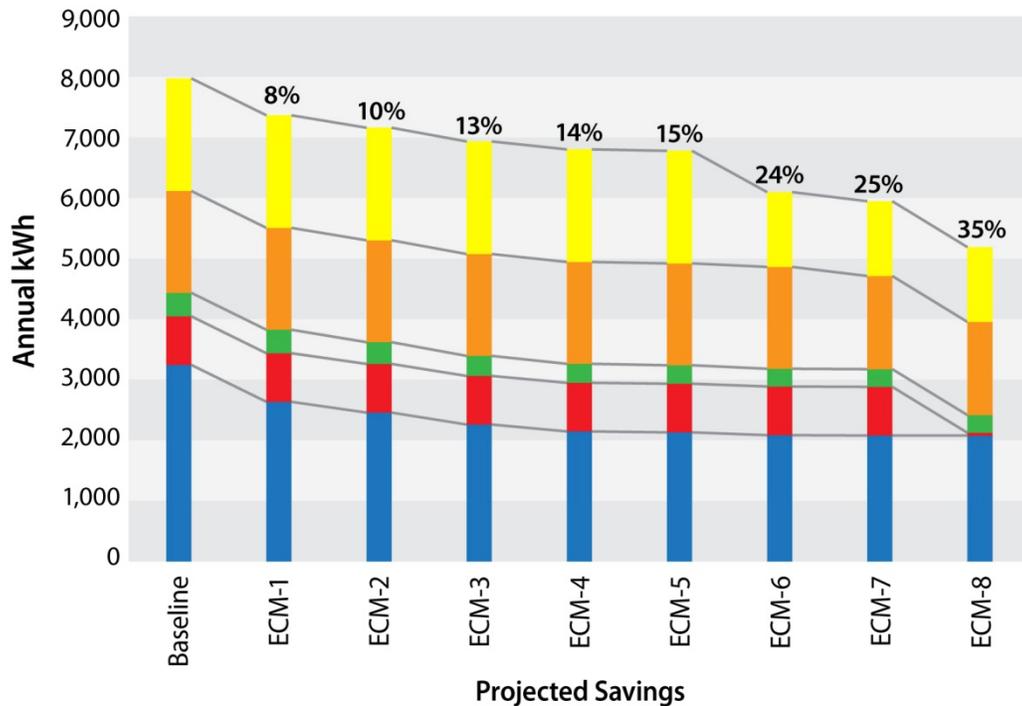
**Figure 15. Impact of individual energy conservation measures in a typical 900 ft$^2$ home with air-conditioning**

Note: Additional detail on modeling inputs and methods is provided in Appendix B.

Detailed cost estimates for individual ECMs in this analysis have not been conducted. However, based on rough costs for compact fluorescent light bulbs and a basic new high-efficiency refrigerator, it was estimated that an average residence would require $300–$500 in order to achieve a 20%–30% improvement in efficiency. Of course, ECMs for vacation homes are likely to be more significant in cost but also result in greater improvements in efficiency. Costs for basic commercial buildings to achieve a similar 20%–30% increase in efficiency were estimated at about $1,000 per unit, assuming these efforts will require more significant equipment and lighting upgrades than would be typical for a residence.

This preliminary modeling work shows that opportunities for increased energy efficiency in the residential building sector are available. These energy use reductions are likely to be important to the future of energy use in the USVI and in meeting the 60x25 goal of reducing fossil-fuel-based energy use. Programs through VIEO have been implemented to help achieve these goals, including weatherization, renewable energy loan programs, and energy efficient appliance rebates. Continued efforts are required to ensure that the penetration of such programs continues within this building sector.

Analyzing additional information on building construction, occupancy schedules, and end-use energy consumption with respect to these specific ECMs could offer more site- and context-specific information regarding impacts in actual buildings. Data detailing the expected implementation costs for energy efficiency technologies could further inform the decision making of USVI residents, businesses, and policymakers. Cost data could also be combined with modeled energy projections to determine explicit cost effectiveness of specific ECMs for

targeted energy efficiency improvements throughout the residential building sector. Similar building modeling work could also be focused on commercial buildings as well as with the island hotels and resorts to help identify cost-effective ECMs to meet the energy reduction goals for these building sectors.

### 5.1.1.3 Solar PV and SWH Technology

The sun in the Caribbean is strong, and solar energy has the potential to make a meaningful contribution to the USVI's 60x25 goal if it is deployed widely. The solar maps in Figure 16 show that the USVI has a good solar resource for solar PV, with an average solar irradiation greater than 5.7 kWh/m$^2$/day.
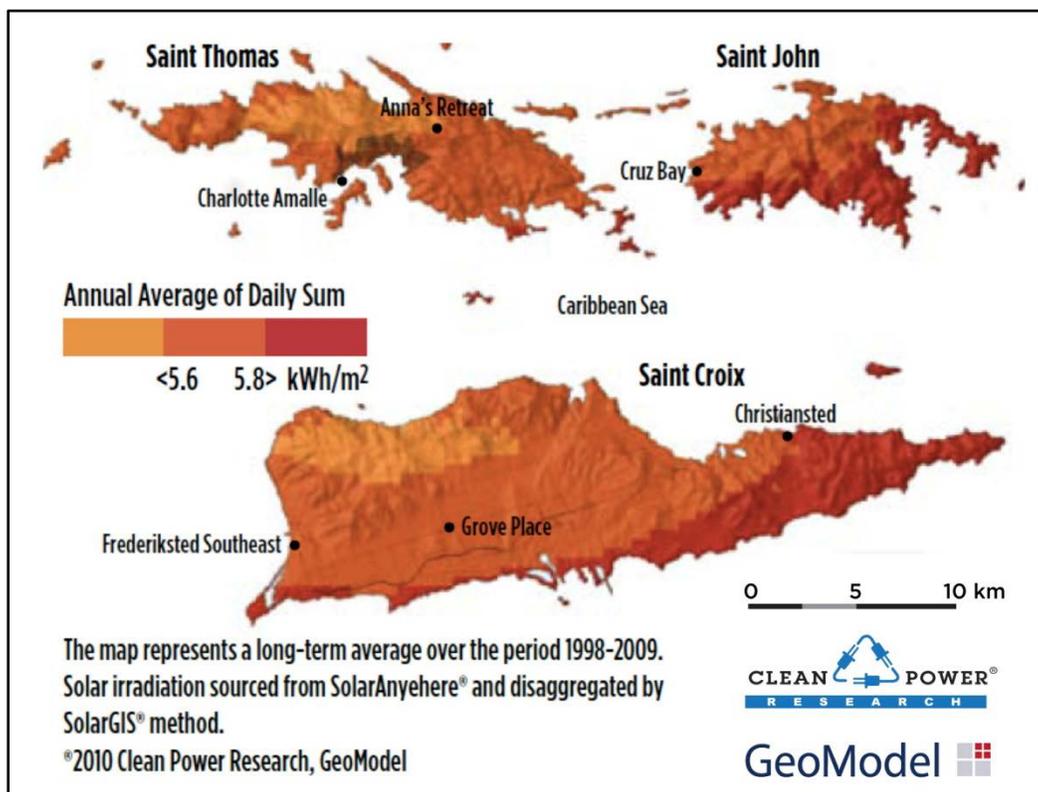


**Figure 16. USVI solar resource map**
Illustration from Clean Power Research

The base case road map scenario assumes 10 MW of solar PV will be deployed by 2025 and 40% of homes will install a SWH system. On the solar PV side, 10 MW represents between 7% and 10% of WAPA's peak load. From an operational perspective, the location of these solar PV systems is also important. Solar PV can add variability to the utility's distribution grid. This variability is exacerbated if all of the solar panels are at one location where a single cloud can reduce the output of the entire system. From a grid control standpoint, greater geographic diversity, or spreading the PV systems across the entire system, is advantageous.

Land and roof space are at a premium in the USVI, and detailed planning is required if appropriate sites are to be found. Solar PV systems require approximately 3 to 6 acres of rooftop or land per megawatt, so the proposed 10 MW of PV will occupy approximately 29 to 57 acres.

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Using a variety of mapping tools, including Google Maps, the EDIN-USVI team worked together to identify appropriate rooftops and government-controlled land sufficient for 10.9 MW of solar PV as shown in Figure 17. However, many of these roofs are ultimately expected to be inappropriate for PV, so more sites are needed and should be identified. Siting SWH systems on residential roofs is not expected to present a barrier to deployment of SWH technology.
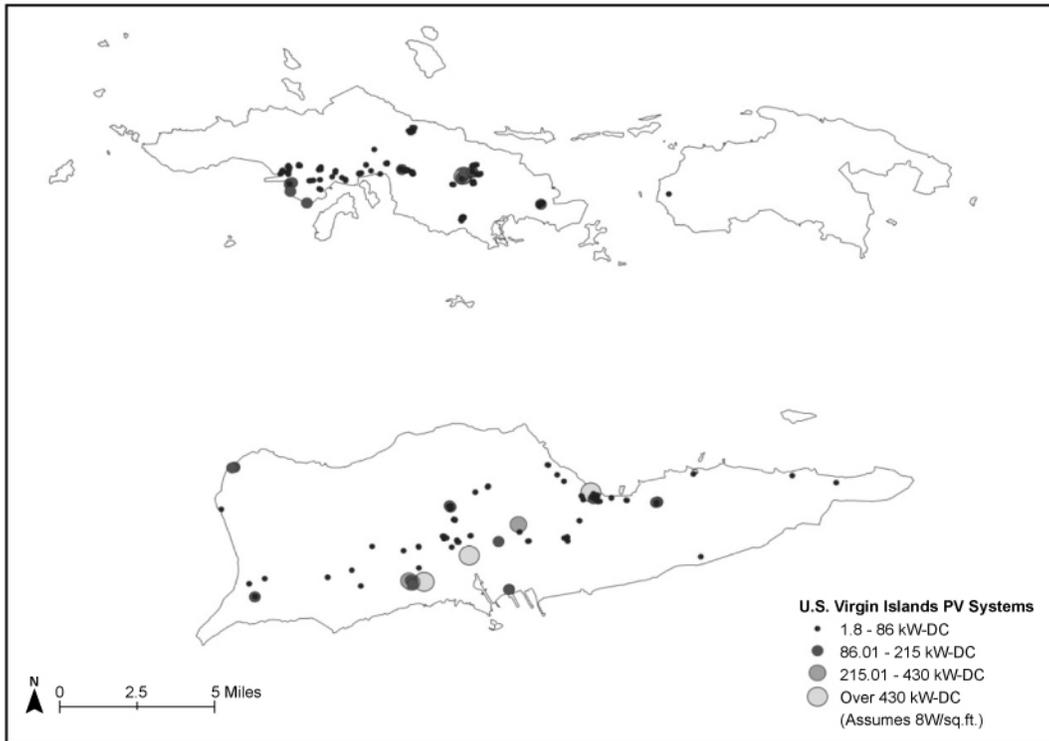


**Figure 17. USVI potential PV system sites**

Illustration by NREL

Solar PV and SWH systems have a relatively minor impact on the land or view-scape. Small- to mid-sized systems are often located on building roofs where they are all but out of sight. Larger PV installations, such as those used by utilities, typically cover large fields. The 451 kW PV system at Cyril E. King Airport is an example of a typical large-scale PV system (Figure 18).

**Figure 18. 451 kW PV system at Cyril E. King Airport on St. Thomas**

Photo by Adam Warren, NREL

The cost of solar PV systems has dropped dramatically in the last five years. However, in the continental United States, the cost of power derived from solar PV systems is still above the cost of fossil-fuel-based power. Federal, state, and local subsidies may be used to offset the higher costs.

In the USVI, there are no large-scale, local subsides for solar PV. However, the cost of conventional diesel-based electricity is sufficiently high to provide economic motivation for deploying PV systems at scale. Price certainty is another motivating factor—once a PV system has been installed, the cost of power from the system is known for at least the next 20 years.

Two economic analyses for the cost of solar PV electricity have been conducted in the USVI, one based on the Hybrid Optimization Model for Renewable Energy (HOMER) (e.g., Burman et al. 2011) and one based on the Cost of Renewable Energy Spreadsheet Tool (CREST) (for greater detail on both these internal modeling efforts, see Appendix A).[28] HOMER is a high-level economic model for systems with a mix of renewable energy and fossil-fuel-based electricity; Burman et al. (2011) details the HOMER results. CREST is a more detailed economic cash-flow model designed to enable public utility commissions and the renewable energy community to assess projects, design cost-based incentives, and evaluate the impact of tax incentives or other support structures. Taken together, these analyses indicate solar PV should

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[28] HOMER is owned and maintained by HOMER Energy, LLC. For additional information on HOMER, see http://homerenergy.com. CREST was developed for NREL by Sustainable Energy Advantage, LLC. For additional information on CREST, see Gifford and Grace (2011).

deliver power between $0.19/kWh and $0.36/kWh. Given the utility's current avoided cost, this range of power costs from utility-scale solar PV will likely not result in reductions in the cost of retail power in the USVI. However, deploying solar PV will help protect the territory from future swings in the price of electricity.

SWH costs have not declined in the same way that solar PV costs have in the recent past, and installation costs are expected to be the primary barrier to deployment of SWH. However, SWH currently offers an economic COE in the USVI. Cost estimates conducted by NREL suggest a range of $0.11/kWh to $0.34/kWh depending on the availability of local USVI incentives (e.g., VIEO grants and USVI tax credits) and the expected life of the system (additional detail is available in Appendix A, Figure A-5).[29]

### 5.1.1.4 Waste-to-Energy

Waste-to-energy technologies consist of various methods for extracting energy from waste materials. These methods include thermo-chemical and biological methods. Figure 19 provides an illustration of the various pathways.
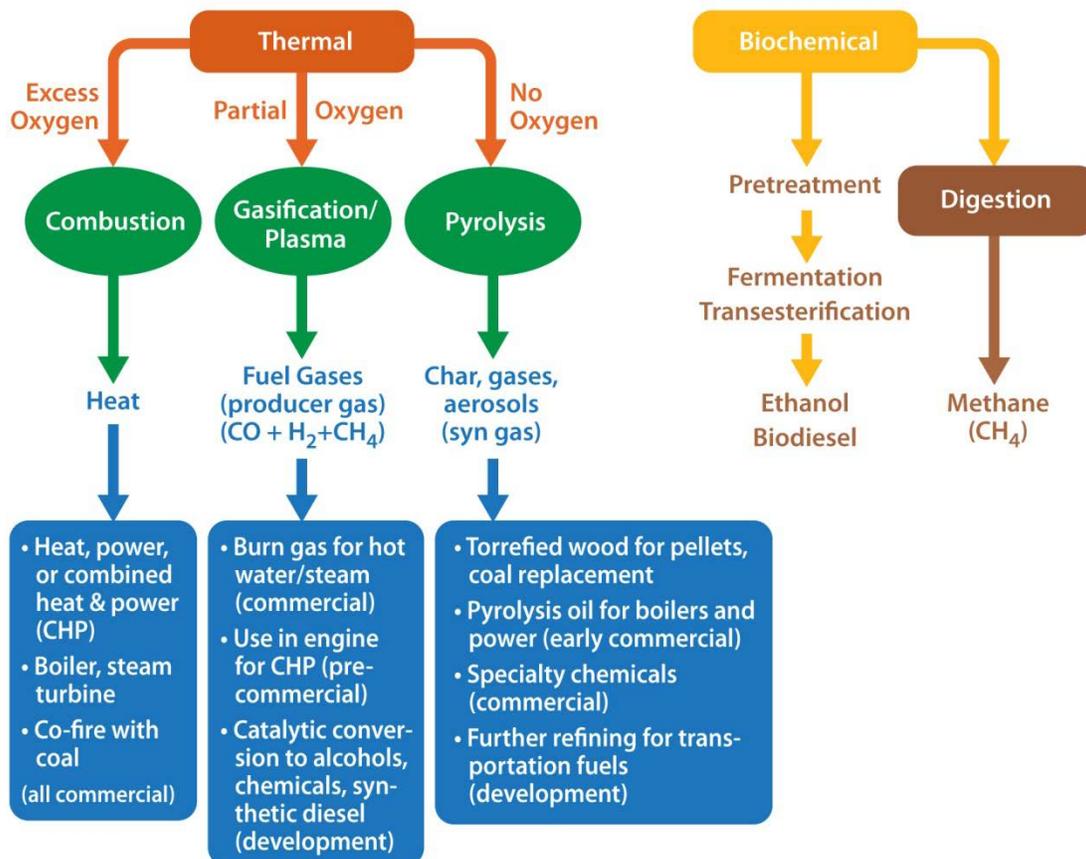


**Figure 19. Waste-to-energy conversion pathways**

Illustration by NREL

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[29] The low end of the range noted here assumes full use of all available USVI incentives and a 20-year system life. The high end of the range represents no use of USVI incentives and a 15-year system life.

Most of these pathways are early in their developmental stages. The only waste-to-energy technology commercially available in the United States using municipal solid waste (MSW) feedstock is combustion. All other processes hold high potential for utilizing MSW feedstock but must overcome various technical or procedural challenges to become commercially viable.

The primary challenge facing these technologies is the heterogeneous nature of MSW, which creates a widely varying chemical constituency of energy products generated from these processes. This variance affects the ability to efficiently extract energy. Solutions are actively being pursued from two angles. The first is to clean up and condition synthetic gas (syngas) products from thermo-chemical conversion and biogas products from biological conversion. This approach makes the gases more usable as a direct fuel in internal combustion engines or gas turbines. Feedstock preparation, including shredding and mixing of MSW to make the feedstock more homogeneous, is the second approach to increasing the quality and performance of the fuel and can be easily incorporated with existing waste-to-energy facilities.

The waste-to-energy project proposed in the USVI utilizes combustion technology with a high level of feedstock processing to improve the fuel quality and performance. There are currently 87 active waste-to-energy plants in the United States (Psomopoulos 2010); of these, 13 facilities are using similar feedstock-processing approaches (Table 7).

**Table 7. Refuse-Derived Fuel Facilities in the United States**

| Company Name | Location | Trash Capacity (tpd) | Generation (MW) | Project Startup |
|---|---|---|---|---|
| Xcel Energy French Island Generating Plant | LaCrosse, WI | 400 | 32 | 1987 |
| Ames Municipal Electric Utility | Ames, IA | 175 | 10 | 1975 |
| Mid-Connecticut Resource Recovery Facility | Hartford, CT | 2,000 | 68 | 1987 |
| Miami-Dade County Resource Recovery Facility | Miami, FL | 3,000 | 77 | 1979 |
| North County Resource Recovery Facility | West Palm Beach, FL | 1,800 | 62 | 1989 |
| Southeastern Public Service Authority of Virginia | Portsmouth, VA | 2,000 | 50 | 1988 |
| Honolulu Resource Recovery Venture | Honolulu, HI | 1,851 | 57 | 1990 |
| Great River Energy - Elk River Station | Elk River, MN | 1,000 | 35 | 1989 |
| SEMASS Resource Recovery Facility | West Wareham, MA | 2,700 | 78 | 1989 |
| Greater Detroit Resource Recovery Facility | Detroit, MI | 2,832 | 68 | 1991 |
| Xcel Energy - Red Wing Steam Plant | Red Wing, MN | 720 | 21 | 1988 |
| Xcel Energy-Wilmarth Plant | Mankato, MN | 720 | 22 | 1987 |
| Maine Energy Recovery Company | Biddeford, ME | 600 | 22 | 1987 |

Source: Davis et al. 2011

Taking the existing recycling opportunities and challenges into account, a likely scenario for the waste available for a waste-to-energy operation in the USVI is outlined in Table 8.

**Table 8. The USVI Waste Stream Profile**

|  | Tons per Year (TPY) |
| --- | --- |
| Total Municipal Solid Waste | 147,000 |
| Metal and Glass Recyclable Material | (14,000) |
| Available for Waste-to-Energy | 133,000 |

Source: Davis et al. 2011

If accurate, the waste available for waste-to-energy in the USVI results in approximately 430 tons per operating day (assuming the facility operates 85% of the time and a 15% allowance for facility maintenance). Using conversion factors from the reference facilities in Table 7, the waste-to-energy plant should produce at least 0.03 MW per ton per day, or about 13 MW. The waste-to-energy plant proposed in the USVI is 16.5 MW. Therefore, the proposed plant must have a higher conversion efficiency, which may be afforded with modern technology (the reference facilities of Table 7 are 20–35 years old), or the proposed plant will require additional feedstock, potentially rum bottoms, or biomass.

A waste-to-energy plant uses the conventional Rankine cycle to generate power from steam. This typically requires a cooling tower or direct water cooling to drive the steam turbine and subsequently condense the steam. As such, a waste-to-energy system needs access to water, so a location along the coast or access to waste water is often preferable. If co-located with the fuel process facility, the waste-to-energy plant will also require a site that can accommodate traffic and some fuel storage prior to use. Both of these requirements and the nature of the waste-to-energy process suggest industrialized areas are the most suitable sites.

Waste-to-energy plants are industrial installations. In many respects, they resemble coal-fired power plants with the associated feeding systems, boilers, and water cooling towers. Figure 20 shows a 50 MW waste-to-energy plant in Oahu, Hawaii.

**Figure 20. 50 MW waste-to-energy facility in Oahu, Hawaii**

Photo by Adam Warren, NREL

The cost of waste-to-energy facilities is estimated at approximately $8,200/kW by the U.S. Energy Information Administration (EIA) (EIA 2010). With typical operation and maintenance costs, electricity produced by these facilities is $0.08–$0.09/kWh. An estimate for a typical 50 MW waste-to-energy facility is presented in Table 9.

**Table 9. General Capital Cost Breakdown for a 50 MW (18,000 Btu/kWh-HHV) Waste-to-Energy Facility**

| | |
|---|---|
| Civil, Structural, Material, and Installation | $33,875,000 |
| Mechanical Equipment Supply and Installation | $183,000,000 |
| Electrical/I&C Supply and Installation | $25,300,000 |
| Engineering, Project Management, Mobilization, and Other Indirects | $56,080,000 |
| EPC Cost before Contingency and Fee | $298,255,000 |
| Fee and Contingency | $44,738,000 |
| Total EPC | $342,993,000 |
| Total EPC ($/kW) | $6,860 |
| Owner's Costs (excluding financing) | $68,599,000 |
| Owner's Costs (excluding financing)($/kW) | $1,372 |
| Total Project Cost | $411,592,000 |
| Total Project Cost ($/kW) | $8,232 |

Source: EIA 2010

The system proposed for the USVI is smaller than the typical waste-to-energy plant size and therefore will not benefit from some typical economies of scale. The proposed USVI waste-to-energy plant also has two refuse-derived fuel (RDF) facilities instead of the typical single site, so additional costs should be expected. Given these factors, a cost of power from $0.12–$0.16/kWh is not unreasonable. A detailed economic analysis was beyond the scope of this work.

### 5.1.1.5 Wind Energy

The consistency of the trade winds from the east provides an excellent source of untapped power in the USVI. This resource is particularly pronounced along the southern coastline and exposed ridges of the islands (Elliot 2008).
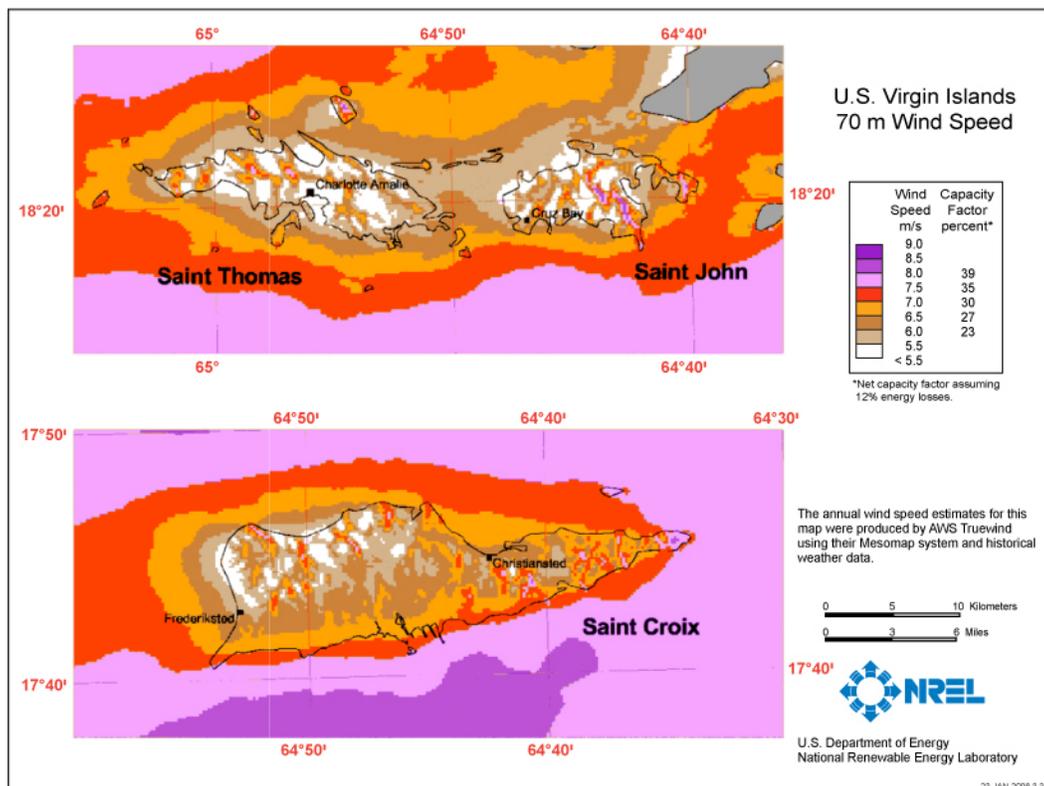


**Figure 21. Estimated annual wind speeds for the USVI**

Unlike solar energy, the wind resource is very site specific. Absent shading, the solar resource at one location is very similar to that found at a location one mile away. Conversely, an excellent wind site and a poor wind site can be separated by a single ridge. Therefore, the wind resource shown in Figure 21 can only be used as a guide. Data from a potential development site is required if successful wind projects are to be deployed. This fact is the impetus behind VIEO's efforts to deploy anemometry (wind measurement) stations on St. Thomas and St. Croix.

The base case road map assumes 22.5 MW of wind will be deployed over the next 15 years. For a utility that peaks at 130 MW, this represents a significant amount of wind power. On an energy basis (megawatt-hours of wind per total annual megawatt-hours), this amount of wind would represent 9.5% of WAPA's annual energy production. This high penetration of wind would put WAPA in a leadership position among utilities that are deploying wind today.

**Table 10. Estimated Percentage of Retail Sales from Wind by Utility**

| | |
|---|---|
| Minnkota Power Cooperative | 38.0% |
| Empire District Electric Company | 18.1% |
| Turlock Irrigation District | 18.0% |
| Otter Tail Power | 14.0% |
| Sunflower Electric Power Corp. | 13.2% |
| Xcel Energy | 11.1% |
| Austin Energy | 10.3% |
| Great River Energy | 10.1% |
| Westar | 10.1% |
| Western Farmers' Electric Cooperative | 9.8% |
| MidAmerican Energy | 9.6% |
| Snohomish Public Utility District | 8.5% |

Source: Wiser and Bolinger 2010

Utility-scale wind development requires significant setbacks from surrounding homes and businesses and adequate spacing of the turbines to avoid blocking the wind from turbines downstream. The typical rule-of-thumb is that wind developments will require 25–50 acres of land (0.1–0.2 km$^2$) per megawatt of wind. For locations with a predominant wind direction like the USVI, turbines can sometimes be installed closer together at the expense of lower efficacy when wind blows from a less-than-ideal direction. For the USVI, it is estimated that the 22.5 MW of wind turbines will occupy 550–1,100 acres (2.2–4.4 km$^2$).

In addition to the quality of the wind resource, there are several other considerations that affect wind siting. Wildlife, view-scape, airports, and proximity to other developments all must be taken into consideration. In the USVI, two sites have been identified that appear to be a trade-off between these sometimes competing criteria—Bovoni Landfill in St. Thomas and the south shore of St. Croix, east of the HOVENSA refinery. These sites appear to have adequate to good wind resources and are located in areas that have already been industrialized.

**Figure 22. Areas considered to have high potential for wind development in the USVI**

Illustration by NREL

Concerns about the impact of wind turbines on view-scape are legitimate and must be addressed if wind is to be a successful contributor to the 60x25 goal. These concerns can be mitigated in part by locating the turbines on sites where industrial equipment is commonplace, such as near the refinery or landfill. In addition, while beauty is always in the eye of the beholder, concern about the aesthetics of wind turbines negatively affecting tourism may be unwarranted, as wind turbines can, in some cases, serve as a tourist attraction and an indication that the tourist is visiting a green locale (Firestone et al. 2009; Firestone et al. 2011; Bladyes 2010).

The first step in understanding the aesthetics of wind turbines is often a computer simulation. While a detailed simulation was beyond the scope of this work, Figure 23 gives a general indication of the appearance of a typical utility-scale wind farm in the USVI.

**Figure 23. Computer simulation of a utility-scale wind farm at Bolvoni Point in St. Thomas**

Illustration by NREL

HOMER  analysis detailed in Burman et al. (2011) indicates that wind can be economically deployed in the USVI; adding 15 MW of wind in the territory was estimated by HOMER analysis to reduce the WAPA fuel use by 9% while reducing the levelized cost of energy (LCOE) by about $0.02/kWh.

## 5.2   High Efficiency Case

Due to its relative cost effectiveness (Figure 24), increased deployment of energy efficiency measures could theoretically result in a lower overall cost to achieve the 60x25 fossil fuel reductions than the base case. The high efficiency scenario considers the implications of even more aggressive pursuit of energy efficiency opportunities. In general, a more aggressive energy efficiency approach means higher penetration of the same technologies and opportunities included in the base case. Figure 24 illustrates the relative balance between energy efficiency and renewable energy as envisioned in the high efficiency case.
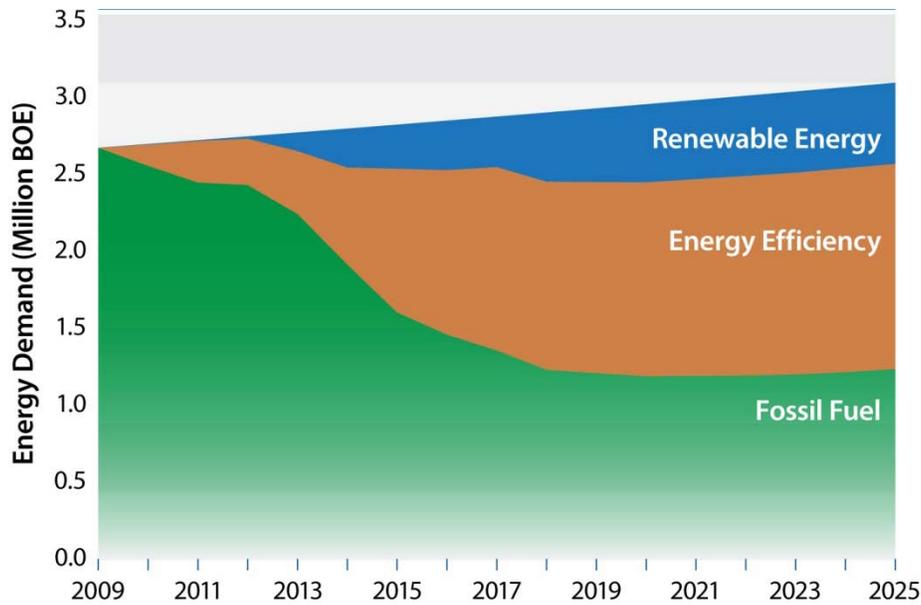
**Figure 24. High efficiency energy mix in the USVI, 2009–2025**

As the power and water supply-side efficiency improvements are fundamental to reduced oil consumption in the USVI, they constitute about 44% of the overall 60x25 goal in all scenarios. As well, waste-to-energy maintains a comparable contribution because of its ability to generate power and reduce MSW. The primary difference associated with this scenario is that end-user efficiency is nearly double its contribution to the 60x25 target relative to the base case. The share of utility-scale renewable energy, as a result, drops to 29% while distributed renewables, buoyed by SWH installations, continue to account for about 4% of the total reduction in oil consumption (Table 11). Drops in installed wind and solar capacity, both of which fall by about 45%, are primarily offset by increases in the penetration efficiency to about 50% of residential, commercial, and industrial end-user loads and a slight increase in the assumed reduction potential in government buildings, from 25% up to 30%.

47

**Table 11. Opportunities and Estimated Impacts from Renewables and Efficiency in the High Efficiency Case**

| Technology/Area of Focus | Action Required | Share of Overall Goal |
|---|---|---|
| **Supply-Side Efficiency** | | |
| Generation | Install state-of-the art heat recovery and operational practices | 28% |
| Desalinization | Install state-of-the art RO technology | 12% |
| Transmission and Distribution | Substation and distribution upgrades | 3% |
| *Subtotal* | | **43%** |
| **End-User Efficiency** | | |
| Residential (Power Only) | Reduce 50% of consumption by 25% | 7% |
| Large C&I (Water & Power) | Reduce 50% of consumption by 25% | 7% |
| Government (Water & Power) | Reduce 75% of consumption by 30% | 5% |
| Small Commercial (Power Only) | Reduce 50% of consumption by 25% | 3% |
| *Subtotal* | | **22%** |
| **Utility-Scale Renewables** | | |
| Waste-to-Energy | 16.5 MW | 16% |
| Wind | 12 MW | 6% |
| Landfill Gas | 5 MW | 6% |
| Solar Photovoltaics | 5 MW | 1% |
| Biomass | 0 MW | 0% |
| *Subtotal* | | **29%** |
| **Distributed Renewables** | | |
| Solar Hot Water | 40% penetration on residences | 4% |
| Solar Photovoltaics | 1 MW | >1% |
| Small Wind | 0.5 MW | >1% |
| *Subtotal* | | **4%** |
| **Total** | | **100%\*** |

*Totals may not sum due to rounding*

In terms of initial investment costs, the high efficiency scenario is about $70 million less in total initial investment cost relative to the base case. There may, however, be significant transaction costs associated with achieving the very high levels of penetration of energy efficiency technologies that are not captured in this analysis. Transaction costs are of particular concern because of the large number of individual decisions and the relatively modest reduction in oil consumption that results from any single energy efficiency action or opportunity when pursuing significant technology deployment in the residential and commercial sectors. As well, energy efficiency potential estimates are some of the least certain in the initial assessment conducted for this effort. Ongoing data collection should provide more information on whether the level of

efficiency improvement per unit is in fact representative of each sector's building stock and realizable potential. Increased efficiency potential could provide the opportunity to reduce the number of units that must be improved in order to achieve the requisite oil reductions with subsequent reductions in transaction costs. Alternatively, increased emphasis on particularly inefficient end users may provide better returns than simply evaluating the average sector building stock. Ultimately, however, aggressive energy efficiency can reduce the level of new renewables required to achieve the targeted 60% reduction in BAU oil consumption.

## 5.3 High Renewables Case

The potential for aggressive energy efficiency to achieve the USVI goal does exist. However, the difficulty associated with such dramatic change in 25% to 50% of end-user electricity use may prove to be quite challenging. An alternative is simply to build more renewable energy generation. This approach, although higher in initial installation costs than either the base case or the high efficiency case, still results in significant oil cost savings over BAU. It may also be somewhat more technically challenging due to increasing levels of variable output renewables, but at the same time, it may actually be easier to implement because of the utility-scale impact that large-scale renewables deployment could bring.

While increased reliance on renewable generation does reduce the need for energy efficiency, improving the efficiency of the existing supply-side infrastructure is critical as existing generation assets will likely remain in use for years to come. In addition, there are likely many end users for which investments in efficiency would be highly cost effective. These elements still make a portion of the overall 2025 energy mix in the high renewables case. However, in this scenario, new renewable generation makes up nearly 50% of the total 60x25 goal. Figure 25 shows the growth in renewables over time and their contribution relative to supply-side and end-user efficiency.
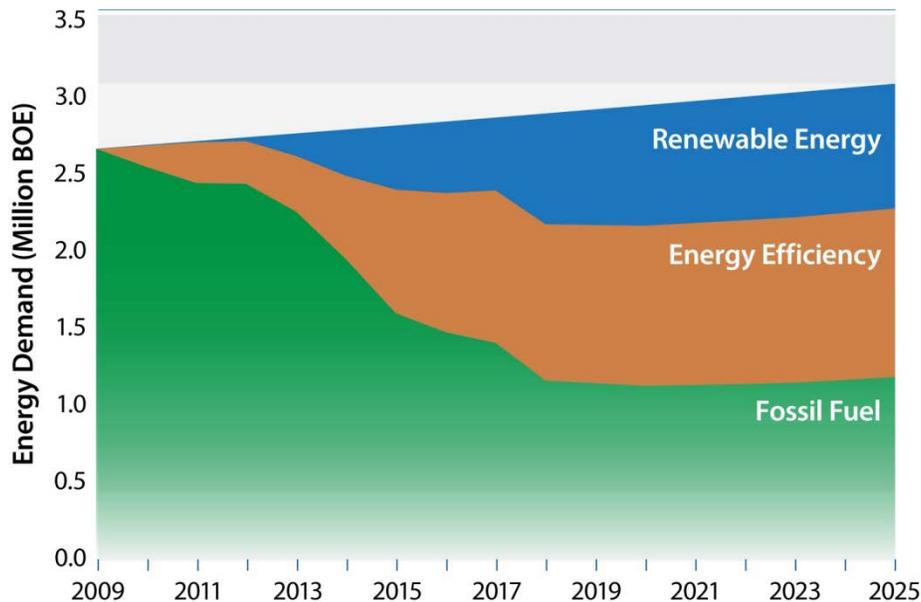


**Figure 25. High renewable scenario energy mix in the USVI, 2009–2025**

In addition to renewable generation, supply-side efficiency improvements constitute about 43% of the oil reduction target. By reducing the estimated potential efficiency improvement per unit and assuming penetration is comparable to that in the base case, end-user efficiency falls to only about 8% of the territory's goal.

In the high renewables case, an additional 11.5 MW of wind, 3 MW of utility-scale solar PV, and the installation of SWH on 50% of residences, as opposed to 40%, is required (Table 12). Increased reliance on renewables must be met by solar or wind technologies because the base case assumes full deployment of all biomass, waste-to-energy, and LFG potential.

**Table 12. Opportunities and Estimated Impacts from Renewables and Efficiency in the High Renewables Case**

| Technology/Area of Focus | Action Required | Share of Overall Goal |
|---|---|---|
| **Supply-Side Efficiency** | | |
| Generation | Install state-of-the art heat recovery and operational practices | 28% |
| Desalinization | Install state-of-the art RO technology | 12% |
| Transmission and Distribution | Substation and distribution upgrades | 3% |
| *Subtotal* | | **43%** |
| **End-User Efficiency** | | |
| Residential (Power Only) | Reduce 25% of consumption by 20% | 3% |
| Large C&I (Water & Power) | Reduce 25% of consumption by 20% | 2% |
| Government (Water & Power) | Reduce 50% of consumption by 20% | 2% |
| Small Commercial (Power Only) | Reduce 25% of consumption by 20% | 1% |
| *Subtotal* | | **8%** |
| **Utility-Scale Renewables** | | |
| Wind | 33 MW | 17% |
| Waste-to-Energy | 16.5 MW | 16% |
| Landfill Gas | 5 MW | 6% |
| Solar Photovoltaics | 12 MW | 3% |
| Biomass | 3 MW | 3% |
| *Subtotal* | | **45%** |
| **Distributed Renewables** | | |
| Solar Hot Water | 50% penetration on residences | 4% |
| Solar Photovoltaics | 1 MW | >1% |
| Small Wind | 1 MW | >1% |
| *Subtotal* | | **4%** |
| **Total** | | **100%\*** |

*Totals may not sum due to rounding

The total initial investment cost of the high renewables scenario is estimated to be about $70 million greater than the base case, or $635 million. Under this scenario, investment in new wind power generation tops $115 million, SWH installations top $85 million, and the waste-to-energy facility remains at about $140 million. If required power system upgrades are identified in future analysis, the approximately 20% variable (wind and solar) generation that is added to the USVI power system will result in additional incremental costs.

# 6 Scenario Comparison, Progress to Date, and Next Steps

The scenarios outlined above differ in various respects, principally in cost and the mix of technologies utilized to meet the goals. Side-by-side comparisons illustrate some of the differences and similarities. In any of the cases, however, the reward for accomplishing the 60x25 goal is large. An estimated average annual fuel savings of more than $100 million is expected over the next 15 years. The initial capital cost associated with full implementation could be offset by fuel savings within the next 10 years. The USVI has already taken some steps to achieve fossil fuel reductions; however, taking the steps to fully implement the level of technology and efficiency deployment expected from these scenarios will require dedication and flexibility in order to incorporate new opportunities and address new barriers as they arise.

## 6.1 Comparing Across Scenarios

In each of the scenarios examined in Section 5, a 60% reduction in BAU electricity sector fossil fuel consumption is achieved by 2025. Much of the technology deployment could occur in the mid to latter half of this decade, so reductions in electricity sector fossil fuel consumption could be quite dramatic over the next 10 years. The expected rate of reduction in fossil fuel consumption is consistent between scenarios with the overall trend shown in Figure 26. Figure 26 also illustrates the annual and cumulative fuel cost savings assuming a constant real (2010) fuel price of $1.91/gal; fuel cost savings exceed the initial capital investment costs required to implement the 60x25 goal by the latter half of this decade and are cumulatively more than $1.5 billion by 2025.
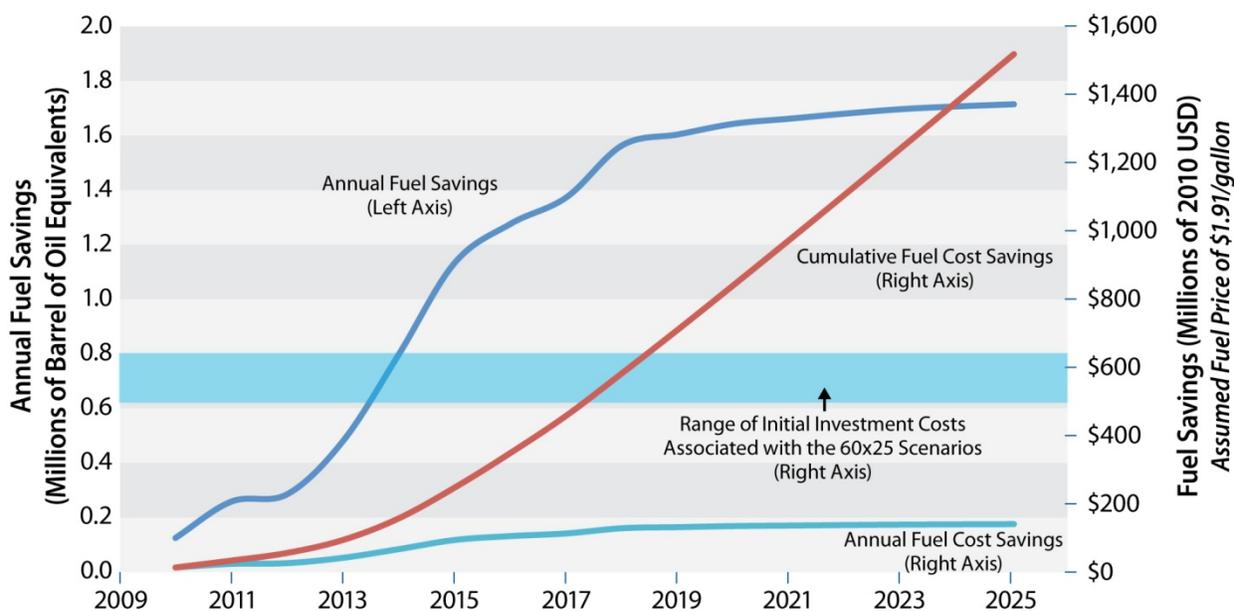


**Figure 26. Expected fuel savings in barrel of oil equivalents, cost savings at $1.91/gal, and capital expenditures required to achieve 60x25**

Note: All dollar values are constant 2010 USD.

While the overall impact on fossil fuel consumption is comparable between individual scenarios, each of the cases does differ around a few critical variables. Figure 27 illustrates the respective

percentage of conventional fossil fuel generation, renewable energy generation, and energy efficiency used to serve the BAU 2025 fossil fuel demand across scenarios. In each case, a roughly 60% reduction in fossil fuel consumption is achieved. Renewables reduce the BAU 2025 fossil fuel demand by 17%–26% while supply-side and end-user efficiency reduce BAU fossil fuel demand by 35%–43%.
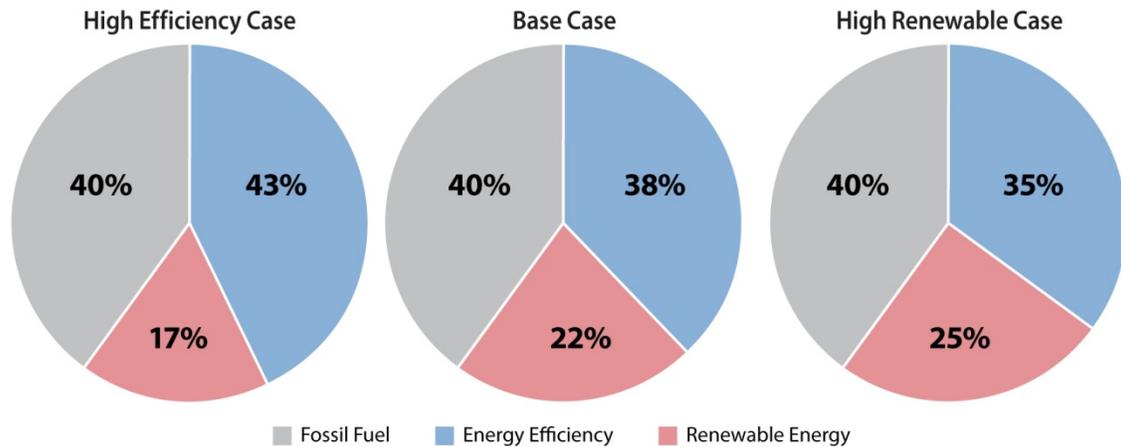


**Figure 27. Percentage of conventional fossil fuel generation, renewable energy generation, and energy efficiency used to serve the expected, business as usual 2025 fossil fuel demand across scenarios**

Because of the reliance on different types of technology to achieve the goals, initial investment costs vary between scenarios (Figure 28). Although the high renewables scenario is the most costly, it also relies on the largest deployment of utility-scale energy generation technology. Arguably, greater reliance on utility-scale power generation technology could make for simpler implementation and reduced transaction costs (not captured here)[30] that might be associated with achieving the very high penetration of energy efficiency technologies envisioned in the high efficiency scenario. Initial investment cost savings associated with increased reliance on energy efficiency is primarily the result of savings resulting from reduced deployment of solar PV, wind, and biomass power generation facilities. Changes in the deployment level of renewable power generation technologies across the scenarios are detailed in Section 5 and summarized in Figure 29.

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[30] Costs discussed and shown here reflect direct capital expenditures. However, mobilizing a broad swath of private residents and business owners to adopt and finance energy efficiency improvements at the level required in the base case and high efficiency scenarios may require significant public education and outreach as well as technical and other support. These latter costs would be in addition to the direct capital expenditures noted here.
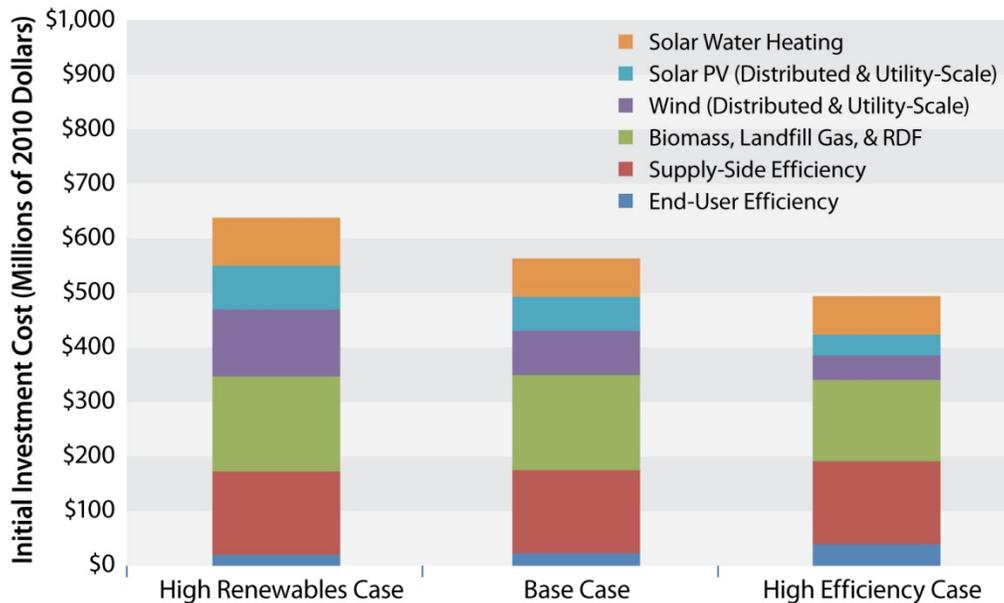
**Figure 28. Estimated initial investment costs to deploy the technology utilized in each scenario**
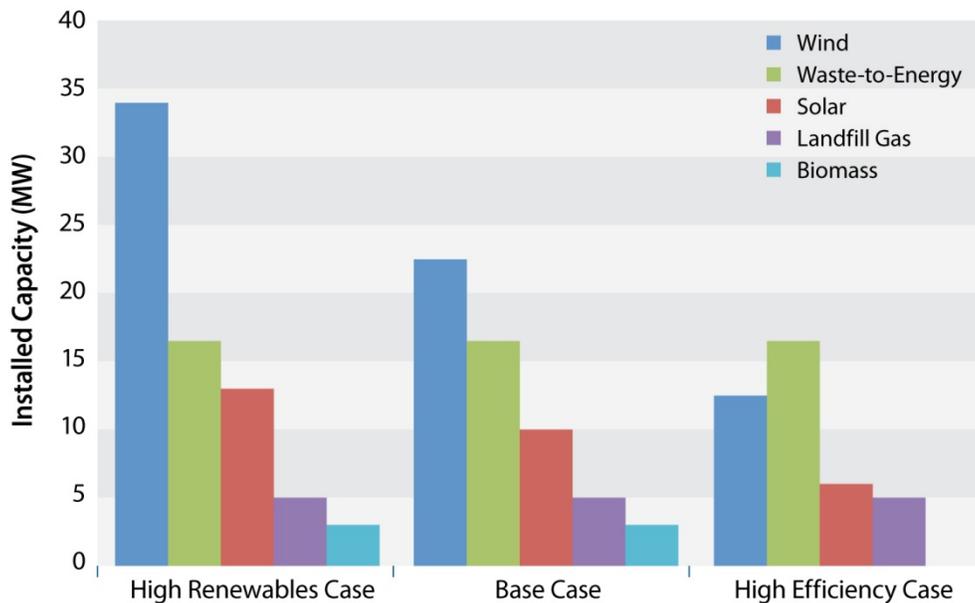


**Figure 29. Deployment of renewable power generation technology across scenarios**

From a utility or grid operations perspective, the penetration of variable output renewables is also an important consideration (Figure 30). Results from this analysis suggest variable generation could constitute something on the order of 10%–20% of WAPA's generation mix, a level that has been successfully managed in a variety of large and small power systems around the world. Analysis of the USVI-specific system impacts and costs resulting from this level of variable generation was outside the scope of this effort.[31]

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[31] Integrating renewable energy into the USVI grid is discussed in somewhat greater detail in Burman et al. (2011).
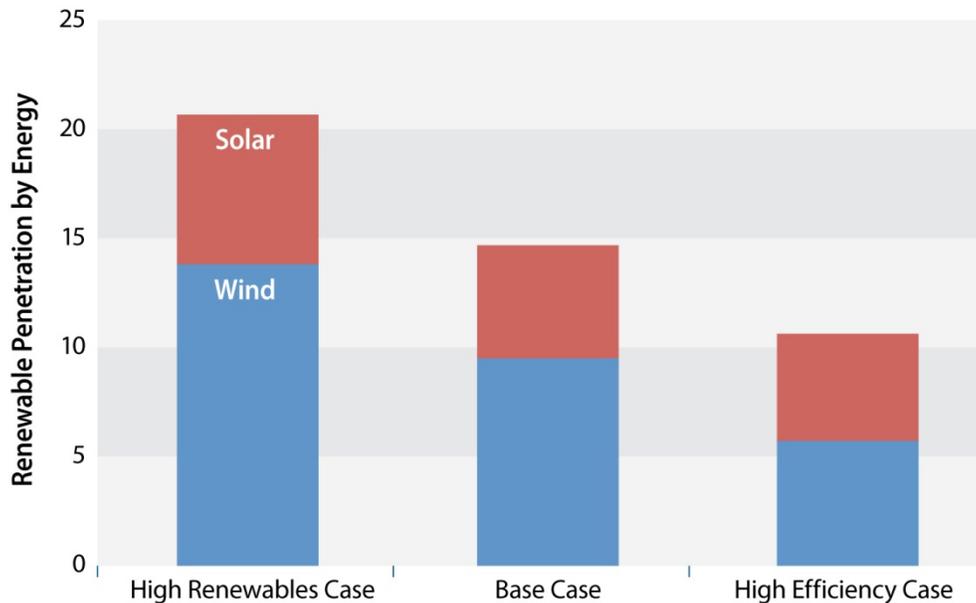
**Figure 30. Average penetration by energy of variable output renewables on the USVI grid across scenarios**

## 6.2 Progress to Date

Initial findings revealed that a diverse set of power sector activities are ongoing in the USVI. Such initiatives have precipitated organically in the USVI as well as from the past two years of collaboration among DOE, DOI, and stakeholders in the USVI. These activities have already begun to have an impact on the future energy portfolio of the USVI relative to BAU dating back to 2009. Assuming these savings can be maintained through 2025, they will account for about 16% of the 60x25 goal (Figure 31).
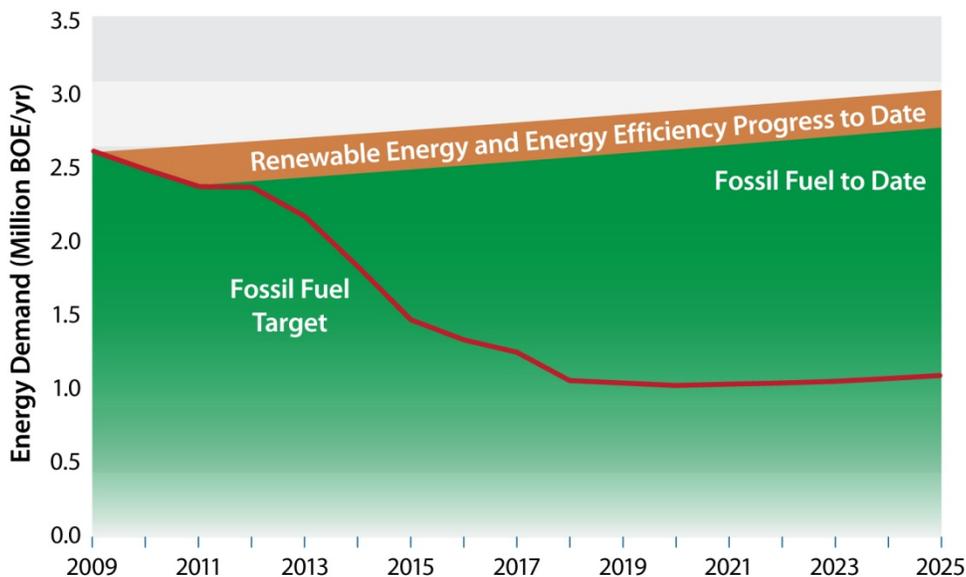


**Figure 31. Estimated reduction in business-as-usual fossil fuel consumption from supply-side efficiency and renewable energy projects completed between 2009 and 2011 (assuming current savings are maintained through 2025)**

The significant majority (more than 95%) of the progress to date has resulted from action WAPA has taken to begin to increase supply-side efficiency. These actions are most clearly represented by the pilot RO facility and recent HRSG installations on St. Croix. With these initial steps underway, WAPA is well positioned to continue to help realize the supply-side efficiency actions that are a fundamental piece (at least 43%) of each of the scenarios put forth here. In addition to WAPA improvements in efficiency, another significant step forward is the installation of the 451 kW solar PV system at the Cyril E. King Airport. Other notable contributors to the progress so far include energy office rebates, which have helped to fund distributed solar PV and SWH projects.

In addition to progress that has resulted in new power generation or increased efficiency, a number of important steps have also been initiated that are intended to facilitate future development. The VIEO steps to install meteorological towers to collect high-resolution wind and solar data are expected to facilitate financing for additional utility-scale PV installations, future utility-scale wind energy projects, and integration studies that will determine the limits of the existing grid system as well as the required improvements to integrate higher penetrations of variable output renewables. Likewise, the data collection and modeling efforts on the end-use efficiency side are necessary to better understand what specific ECMs exist and subsequently to determine how efforts to deploy these ECMs must be structured. Although work remains, efforts on the policy front also continue to reduce market and regulatory barriers to efficiency and renewables.

## 6.3  Uncertainties and Next Steps

Throughout this process, numerous uncertainties persist and assumptions must be made. In reality, fully implementing the portfolio of supply-side and end-user activities will require a sustained, concentrated effort among WAPA, territorial government, local business, and local residents for years into the future. It may also require strategic outreach to build and maintain public support and perhaps workforce development activities to provide the requisite human resources. In addition, it will likely require policy and regulatory changes to facilitate new development. At the same time, new technologies or significant cost reductions for existing renewable energy or energy efficiency technologies could dramatically change the future energy portfolio of the USVI. Given these uncertainties, the paths forward identified here should be viewed as dynamic and subject to adaptation and evolution as new information becomes available and technology and markets change.

Of particular concern in this analysis is the relative cost of the renewable energy technology, energy efficiency measures, and the price of fossil fuel. The suggested mix of technologies included is a function of both resource potential and relative cost. Existing initiatives and their continued development in the USVI are largely driven by the relative price differences between technologies as they exist today. However, the relative cost difference among technologies and even between distributed and utility-scale power generation will ultimately determine the extent to which any individual technology is deployed over or before another. Changes in relative price among technologies could significantly alter the mix of technologies deployed in the USVI from that detailed here. For example, a large cost reduction for offshore wind might allow greater wind energy capacity to be installed in the USVI with virtually no impact to USVI land area. Alternatively, significant cost reductions for solar PV could increase the viability of distributed PV generation, effectively reducing the need for centralized power production (conventional or

renewable) and potentially even reducing the need for energy efficiency improvements. In addition, there is significant uncertainty in future oil prices, which once again passed $100/barrel in early 2011 and will fundamentally determine the level of investment that is most rational.[32]

The uncertainties associated with the future, as well as the inertia of the status quo, suggest that achieving a future where the USVI consumes 60% less fossil fuel than expected by BAU is not likely to occur without local initiative and leadership. Sustained investment across sectors is also necessary to achieve the desired outcomes. Financing new power generation capacity and significant investments in energy efficiency will require risk taking and coordination among the private and public sectors. Maintaining coordination among regulatory agencies, the utility sector, and local residents—institutions that may not be used to working together—is also likely to be necessary. To some extent, all of these conditions are assumed to be in place by the road map; in reality, however, ensuring that such conditions are in place is likely to require dedicated efforts from an array of stakeholders.

To maintain the momentum of existing fossil fuel reduction activities, a number of important next steps across an array of fronts are expected to be necessary. High-resolution resource assessment is fundamental to demonstrate the commercial viability of the USVI wind and solar resources, attract commercial interest in these projects, and understand the potential grid implications of a high-penetration renewable energy future.[33] A better understanding of specific energy efficiency opportunities within each sector will allow the stakeholders in the USVI to better communicate the value and practicality of specific actions individuals and businesses can take to reduce energy consumption. Finally, by identifying specific sites where renewable energy projects are viable and attempting to analyze these sites as actual projects, stakeholders will gain a better understanding of actual project potential.

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[32] With sustained high oil prices and reduced renewable energy costs over time, the USVI may ultimately desire a greater reduction in use of imported oil than the goals stated here, further altering the required deployment of renewable and energy efficiency technologies.

[33] Project developers often conduct their own resource assessment; however, by jumping ahead of the curve and collecting data independently, the USVI will be better positioned to attract developers and evaluate specific project proposals.

# 7  Conclusions

The relative size, remoteness, and limited indigenous resources of island communities make energy a particularly challenging dilemma. However, island communities are uniquely situated to demonstrate the benefits of deploying energy efficiency and renewable energy at scale. Island communities have the potential to take the lead and to show the rest of the world how to transform our shared energy future. Through the EDIN-USVI effort, a broad group of federal and local stakeholders are working together to help transform the energy economy in the USVI and to set an example for other islands to follow.

Reducing oil consumption 60% from BAU by 2025 is ambitious and will require aggressive deployment of energy efficiency and renewable energy technologies. It is, however, technically and economically attainable using renewable energy and efficiency technologies on the market today, and the benefits of realizing this goal are noteworthy; average annual fuel cost savings of over $100 million, 400 new jobs by 2025, and greenhouse gas and other emissions reductions.

Many steps have already been taken to move the USVI toward its goal, and initial progress has been impressive. WAPA's ongoing efforts to improve efficiency through the use of HRSGs and RO are fundamental to achieving the USVI goals. The building efficiency work led by the USVI Department of Education and VIEO are showing that dramatic reductions in electricity and water use are achievable and economic. The 451 kW solar PV installation at the Cyril E. King Airport is the first example of large-scale solar in the region. However, a variety of additional initiatives on the electricity and water supply side and the end-user or consumer side have been identified that will also be necessary for the USVI to fully realize its 60x25 goal.

As a result of technology evolution and new information, the ultimate achievement of the 60x25 goal may not precisely resemble the scenarios laid out here. In fact, the future will likely be determined by a diverse set of technical and economic variables as well as public input. Nevertheless, the scenarios envisioned here provide a starting point for continued analysis, discussion, and decision making.

The 60x25 goal, however, will not be achieved simply by technology alone. New policy measures, which allocate costs and benefits among WAPA, ratepayers, and others in the USVI in a fair and equitable manner and some degree of risk taking are also expected to be necessary. A sustained investment of human and financial resources and a coordinated effort among the utility sector, government agencies, private business, and USVI residents will also be important.

The approach adopted for this effort can be extended to other island communities that face similar challenges of high energy costs and heavy dependence on foreign energy sources. Identifying existing initiatives and resources is critical to establishing a path to a sustainable energy future. It may not always be the case that other islands are able to ramp up as quickly as the USVI. However, by identifying existing resources, analyzing how these assets might be leveraged to accomplish more, and identifying a concrete set of actions that can achieve ambitious goals, other island states can gain a firm understanding of the actions necessary to reduce dependence on imported oil.

# References

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE). (2004). "ANSI/ASHRAE Standard 55-2004: Thermal Environmental Conditions for Human Comfort." ISSN 1041-2336. Atlanta, GA: ASHRAE.

American Wind Energy Association (AWEA). (January 2011). *Year End 2010 Market Report.* Washington, D.C.: AWEA.

Bain, R.; Amos, W.; Downing, M.; Perlack, M. (2003). *Biopower Technical Assessment: State of the Industry and Technology*. NREL/TP-510-33123. Golden, CO: National Renewable Energy Laboratory.

Baring-Gould, I.; Conrad, M.; Haase, S.; Hotchkiss, E.; McNutt, P. (2011). *Guam Initial Technical Assessment Report.* NREL/TP-7A40-50580. Golden, CO: National Renewable Energy Laboratory.

Bolinger, M. (2009). *Financing Non-Residential Photovoltaic Projects: Options and Implications.* LBNL-1410E. Berkeley, CA: Lawrence Berkeley National Laboratory.

Burman K.; Olis, D.; Gevorgian, V.; Warren, A.; Butt, R.; Lilienthal. P; Glassmire, J. (2011). *Integrating Renewable Energy into the Transmission and Distribution System of the U.S. Virgin Islands.* NREL/TP-7A20-51294. Golden, CO: National Renewable Energy Laboratory.

Burman, K.; Walker, A. (July 2009). *Ocean Energy Technology Overview.* Washington, D.C.: U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program.

Central Intelligence Agency (CIA). (2011). *The World Factbook: U.S. Virgin Islands.* https://www.cia.gov/library/publications/the-world-factbook/geos/vq.html . Accessed July 27, 2011.

Chakroff, P.; Haines, K. (2010). *Survey of a Stand of Common Tan Tan (Leucaena Leucocephala) Located Across from Woodson Jr. High School*. St. Croix, USVI.

Clean Power Research. (2010). *U.S. Virgin Islands Global Horizontal Irradiation.* DE-AC36-08GO28308. Golden, CO: National Renewable Energy Laboratory.

Couture, T. D.; Cory, K.; Kreycik, C.; Williams, E. (2010). *Policymaker's Guide to Feed-In Tariff Policy Design.* TP-6A2-44849. Golden, CO: National Renewable Energy Laboratory, 144 pp.

Davis, J.; Haase, S.; Warren, A. (2011). *Waste-to-Energy Evaluation: U.S. Virgin Islands.* NREL/TP-7A20-52308. Golden, CO: National Renewable Energy Laboratory.

Denholm, P.; Hand, M.; Jackson, M.; Ong, S. (August 2009). *Land-Use Requirements of Modern Wind Power Plants in the United States.* NREL/TP-6A2-45834. Golden, CO: National Renewable Energy Laboratory.

Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Seyboth, K.; Arvizu, D.; Bruckner, T.; Christensen, J.; Devernay, J.M.; Faaij, A.; Fischedick, M.; Goldstein, B.; Hansen, G.; Huckerby, J.; Jäger-Waldau, A.; Kadner, S.; Kammen, D.; Krey, V.; Kumar, A.; Lewis, A.; Lucon, O.; Matschoss, P.; Maurice, L.; Mitchell, C.; Moomaw, W.; Moreira, J.; Nadai, A.; Nilsson, L.J.; Nyboer, J.; Rahman, A.; Sathaye, J.; Sawin, J.; Schaeffer, R.; Schei, T.; Schlömer, S.; Sims, S.; Verbruggen, A.; von Stechow, C.; Urama, K.; Wiser, R.; Yamba, F.; Zwickel, R. (2011). "2011: Summary for Policy Makers." Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Seyboth, K.; Matschoss, P.; Kadner, S.; Zwickel, T.; Eickemeier, P.; Hansen, G.; Schlömer, S.; Stechow, C.V., eds. *Special Report on Renewable Energy Sources and Climate Change Mitigation.* Cambridge, UK: Cambridge University Press, 2011. http://www.ipcc-wg3.de/publications/special-reports/srren. Accessed May 27, 2011.

EDIN-USVI. (March 2011). *EDIN-USVI Clean Energy Quarterly.* 1:2. NREL/NS-7A20-50637. Golden, CO: National Renewable Energy Laboratory.

Elliot, D. (2008). "U.S. Virgin Islands Wind Resources." Presented at the 2008 U.S. Virgin Islands Wind Workshop, St. Thomas, USVI. http://www.vienergy.org/menubar/USVI%20Wind%20Resources%20-%20Dennis%20Elliott.ppt Accessed July 28, 2011.

Energy Information Administration (EIA). (2010a). *Geothermal Heat Pump Manufacturing Activities, 2009.* http://www.eia.gov/cneaf/solar.renewables/page/ghpsurvey/ghpssurvey.html. Accessed July 28, 2011.

EIA (2010b). *Updated Capital Cost Estimates for Electricity Generation Plants.* Washington D.C.: U.S. EIA Office of Energy Analysis.

EIA. (2008). *Landfill Gas Data for 2006.* http://www.eia.gov/cneaf/solar.renewables/page/landfillgas/landfillgas.html. Accessed August 8, 2011.

Environmental Protection Agency (EPA). (2011). *Landfill Methane Outreach Program Interactive Conversion Tool.* http://www.epa.gov/lmop/projects-candidates/interactive.html. Accessed August 9, 2011.

European Renewable Energy Council (EREC); Greenpeace International (GPI). (2008). *Energy [R]evolution: A Sustainable World Energy Outlook*. Brussels, Belgium: GPI, EREC.

European Wind Energy Association (EWEA). (2009). *Wind Energy, the Facts.* Brussels, Belgium: EWEA.

Firestone, J.; Kempton, W.; Krueger, A. (2009). "Public Acceptance of Offshore Wind Power Projects in the USA." *Wind Energy* (12); pp. 183–202.

Georgia Institute of Technology. *Assessment of Energy Production Potential from Tidal Streams in the United States.* (2011). http://www.tidalstreampower.gatech.edu/. Accessed August 3, 2011.

Gifford, J.; Grace, B. (2011). *CREST Cost of Renewable Energy Spreadsheet Tool: A Model for Developing Cost-Based Incentives in the United States.* NREL/SR-6A20-50374. Golden, CO: National Renewable Energy Laboratory.

Global Wind Energy Council (GWEC). (2011). *Global Wind 2010 Report.* Brussels, Belgium: GWEC.

Granade, H.; Creyts, J.; Derkach, A.; Farese, P.; Nyquist, S.; Ostrowski, K. (2009). *Unlocking Energy Efficiency in the U.S. Economy.* McKinsey & Company.

GTM Research. (2010a). *U.S. Solar Energy Trade Assessment 2010: Trade Flows and Domestic Content for Solar Energy-Related Goods and Services in the United States.* Washington, D.C.: Solar Energy Industries Association.

GTM Research. (2010b). *U.S. Solar Market Insight 2010 Year-in-Review*. Washington, D.C.: Solar Energy Industries Association. http://www.seia.org/galleries/pdf/SMI-YIR-2010-ES.pdf. Accessed August 8, 2011.

Hawaii Clean Energy Initiative (HCEI). (2011). http://www.hawaiicleanenergyinitiative.org/. Accessed July 27, 2011.

Hoen, B.; Wiser, R.; Cappers, P.; Thayer, M. (2011). *An Analysis of the Effects of Residential Photovoltaic Energy Systems on Home Sales Prices in California.* LBNL-4476E. Berkeley, CA: Lawrence Berkeley National Laboratory.

Holmes, S.; Kao, K. (2010). *Developing Residential Design Parameters for Naturally Ventilated and Low-Energy Homes in the United States Virgin Islands*. Somerville, MA: Kao Design Group.

International Code Council. (2009). *2009 International Energy Conservation Code*. Country Club Hills, IL: International Code Council. http://publicecodes.citation.com/icod/iecc/2009/index.htm. Accessed August 8, 2011.

International Geothermal Association (IGA). (2011). *Installed Generation Capacity.* http://www.geothermal-energy.org/226,installed_generating_capacity.html. Accessed July 28, 2011.

Jamaica Information Service (JIS). (2010). "Wind Turbines for Wigton Windfarm Being Offloaded." http://www.jis.gov.jm/news/111/23549?mode=redirect. Accessed July 28, 2011.

Jennejohn, D. (March 2011). "Annual Geothermal Power Production and Development Report: March 2011." Washington, D.C.: Geothermal Energy Association.

Kanteralis, C.; Walker, J.G. (1988). "The Identification and Subjective Effect of Amplitude Modulation in Diesel Engine Exhaust Noise." *Journal of Sound and Vibration* (120:2); pp. 297–302.

Khan, J.; Bhuyan, G; (2009). *Ocean Energy: Global Technology Development Status Report*. Prepared by Powertech Labs for the International Energy Agency-Implementing Agreement on Ocean Energy Systems. http://www.iea-oceans.org/_fich/6/AoNNEX_1_Doc_T0104.pdf. Accessed August 8, 2011.

Kodiak Electric Association (KEA). (2011). *Generation.* http://www.kodiakelectric.com/generation.html. Accessed July 27, 2011.

Kollins, K.; Speer, B.; Cory, K. (2009). *Solar PV Project Financing: Regulatory and Legislative Challenges for Third-Party PPA System Owners*. TP-6A2-46723. Golden, CO: National Renewable Energy Laboratory; 55 pp. http://www.nrel.gov/docs/fy10osti/46723.pdf. Accessed July 29, 2011.

Langniss, O.; Ince, D. (2004). "Solar Water Heating: A Viable Industry in Developing Countries." *REFocus* (5:3); pp. 18-21.

Lantz, E.; Oteri, F.; Tegen, S.; Doris, E. (2010). *State Clean Energy Policies: State Policy and the Pursuit of Renewable Energy Manufacturing*. NREL/TP-6A2-46672. Golden, CO: National Renewable Energy Laboratory.

Lazard Ltd. (June 2008). "Levelized Cost of Energy." Presented at the National Association of Regulatory Commissioners (NARUC). http://www.narucmeetings.org/Presentations/2008%20EMP%20Levelized%20Cost%20of%20Energy%20-%20Master%20June%202008%20(2).pdf. Accessed July 28, 2011.

Lemming, J.K.; Morthorst, P.E.; Clausen, N.E.; Hjuler Jensen, P. (2009). *Contribution to the Chapter on Wind Power in Energy Technology Perspectives 2008*. Risø-R-1674(EN). Roskilde, Denmark: Risø National Laboratory for Sustainable Energy.

Lesh, P. (2009). "Rate Impacts and Key Design Elements of Gas and Electric Utility Decoupling: A Comprehensive Review." *Electricity Journal* (22:8).

Lilley, M.; Firestone, J.; Kempton, W. (2010). "The Effect of Wind Power Installations on Coastal Tourism." *Energies* (3:1); pp. 1–22.

Maguire Group Inc. (2007). *Revised Design Capacity and Landfill Gas Emission Calculation. Bovoni Landfill – St. Thomas, USVI.* Project No. 17858. Christiansted, USVI: VI Waste Management Authority.

McCunney, R.J.; Meyer, J. (2007). "Occupational Exposure to Noise," Chapter 85. Rom, W. and Markowitz, S., eds. *Environmental and Occupational Medicine.* 4th Edition, Baltimore, MD: Lippincott Williams and Wilkins; pp. 1295–1307.

Munasinghe, M.; Mayer, P.; (1993). *Energy Policy Analysis and Modeling.* New York, NY: Cambridge University Press.

National Renewable Energy Laboratory (NREL). (11 July 2011). "Concentrating Solar Power." *Learning About Renewable Energy.* http://www.nrel.gov/learning/re_csp.html. Accessed August 1, 2011.

Orloff, S.; Flannery, A. (1992). *Wind Turbine Effects on Avian Activity, Habitat Use, and Mortality in Altamont Pass and Solano County Wind Resource Areas.* Work performed by BioSystems Analysis, Inc., Tiburon, CA. Sacramento, CA: California Energy Commission.

Ottley, B. (July 2011). Personal communication. U.S. Department of Interior, USVI Field Office.

Pedersen, E.; Van den berg, F.; Bakker, R.; Bouma, J. (2009). "Response to Noise from Modern Wind Farms in The Netherlands." *Journal Acoustical Society of America* (126:2); pp. 634–643.

Pedersen, E.; Waye, K.P. (2007). "Wind Turbine Noise, Annoyance and Self-Reported Health and Well-Being in Different Living Environments." *Occupational and Environmental Medicine* (64); pp. 480–486.

Petersen, D.; Haase, S. (2009). *Market Assessment of Biomass Gasification and Combustion Technology for Small- and Medium-Scale Applications*. NREL/TP-7A2-46190. Golden, CO: National Renewable Energy Laboratory.

Pierpont, N. (2010). *Wind Turbine Syndrome: A Report on a Natural Experiment.* Santa Fe, NM: K-Selected Books.

Psomopoulos, C.; Bourka, A.; Themelis, N. (2009). "Waste-to-Energy: A Review of Status and Benefits in the USA." *Waste Management* (29); pp. 1718–1724.

Puerto Rico Electric Power Authority (PREPA). (2009). "PREPA Electric System." http://www.prepa.com/aeees2_eng.asp. Accessed July 28, 2011.

Rose, J. (2010). *Freeing the Grid: Best Practices in State Net-Metering Policies and Interconnection Procedures*. 4th Edition. New York, NY: Network for New Energy Choices. http://www.newenergychoices.org/uploads/FreeingTheGrid2010.pdf. Accessed July 29, 2011.

RW Beck. (2010). *Consulting Engineer's Report on the Electric System of the Virgin Islands Water and Power Authority.* Christiansted, USVI: WAPA.

RW Beck. (2011). *Avoided Energy and Capacity Cost Study 2011.* Christiansted, USVI: WAPA.

Saleem, A. (7 July 2011). Email. Virgin Islands Energy Office (VIEO), Fredriksted, USVI.

Schwabe, P.; Lensink, S.; Hand, M. (2010). *IEA Wind Task 26: Multi-National Case Study of the Financial Cost of Wind Energy*. Paris: International Energy Agency.

Shirley, R.; Kammen, D.; (2010). Presentation by R. Shirley at EDIN Working Group Meeting November 15, 2010. St. Croix, USVI.

Tidball, R.; Bluestein, J.; Rodriguez, N.; Knoke, S. (2010). *Cost and Performance Assumptions for Modeling Electricity Generation Technologies*. NREL/SR-6A20-48595. Golden, CO: National Renewable Energy Laboratory.

U.S. Bureau of Economic Analysis (BEA). (2010). "Estimates of the Major Components of Gross Domestic Product for the U.S. Virgin Islands." BEA press release. http://www.bea.gov/newsreleases/general/terr/2010/vi_070610.htm. Accessed July 29, 2011.

U.S. Census Bureau. (2003). *U.S. Virgin Islands: 2000 Social, Economic, and Housing Characteristics*. PHC-4-VI. Washington D.C.: U.S. Department of Commerce, Economics and Statistics Administration.

U.S. Census Bureau. (2010). *Income, Poverty, and Health Insurance Coverage in the United States: 2009*. P60-238. Washington D.C.: U.S. Department of Commerce, Economics and Statistics Administration.

U.S. Department of Energy (DOE). (July 2008). *20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply*. DOE/GO-102008-2567. Washington, D.C.: DOE.

U.S. Environmental Protection Agency (EPA). (2011). "Landfill Methane Outreach Program." http://www.epa.gov/lmop/. Accessed July 28, 2011.

U.S. Internal Revenue Service (IRS). (2009). *Internal Revenue Bulletin: 2009-17*. Section 45K(d)(5). http://www.irs.gov/irb/2009-17_IRB/ar05.html. Accessed July 28, 2011.

U.S. Virgin Islands Bureau of Economic Research (VIBER). (2011). *Civilian Employment*. U.S.Virgin Islands Bureau of Economic Research Historical Archive. http://usviber.org/publications.htm. Accessed July 28, 2011.

U.S. Virgin Islands Forest Resources Assessment and Strategies. (June 2010). Provided by Marilyn Chakroff, Kingshill, USVI: VI Department of Agriculture, Forestry Division.

U.S. Virgin Islands Governor (VI Governor). (2009). *Act 7075*. Bill No. 28-0009. Regular Session 2009 (Signed July 3, 2009). Fredriksted, USVI.

U.S. Virgin Islands Senate (VI Senate). (2009). *Act 7075*. Bill No. 28-0009. Regular Session 2009 (Signed May 22, 2009). Fredriksted, USVI.

United Nations Development Program (UNDP). (2011). *Energy for Sustainable Development: Overview*. UNDP Environment and Energy. http://www.undp.org/energy/. Accessed July 27, 2011.

VINow. (2011). "Weather in the Virgin Islands." VINow.com. http://www.vinow.com/usvi/weather.php. Accessed July 27, 2011.

Virgin Islands Energy Alliance (VIEA). (2010). *Virgin Islands Energy Alliance Task 1Report: Goals.* PC-VIEO-001-2010. Bostonia Partners LLC. Frederiksted, USVI: Virgin Islands Energy Office.

Virgin Islands Public Service Commission (VI PSC). (8 July 2011). Internal Data. Obtained by request.

Virgin Islands Water & Power Authority (WAPA). (2011a). Internal Data. Christiansted, VI: WAPA.

WAPA. (2010). *Official Statement: New (Bond) Issue.* Christiansted, USVI: WAPA.

WAPA (2011b). *What is the LEAC?* Chistiansted, USVI: WAPA. http://www.viwapa.vi/Customers/RatesFees/What_is_the_LEAC.aspx. Accessed August 30, 2011.

Walker, A.; Jhaveri, A. (2011). *Renewable Energy Technology Characterizations and Resource Assessment for Microsoft Corporation Facilities.* NREL/TP-7A40-51280. Golden, CO: National Renewable Energy Laboratory.

Walsh, B. (2008). "Going Green: What is a Green Collar Job, Exactly?" *TIME Magazine*. http://www.time.com/time/health/article/0,8599,1809506,00.html. Accessed August 8, 2011.

Wei, M.; Patadia S.; Kammen D.M. (2010). "Putting Renewables and Energy Efficiency to Work: How Many Jobs Can the Clean Energy Industry Generate in the U.S.?" *Energy Policy* (38:2); pp. 919–931.

Weisser, D. (2004). "On the Economics of Electricity Consumption in Small Island Developing States: A Role for Renewable Energy Technologies?" *Energy Policy* (32); pp. 127–140.

Wiser, R.; Bolinger, M. (August 2010). *2009 Wind Technologies Market Report.* DOE/GO-102010-3107. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy.

Wiser, R.; Bolinger, M. (July 2011). *2010 Wind Technologies Market Report.* DOE/GO-102011-3322. Washington, D.C.: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy.

# Appendix A: Technology Descriptions and Relevant Considerations in the USVI

This appendix describes the renewable energy resources considered in developing this energy road map. A general overview of the technology will be presented, followed by a discussion of the screening method. The feasibility screening attempted to answer the following questions related to resource availability, technology maturity, and economic viability:

1. To what extent is this resource available in the USVI?

2. Is the technology in commercial use?

3. What is the estimated installed capacity in the United States and globally?

4. How long has this technology been commercially available?

5. If it is not commercially available, what are the barriers to commercialization and the expected timeline?

6. Based on current technology, what is the range of estimated COE ($/kWh)?

Technologies covered in this appendix and a summary of findings are shown in Table A-1.

**Table A-1. Renewable Energy Technology Screening Results**

| Technology | Resource Potential in USVI | Technical Maturity | Approximate Cost of Delivered Energy* | Estimated USVI (Island-Specific) Installation Cost | Land Use Impact | Included In Road Map |
|---|---|---|---|---|---|---|
| Biomass Power | Medium | Commercial | $0.13 - $0.18 /kWh | $8,500/kW | High | Yes |
| Concentrating Solar Power | Low | | | | | No |
| Geothermal Power | None | | | | | No |
| Landfill Gas | Medium | Commercial | $0.18 - $0.27/kWh | $1,715/kW | Low (existing landfills) | Yes |
| Marine and Hydro-kinetic Power | Uncertain, likely low | R&D/ prototype | | | | No |
| Ocean Thermal Energy Conversion | High | R&D/ prototype | | | | No |
| Solar Photovoltaics | High | Commercial | $0.19 - $0.36 /kWh | $6,000/kW (utility) $8,000/kW (residential) | Medium (5-8 acres per MW) | Yes |
| Solar Hot Water** | High | Commerial | $0.15 - $0.20 /kWh | $4,000/system (4-person household) | Low (typically rooftops) | Yes |
| Waste to Energy | Medium | Commercial | $0.08 - $0.16 /kWh | $8,200 - $8,500/kW | Low | Yes |
| Land-Based Wind Power | High | Commercial | $0.10 - $0.20 /kWh | $3,600/kW (utility) $4,000/kW (residential) | Medium (~2 acres per MW)*** | Yes |
| Offshore Wind Power | High | No commercial facilities in North America | $0.20 - $0.30 /kWh | >$4,250/kW | Low | No |

*COE estimates are for general, high-level cost comparisons only and may or may not ultimately be representative of the cost of delivered energy from projects in the USVI. As such, these values were used only as a general screening tool to assess basic competitiveness. Conventional oil-fired generation existing on the islands today is estimated to produce electricity at about $0.15/kWh (RW Beck 2011).

**Estimated COE is based system costs and energy consumption offset by use of a SWH

***Land removed from service (required for turbines, access roads, related infrastructure) is approximately 2 acres per MW; however, due to turbine spacing requirements, the total footprint of a project may be on the order of 30–45 acres per MW (Denholm et al. 2009).

Note: Sources for data shown here include Clean Power Research 2010; Denholm et al. 2009; EIA 2010; EPA 2011; IPCC 2011; JIS 2010; and KEA 2011; some data were generated with internal NREL modeling. For additional detail, see Section 5.2 and Appendix A.

Note: If the resource potential was low or if there was no resource potential, the technology was not considered any further.

## Biomass Power and Waste-to-Energy
### Technology Overview

Biomass energy has been used for millennia—burning wood to cook food and keep warm. Although wood is still the largest biomass energy resource today, other resources include food crops, grassy and woody plants, residues from agriculture or forestry, and the organic component

of municipal and industrial wastes. Even the gases produced by landfills, which are largely methane, can be used as a biomass energy source. Like biomass, many federal and state laws, executive orders, the Federal Energy Regulatory Commission, and the Internal Revenue Service treat waste-to-energy as a renewable resource. However, the issue of pollution control is more critical for waste-to-energy plants. The technologies used to convert biomass or waste into energy are similar, so they are discussed together below.

Several technologies are available to convert biomass or waste feed stocks into heat and electricity. Generally, the biomass or waste can be transformed thermally, biologically, or chemically. If the biomass or waste is thermally transformed, varying amounts of oxygen can be added, ranging from excess oxygen (direct combustion), reduced oxygen (gasification), or no oxygen (pyrolosis). In biological conversion, the biomass or waste is allowed to decompose naturally resulting in the release of methane (discussed in the Landfill Gas section). Chemical processes attempt to mimic this natural decomposition using special enzymes and other chemicals. In the USVI, the thermal pathway is most likely to be deployed in the near future. Direct combustion and gasification systems each have a number of general strengths and weaknesses—primary among them is the commercial status of the technologies. Direct combustion is a commercially proven technology. Gasification has great potential but has not been commercially proven in the United States.

*Direct Combustion*
Direct combustion in the presence of excess oxygen is the most common method of converting biomass or waste into heat and power. A direct combustion system burns the feedstock to generate hot flue gas, which is either used directly to provide heat or fed into a boiler to generate steam. In a boiler system, the steam can be used to provide heat for industrial processes or space heating or a steam turbine can be used to generate electricity (Petersen and Haase 2009). Figure A-1 shows the basic configuration for a biomass or waste-to-energy system.
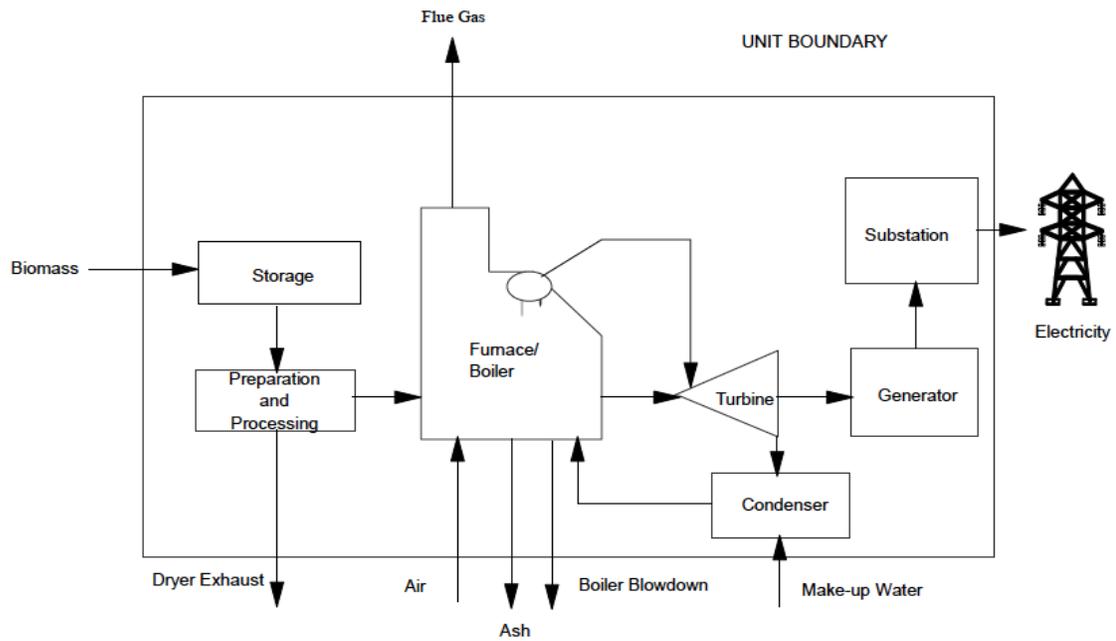
**Figure A-1. Direct-fired biomass**

Source: Bain et al. 2003

## *Gasification*

If biomass is heated with limited oxygen (about one-third is needed for ideal combustion), it gasifies to a "syngas" composed mostly of hydrogen and carbon monoxide. This mixture can be burned directly in a boiler or it can be treated and burned in an internal combustion engine or gas turbine (Petersen and Haase 2009). A gasification system is illustrated in Figure A-2. Strengths and weakness of direct combustion and gasification technologies are summarized in Table A-2.

69
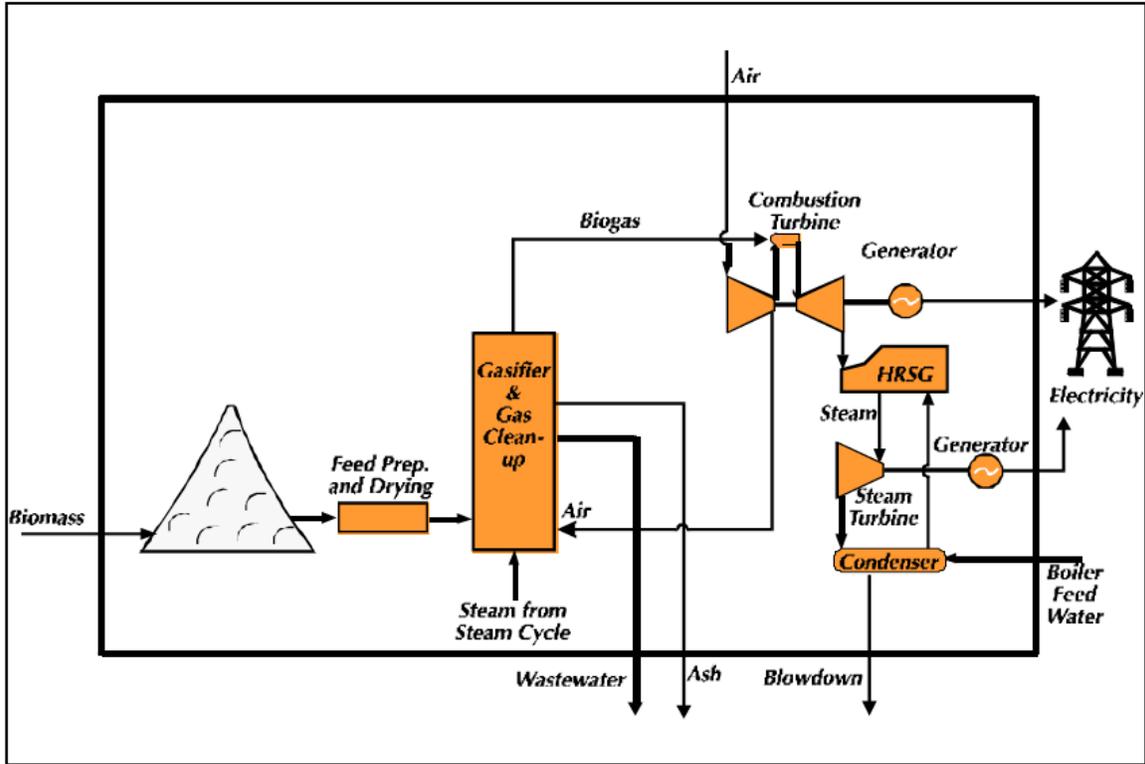
**Figure A-2. Example of gasification combined cycle system**

Source: Bain et al. 2003

**Table A-2. Characteristics of Biomass/Waste-to-Energy Power Generation Technologies**

| Technology | Strengths | Weaknesses |
|---|---|---|
| Direct Combustion | • Commercially proven technology with dozens of operating examples in the United States<br>• Equipment is widely available, complete with warranties<br>• Fuel flexibility in moisture and size<br>• Lenders comfortable with technology | • Potential for greater NOx, CO, and particulate emissions<br>• Requires water if generating power with a steam turbine |
| Gasification | • Lower NOx, CO, and particulate emissions relative to direct combustion<br>• Potential for more efficient conversion process when generating power<br>• Virtual elimination of water needs if generating power without a steam turbine | • Still has the potential for greater NOx, CO, particulate emissions<br>• Requires water if generating power with a steam turbine |

Source: Petersen and Haase 2009

## *Installed Capacity*

As of 2003, there were approximately 11 GW of biomass and waste-to-energy electricity plants in the U.S. About 7.5 GW utilized forest product and agricultural residues as fuel. Roughly 3.0

GW relied on MSW for fuel. 0.5 GW derived fuel from other biomass sources such as LFG (Bain et al. 2003). Through 2009, there were 88 waste-to-energy plants in the United States combusting about 26.3 million tonnes of MSW and serving a population of 30 million (see Table A-3) (Psomopoulos et al. 2009). All waste-to-energy plants in the United States are direct combustion plants.

**Table A-3. Waste-to-Energy Plants by Technology and Capacity (tons)**

| Technology | Number of Plants | Capacity (tons/day) | Capacity (million tons/yr) |
|---|---|---|---|
| Mass Burn | 65 | 64,731 | 20.0 |
| Refuse-Derived Fuel (RDF) | 15 | 18,162 | 5.7 |

Source: Psomopoulos et al. 2009

## *Barriers*

A variety of barriers to biomass and waste-to-energy exist in the market today. Chiefly among these are:

- Complex business arrangements involving waste haulers, recyclers, and utilities

- Access to capital and investors in today's market where demand for new power generation is modest

- Negative public perceptions resulting from mischaracterization as "incinerators" or highly polluting

- Air-quality standards imposed by the U.S. EPA

- Public concern over displacement of food crops.

## *USVI Resource Availability*

For waste-to-energy, the amount of electricity that can be generated depends on the energy content of the waste, the amount of waste available, and the efficiency of the waste-to-energy plant. The USVI creates approximately 150,000 tons per year (tpy) of waste, of which approximately 135,000 tpy is appropriate for use in a waste-to-energy plant (Davis et al. 2011). An evaluation of 12 operating waste-to-energy facilities in the United States yielded an average conversion efficiency of 0.029 MWe per ton per day (Davis et al. 2011). Using this efficiency, a waste-to-energy facility operating 85% of the time (typical industry thumb rule) and fueled by 135,000 tpy of RDF would consume about 435 tons per day (tpd) and generate 13 MW of electricity. This conservative estimate assumes efficiency for new equipment in line with facilities that are 15–30 years old. Assuming some incremental improvement with modern technology, the proposed waste-to-energy plant in St. Croix is rated at 16 MW.

For biomass, the amount of electricity that can be generated is dependent on the same variables as waste-to-energy. A key uncertainty is the amount of biomass that can be sustainably harvested from the non-forested areas of the USVI. A preliminary estimate indicates that 8.8 tonnes of biomass can be sustainably harvested per hectare per year (Chakroff 2010). This biomass might

consist of fast-growing or invasive species such as tan tan (*Leucaena leucocephala*) or Australian pine (*Casuarina equisetifolia*).

As an example, Figure A-3 indicates there are 21,795 hectares (Ha) of land on St. Croix. If 10% of this land were available for the development of biomass, 20,000 tons of biomass per year could be sustainably harvested. Using the rule-of-thumb of one bone-dry-ton of biomass per hour per megawatt and estimated biomass moisture of 50% yields a high-level estimated biomass potential of 1–2 MW on St. Croix. Additional work is required to further evaluate the feasibility of a 1–2 MW biomass potential on St. Croix.



**Figure A-3. Forested land area on St. Croix**

Illustration from U.S. Virgin Islands Forest Resources Assessment and Strategies 2010.

### *Estimated Cost of Energy*
Installed costs for waste-to-energy systems have been projected by the U.S. Energy Information Administration (EIA) to be approximately $8,200/kW on the U.S. mainland (EIA 2010). COE estimates based on the EIA's capital cost estimates are about $0.08–$0.09/kWh. In the USVI, the capital costs for projects are higher than the mainland due to decreased accessibility and fewer economies of scale. The reported cost of power from the proposed waste-to-energy plant in the USVI was approximately $0.14/kWh. As any biomass resources grown in the USVI will be co-fired with MSW, the cost for biomass power is assumed to be roughly comparable. However, fuel production and processing costs may vary.

## Concentrating Solar Power

*Note: Portions of text in this section are taken from other NREL sources (e.g., NREL 2011; Walker 2011).*

### *Technology Overview*

CSP includes a class of electrical generating systems that rely on mirrors to focus lower intensity sun rays onto a collector to generate high grade heat capable of running conventional power cycles. There are three main types of CSP systems: linear concentrator, dish/engine, and power tower systems.

A linear concentrator system is shown in Figure A-4. Linear concentrators collect the sun's energy using long rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun and focus sunlight on tubes (or receivers) that run the length of the mirrors. The reflected sunlight heats a fluid flowing through the tubes. The hot fluid then is used to boil water in a conventional steam-turbine generator to produce electricity. There are two major types of linear concentrator systems: parabolic trough systems, where receiver tubes are positioned along the focal line of each parabolic mirror, and linear Fresnel reflector systems, where one receiver tube is positioned above several mirrors to allow the mirrors greater mobility in tracking the sun.



**Figure A-4. SkyFuels' SkyTrough large-scale parabolic trough**

NREL PIX 18227

A dish/engine system uses a mirrored dish similar to a very large satellite dish (Figure A-5). The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to the engine generator. The most common type of heat engine used today in dish/engine systems is the Stirling engine. This system uses the fluid heated by the receiver to move pistons and create mechanical power. The mechanical power is then used to run a generator or alternator to produce electricity. Dish/engine systems are modular and are either utilized in single-dish applications or grouped in dish farms to create larger projects.

**Figure A-5. The Stirling Energy System's SunCatcher, a 20-KW dish/engine CSP system with a Stirling engine**

NREL PIX 18380

A power tower system uses a large field of flat, sun-tracking mirrors known as heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the heat-transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer and energy-storage capabilities. The energy-storage capability, or thermal storage, allows the system to continue to dispatch electricity during cloudy weather or at night.

An advantage with CSP systems is that problems of solar intermittency can be addressed with the incorporation of thermal storage or hybridization with natural gas. For troughs and towers, recent research has focused on thermal storage technologies that can extend the operating hours of plants (capacity factors) to better serve high-value peak and intermediate demand by increasing dispatch capability. Thermal storage can consist of a fluid tank, tubes in sand, or tubes in concrete.

### Commercial Status and Installed Capacity
CSP is a utility-scale power plant technology. Electrical generation projects that utilize this technology are typically large, grid-connected projects in the 50 MW to 200 MW range and have a large space requirement for a single system. An exception is the modular dish/engine systems; however, such systems are considered pre-commercial.

The United States saw considerable development of CSP in the 1980s in California and then no activity for two decades. Spain is the current world leader with more than 580 MW of operating CSP capacity. In the United States, CSP is currently experiencing renewed vigor with 41 projects in the planning and development stage with a total combined capacity of 9,000 MW set for installation in the Southwest (GTM Research 2010a). Currently in the United States, there are 17 operating CSP plants with a total installed capacity of 507 MW (GTM Research 2010b).

### Barriers
USVI's DNI is considered borderline for CSP development. More critically, however, are the severe land constraints and relatively small electrical loads that make CSP commercially unviable at this time in the USVI.

### USVI Resource
Shadow-casting, direct-beam radiation coming directly from the sun is known as DNI. Sunlight that has been scattered by dust, haze, or water in the atmosphere is called diffuse solar radiation. Focusing collectors (i.e., those used for CSP) can utilize only the DNI component of the sunlight, whereas flat plate collectors use both DNI and diffuse.

CSP developers typically set a bottom threshold for DNI of 5.5 kWh/m$^2$/day. Such values are found in the southwestern United States and other desert parts of the world. Below that, other solar electric technologies such as PV are considered to be more competitive. DNI is also significantly better at higher altitudes, where absorption and scattering of sunlight are much lower (Walker 2011). The value of DNI for the USVI is borderline, between 4.8 and 5.6 kWh/m$^2$/day, because of the scattering caused by high humidity (Figure A-6).
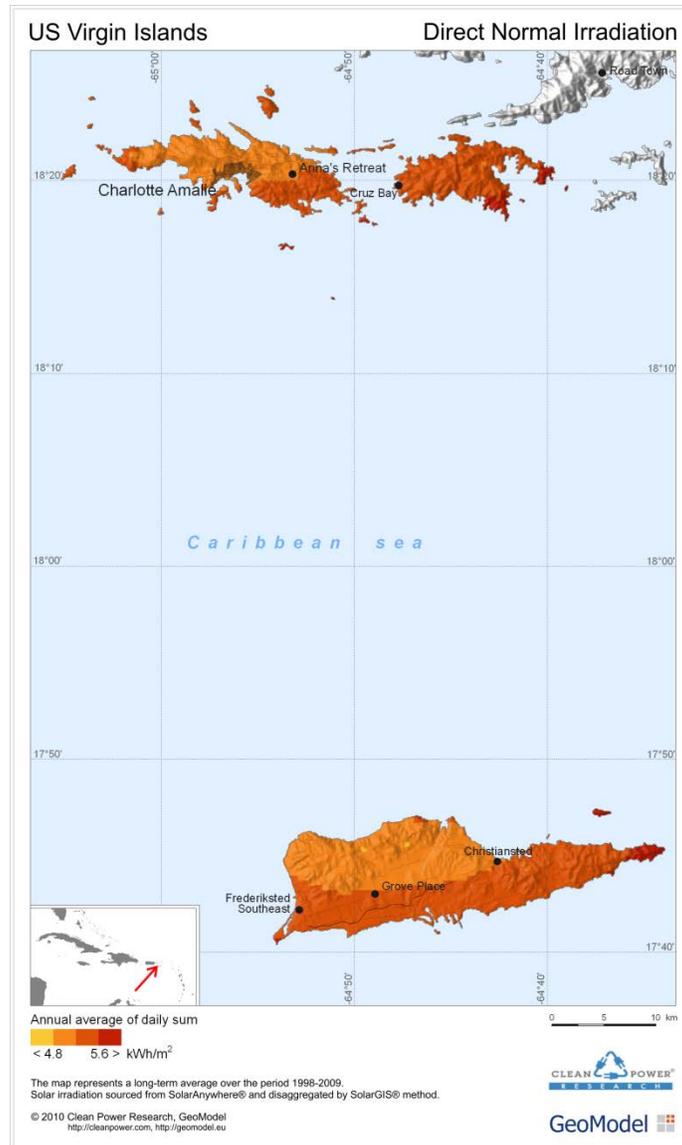
**Figure A-6. Direct normal radiation estimates for the USVI**

Illustration from Clean Power Research

## Geothermal Heat Pumps
### *Technology Overview*

A geothermal heat pump, also known as a ground source heat pump (GSHP), couples a highly efficient heat pump with the relatively constant temperature of the earth near the surface. The earth (i.e., ground, ponds, lakes, aquifers, or the ocean) is used as an exchange medium and functions as a heat sink for cooling and a heat source for heating. A GSHP uses a series of pipes buried in the ground or underwater (known as the ground loop) to transfer heat out of a building and into the ground in hot climates and into the building in cooler climates.

GSHPs are appropriate for retrofit or new buildings (residential, commercial, school, or industrial) where either heating or cooling is desired but may be less cost effective for buildings that require new ductwork, are already highly efficient, or are in localities where the local geology results in very high costs to install the ground loop.

GSHPs are most effective when there is a significant temperature difference between the outside air and the exchange medium (ground or water). When the temperature difference is small, there is less efficiency gain as less heat is transferred between the air to be used for conditioning and the exchange medium. For this reason, GSHPs are ideal (and most cost effective) for latitudes with significant daily and seasonal variations in temperature. When seasonal variations are present, heat may be transferred into the ground during hot summer months and into the building during the cold winter months.

In more tropical climates where the temperature difference between the ground or groundwater and the air is less, the efficiency of the system is reduced. Nevertheless, GSHPs coupled with sources of groundwater have been used successfully for cooling in the southeastern United States and in Florida. Where GSHPs are used for exceptionally large buildings and easy access to the ocean is available, the ocean may also be a viable exchange medium. Ocean-based GSHP systems have been installed successfully at military bases in Norway and Greece among other locations.

Because a GSHP effectively pre-conditions the air, reducing the conventional energy required to condition a particular building or home, it is typically regarded as an efficiency technology.

### Installed Capacity
Geothermal heat pumps have been commercially available for many years but have experienced significant growth over the past decade. Data on manufacturer shipments collected by the EIA (2010) indicate that shipments in the United States have grown from about 35,000 units in 2000 to more than 115,000 units in 2009. These units equate to about 140,000 tons in 2000 to more than 400,000 tons in 2009 (one ton is equivalent to 12,000 Btu/hr). About 15%–20% of total U.S. shipments are exports, with more than 80% of exports going to Canada. Residential systems constitute about 51% of the U.S. market and were followed by the commercial sector at 46% and the industrial sector at 3%. States with more extreme climatic conditions tend to be the primary markets; however, Florida and Texas are also significant U.S. markets (EIA 2010). Data from the World Geothermal Congress indicate there are about 3 million units installed around the world and about 1 million of those are in the United States (Walker 2011).

### Barriers
GSHP technology is relatively straightforward, mature, and proven. The heat pumps used with ground source applications are comparable to those used in the much broader air-source heat pump market. The primary difference is that GSHPs include the ground loop. As such, barriers are typically cost and regulatory rather than technical. With regards to cost, the additional investment required for the ground loop is sometimes difficult to justify, especially in localities where drilling wells or doing extensive excavation is costly. Moreover, in localities without the requisite temperature difference to achieve significant efficiency gains, the ground loop may also be cost prohibitive. Obtaining approvals and permitting, especially for smaller GSHP systems, may also be a challenge.

### USVI Resource Availability

GSHPs were not considered in detail in this analysis because of a general lack of resource potential. GSHPs are most cost effective in localities that experience significant temperature extremes (high and low). In the more mild climates (e.g., Florida) where GSHPs have been widely installed, they are typically "open loop," or systems that rely on ground water as the primary exchange medium. Because the year-round temperature of the USVI varies little and ground water resources in the USVI are extremely limited, this opportunity is likely not significant for the USVI. There may be a limited number of site-specific opportunities where ocean water may be used as the primary heat exchange medium; nevertheless, GSHPs are not likely to be a major contributor to the clean energy goals of the USVI.

## Geothermal Power Generation
### Technology Overview

Geothermal electricity generation relies on high temperature and thermal resources present in the earth's crust as a source of heat to produce steam for the purpose of power generation. Traditional geothermal power generation sites must have high temperatures (225°F or greater), water, and permeability. Such resources may be present at the earth's surface or thousands of feet below the surface. Enhanced geothermal systems allow for power production from sites that are sufficiently hot but otherwise lack the water and permeability necessary for conventional geothermal power generation. Geothermal power plants to date have been multi-megawatt, centralized, and utility scale.

Due to variability in geothermal power resources, a variety of technologies have emerged to capture the available geothermal resources. Hydrothermal systems, enhanced geothermal systems, and co-production systems are the primary technologies under consideration today. Hydrothermal systems represent the traditional form of power generation from geothermal resources. Hydrothermal plants are very site specific because they require sufficient heat, fluid, and permeability.

Co-production systems are an alternative to hydrothermal systems and allow for electricity generation from hot water that is extracted from oil and gas wells. Because large amounts of hot water may be produced by oil and gas wells, co-production systems are often used to provide on-site power to operate pumps and other equipment at active oil and gas wells.

Enhanced geothermal systems are an emerging geothermal power technology that currently exists only in research and development. Enhanced geothermal systems have the potential to significantly expand geothermal power resource potential by engineering the required fluid and reservoir permeability at sites that have adequate thermal properties (i.e., hot dry rocks) but lack the other components necessary to successfully produce power. By injecting fluids and fracturing rock layers around a specific thermal site, engineering allows these sites to function as a hydrothermal system.

### Installed Capacity

Traditional hydrothermal power generation facilities have been in operation for decades in the United States and around the world. EGS has not yet reached commercial maturity. Today, there are nearly 3,100 MW (GEA 2011) installed in the United States and about 10,700 MW installed globally (IGA 2011). The western United States and parts of the Southeast also have a large

number of projects under development (GEA 2011). Growth since 2005 has been modest (1%–5%) but steady, with nearly 200 MW coming online in the United States in 2009.

### Barriers
Primary barriers to continued development of hydrothermal systems include high initial costs, significant and relatively high-risk development costs, limited transmission access (due to its site-specific nature), and permitting and regulatory approvals. Initial costs are often high due to the use of advanced materials necessary to handle the corrosive fluids that are often extracted. Proving resource adequacy may require drilling multiple wells simply in order to understand resource viability or lack thereof. Deployment of EGS is limited by a lack of commercially available technology. A lack of clear, consistent, and well-defined permitting processes are also frequently raised as barriers to continued growth.

### USVI Resource Availability
Parts of the Caribbean have abundant geothermal power resources. However, these sites are largely limited to the eastern arc of the Lesser Antilles where geologic activity is still ongoing. No known potential for geothermal power resource exists on any of the islands that make up the USVI. For this reason, geothermal power generation was not included in the 60x25 energy road map. Should an interconnected Caribbean grid system become a reality in the future, geothermal power generation could potentially be shipped into the USVI from islands further east. However, the development of such an interconnected grid is not expected within the next decade and a half.

## Landfill Gas
### Technology Overview
LFG involves energy production from the anaerobic decomposition of carbon-based waste streams deposited in a landfill. Organic material releases methane as it decomposes in a landfill. Collection pipes can be installed in the landfill mass to collect this gas, which is then routed to a generator to produce electric power. Decomposing trash in landfills naturally and continually produces LFG.

LFG is primarily composed of methane and carbon dioxide. Typically a gas-handling system at the landfill traps, collects, and transports the produced fuel. It is often necessary to clean up LFG prior to combustion in order to remove potentially hazardous compounds such as sulfur. Once a landfill is capped and closed off, it will continue to produce gas for 15 to 20 years. A good candidate for LFG collection should have at least 1 million tons of waste in place, be at least 30 ft deep, and be active or recently closed. It should also have a high organic content because non-organic waste does not break down and emit methane. The use of LFG has greenhouse gas reduction benefits from reducing carbon dioxide emissions and methane emissions, which have a much more potent greenhouse gas effect than carbon dioxide.

Once the LFG is collected and treated, it can be used as fuel in a conventional engine or gas turbine or create steam in a boiler to drive a steam turbine.

### Installed Capacity
EIA (2008) reports that in 2006, 1,429 MW of LFG capacity contributed 7,100 GWh of electricity nationally. There are 407 plants, over half of which are independent power producers (EIA 2008).

### USVI Resource Availability
The USVI Waste Management Authority has been working with the U.S. Environmental Protection Agency's Landfill Methane Outreach Program (LMOP) to estimate the potential for LFG in the USVI. Using the Environmental Protection Agency's Landfill Gas Emission Model program, it was estimated that Bovoni Landfill has the capacity to create a peak of 1,325 average cubic feet per minute (Maguire Group 2007). Assuming that St. Croix's Anguilla landfill has similar capacity, the USVI should produce enough gas for about 5 MW of electricity (EPA 2011).[34]

### Estimated Cost of Energy
Costs in the USVI are estimated to be significantly higher than typical sites in the continental United States. Estimates conducted with LMOP tools range from $0.18/kWh to $0.27/kWh.

## Ocean Energy Technology
*Note: Portions of text in this section are taken from other NREL sources (e.g., NREL 2011; Burman and Walker 2009).*

### Technology Overview
Oceans cover 70% of the earth's surface and contain an enormous amount of energy in the form of wave, tidal, current, and thermal resources. Four basic types of ocean energy conversion exist: wave energy, tidal energy, marine hydrokinetic energy, and OTEC. These can be more broadly categorized into two primary types of ocean energy: mechanical and thermal.

The rotation of Earth and the moon's gravitational pull create mechanical forces. The rotation of Earth creates wind on the ocean surface that forms waves, while the gravitational pull of the moon creates coastal tides and currents. Thermal energy is derived from the sun, which heats the surface of the ocean while the depths remain colder. This temperature difference allows energy to be captured and converted to electric power.

### Wave Energy
Wave energy is generated by the movement of a device either floating on the ocean surface or moored to the ocean floor. Many different techniques for converting wave energy to electric power have been studied. Wave conversion devices that float on the surface have joints hinged together that bend with the waves. This kinetic energy pumps fluid through turbines and creates electric power. Stationary wave energy conversion devices use pressure fluctuations produced in long tubes from the waves swelling up and down. This bobbing motion drives a turbine when critical pressure is reached. Other stationary platforms capture water from waves on their platforms. This water is allowed to runoff through narrow pipes that flow through a typical hydraulic turbine.

### Current Energy
Marine current is ocean water moving in one direction. Tides also create currents that flow in two directions. Kinetic energy can be captured from the Gulf Stream and other tidal currents with submerged turbines that are very similar in appearance to miniature wind turbines. As with wind

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[34] Estimate from production based on EPA Web-tool (see EPA 2011).

turbines, the constant movement of the marine current moves the rotor blades to generate electric power.

## Ocean Thermal Energy Conversion

OTEC uses ocean temperature differences from the surface to depths lower than 1,000 m to extract energy. A temperature difference of only 20°C (36°F) can yield usable energy through a heat engine. One significant expense of an OTEC system is the cold water pipe, which draws cold water from the sea bottom. The cold water is used as a heat sink in the heat engine. Cold water can also be used in district cooling systems, providing energy efficiency opportunities. Desalinated water is a byproduct of some OTEC systems, which fits well with the USVI freshwater needs. Research focuses on two types of OTEC technologies to extract thermal energy and convert it to electric power: closed cycle and open cycle.

## Open Loop Cycle OTEC

Open loop cycle technologies (Figure A-7) use warm surface ocean water placed in a vacuum vessel, which causes it to boil at low temperature. Water vapor from the boiling water turns a turbine that is connected to a generator. The water vapor, almost fresh water, is then condensed with the cold ocean water. The desalinated water produced in open loop cycle OTEC can be used as fresh drinking water, an additional advantage of this methodology.
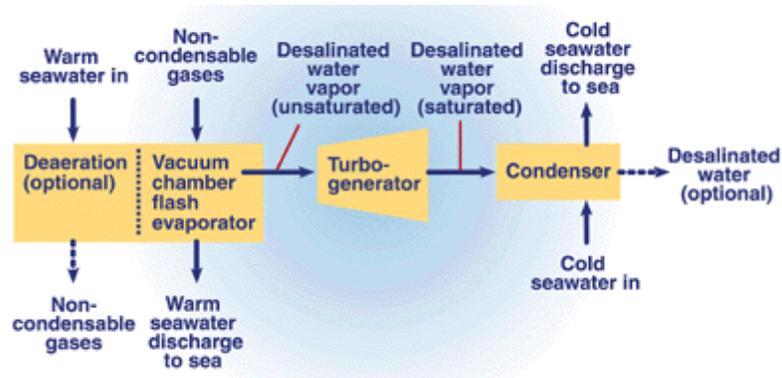


**Figure A-7. Open loop cycle OTEC**

Illustration by NREL

## Closed Loop Cycle OTEC

Closed loop cycle OTEC is similar to open loop cycle OTEC but uses a working fluid, like ammonia, that boils at a lower temperature than water. The working fluid creates a vapor and runs a turbo generator as shown in Figure A-8. The vapor is condensed with the cold water from lower depths, and the ammonia returns to the liquid state to start the cycle again.
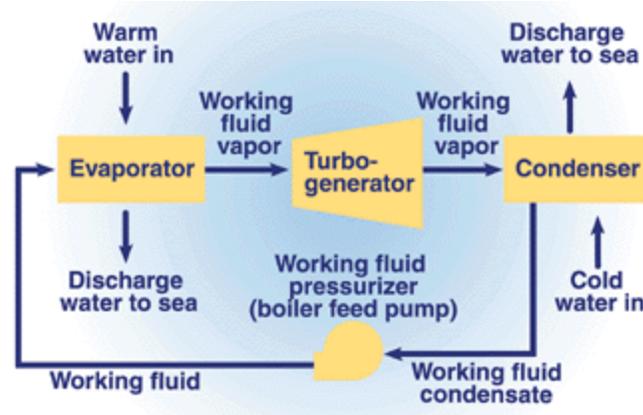
**Figure A-8. Closed loop cycle OTEC**

Illustration by NREL

### Barriers

Ocean energy system types would be a good fit for the USVI due to proximity of the resource and demand for potable water. However, tidal energy based on dams, or barrages, and generators similar to conventional hydroelectric river systems is the only commercially available ocean energy technology at present (Khan and Bhuyan 2009). In this type of system, dams open and close with tidal cycles to create sea elevation differences. Tidal barrage systems are not viable in the USVI due to small tidal elevation changes in the region. Other ocean energy conversion technologies have been designed and tested; however, none yet are commercially viable or deployed at significant scale (Khan and Bhuyan 2009). Complicating ocean energy systems is the marine environment, which presents a number of operational challenges: corrosive seawater, presence of marine animals, plants, foreign debris, and severe storm surges. Due to the absence of commercially viable technologies for the USVI and the high risk associated with operating in the marine environment, ocean projects in the USVI are unlikely to become a reality in the near future. Ocean energy systems could become a source of energy in the future, but they are not believed to be viable sources of power to achieve the 60x25 goal.

### USVI Resource Availability

#### Wave Energy

Wave energy potential is generally lowest along the equator and increases with latitudes north and south. Latitudes greater than 40° have the best wave energy resource. Wave energy potential in the USVI is low.

#### Current Energy

Tidal currents of 2 m/s or greater are considered necessary for current energy conversion systems (Khan and Bhuyan 2009). An interactive online map developed for DOE shows tidal velocities around the USVI of less than 0.3 m/s, so current energy potential in the USVI is very low.

#### Ocean Thermal Energy Conversion

A temperature difference between the warmer, top layer of the ocean and the colder, deep ocean water of about 20°C (36°F) is required for potentially viable power generation. Figure A-9 shows global estimates of ocean temperature gradients between the surface and the ocean floor. A deep trench resides in the USVI basin between St. Croix and St. Thomas and St. John. With depths to

4,500 m, the cold seawater at the ocean floor presents a potentially viable resource for OTEC when the technology matures.
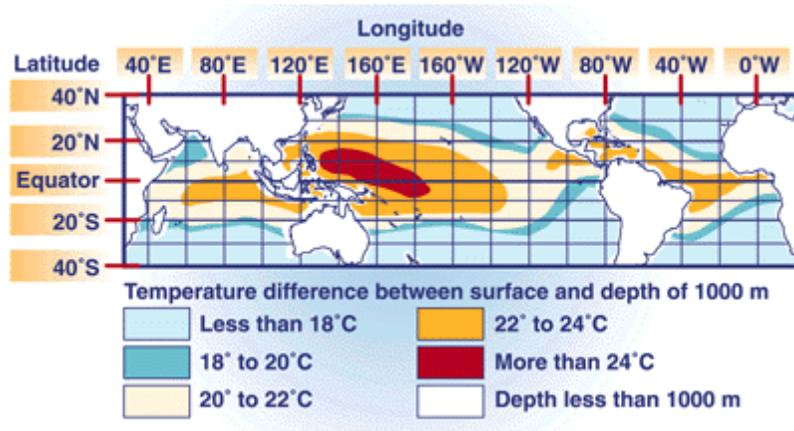


**Figure A-9. Sites with theoretical OTEC potential**

Illustration by NREL

## Photovoltaics
*Note: Portions of text in this section are taken from other NREL sources (e.g., Walker 2011).*

### Technology Overview
PV panels convert sunlight directly into electricity. PV gets its name from the process of converting light (photons) to electricity (voltage), which is called the PV effect. PV panels have no moving parts, require very little maintenance, make no noise, emit no pollution, and consume very little water for periodic cleaning.

Traditional solar cells are made from silicon, are usually flat-plate, and generally are the most efficient PV cell type commercially available. Second-generation solar cells are called thin-film solar cells because they are made from amorphous silicon or non-silicon materials such as cadmium telluride. Thin-film solar cells use layers of semiconductor materials only a few micrometers thick. Because of their flexibility, thin-film solar cells can double as rooftop shingles and tiles, building facades, or the glazing for skylights.
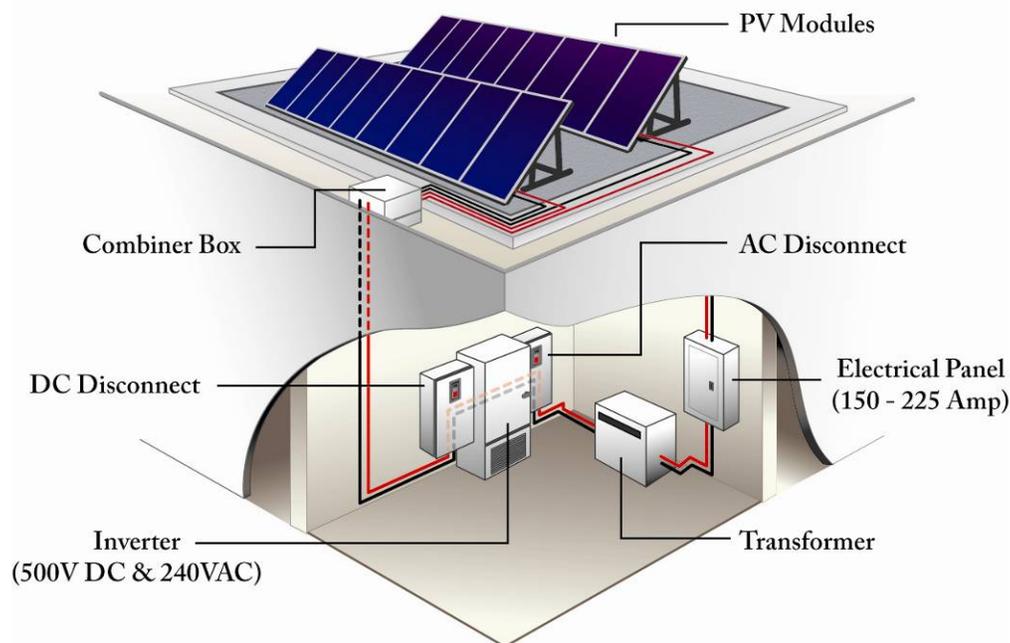
**Figure A-10. Photovoltaic system schematic**
Illustration from Jim Leyshon, NREL

PV panels generate direct current (DC) electricity and require a DC to alternating current (AC) inverter to convert generated electricity into a power form useful to most residential, commercial, and industrial facilities. PV system size is usually described in terms of the nameplate capacity in kilowatts-DC of all of the panels, while sometimes the AC rating of the system inverter is used.

The useful electrical energy output from a PV system depends on the total solar resource, level of atmospheric moisture and aerosols, seasonal temperatures, panel orientation, and absence of shading from trees, buildings, and other structures.

Capacity factor is a measure of performance that describes annual energy output per unit size as a percent. If a system were to produce electrical energy every hour of the year at full nameplate power, it would have a capacity factor of 100%. In the United States, well-placed PV systems have capacity factors between 12% and 20%. Figure A-11 shows a map of predicted capacity factor performance of typical systems in the continental United States. Based on local weather files, systems in the USVI are predicted to operate at approximately 16% capacity factor, which is similar to southern Florida.

**AC Capacity Factor - Flat Plate Tilted at Latitude**
**Assuming Derate value of 0.77**

Legend:
- > 19
- 18 - 19
- 17 - 18
- 16 - 17
- 15 - 16
- 14 - 15
- 13 - 14
- 12 - 13
- < 12

Annual average solar resource data for a tilt=latitude collector were used for capacity factor calculation. The data are a 10 km satellite modeled dataset (SUNY/NREL, 2007) representing data from 1998-2005.

This map was produced by the National Renewable Energy Lab for the US Department of Energy. Author: Billy Roberts March 2, 2010

**Figure A-11. PV system performance by region**

It is very common to mount PV flat on a roof for several reasons: it is a good orientation for summer when the sun is almost directly overhead (many utilities have a 12-month net-metering policy, which encourages summer generation), it is low cost, and it is visually unobtrusive. Horizontal roof-mounted PV systems have also gained popularity due to the relative simplicity of installation. Very large distributed generation and utility-scale systems are often ground-mounted simply because of insufficient availability of rooftop area.

### *Commercial Status*

Today, thousands of people power their homes and businesses with individual solar PV systems. Utility companies are also using PV technology for large power stations.

Both flat-plate crystalline and thin-film technologies are commercially available; however, the vast majority of global installations to date are crystalline. Crystalline PV modules have a higher efficiency than thin-film PV and occupy considerably less space per kilowatt of installed capacity. Both types have a roughly equivalent installed cost per unity capacity ($/Watt-DC). Thin-film PV can be used as a "peel and stick" product and has opened up the possibility for building-integrated PV (i.e., as part of roofing or wall membranes including shingles and siding). Thin-film PV also has slightly better temperature performance, meaning its efficiency does not

degrade as much as crystalline PV with high ambient temperatures. This characteristic plus its inherent resistance to wind loads may make it a good alternative to crystalline panel systems in the USVI.

Estimated global installed PV capacity in 2009 was 13.9 GW. Estimated installed U.S. PV capacity in 2009 was over 1 GW. The PV industry has been growing tremendously as demand for the technology has been fueled by government incentives in the United States, Japan, and Europe and by the need for remote power in developing countries. U.S. production of PV rose from 7 MW in 1980 to 14 MW in 1990, 75 MW in 2000, and 539 MW in 2009. U.S. installations in 2009 were reported at 1,282 MW, which indicates the amount imported over U.S. production was 743 MW. Worldwide production of PV grew from 46 MW in 1990 to 288 MW in 2000 to 6,941 MW in 2008.

### Barriers

One barrier to broader adoption is a high initial cost, which in many markets is currently mitigated, in part, by subsidy schemes and innovative financing vehicles. Annual market growth has been a result of reduced prices, government incentives, and successful global marketing. Hundreds of applications are cost effective for off-grid needs. However, the fastest growing segment of the market is grid-connected PV, such as roof-mounted arrays on homes and commercial buildings in the United States.

Visual and operational intrusion may be low depending on where PV modules are installed. If installed flush on the rooftop, PV is generally not visible from the ground, while ground-mounted systems typically become part of the built-up visual landscape. Land constraints in the USVI, particularly on St. Thomas, may limit total installed capacity of ground-mounted systems (Walker 2011).

For crystalline (rigid) panels, hurricane-resistant design requires more robust racking systems and consideration of possible load impacts on building structures for roof-mounted installations. These additional design constraints may inflate total installed cost. Amorphous systems directly adhered to rooftops may be a good alternative to crystalline panels to mitigate this issue.

A number of innovative third-party financing structures developed in recent years have increased total deployment of residential and commercial systems, including power purchase agreements and solar lease programs. These third-party agreements allow individuals, businesses, and non-profits to benefit from PV without requiring a high initial capital out-lay or to self-finance with loans. Additionally, as a result of the current structure of the U.S. tax code, businesses with high tax burdens may benefit more from PV tax incentives than individuals, non-profits, and businesses with relatively lower tax burdens. Third-party finance structures are designed to exploit these tax incentives in a way that benefits individuals, non-profits, and others that would not otherwise benefit from their full theoretical value. Third-party financing also provides an option to those that are interested in consuming PV-generated electricity but unable to purchase a system outright. Third-party finance structures maximize use of the tax incentives, creating win-win scenarios for the power consumer, project developer, and financing institutions. Nationally, about 16% of all residential systems and 37% of all non-residential systems were financed through a third-party ownership structure (GTM Research 2010a). In the USVI, the legality of third-party financing structures is not clear.

The solar resource or "fuel" for PV systems is variable and therefore the electrical output needs to be either used as generated, stored, discarded, or credited as net-metered energy. Energy that can be generated on demand is called "dispatchable" while energy that varies as the sun shines or wind blows is "non-dispatchable." Integration of energy storage devices with non-dispatchable PV will convert it to a dispatchable power system. However, batteries and flywheels, for example, add significant costs. Net metering permits a utility customer to use the utility like a battery; excess energy is sent to the grid and a customer is given a credit that is redeemed the next time the customer's load exceeds the renewable energy system's output. In most cases, net metering as a policy does not address a utility's technical challenges that may arise when significant levels of non-dispatchable power are interconnected to an islanded electrical system as could result in the USVI.

### USVI Resource Availability

An advantage of solar compared to other renewable resources is that it is available in some amount in all locations. The best resources in the United States are in the desert southwest, where regular clear skies cause little scatter of the sun rays. The lowest solar resource in the continental United States is about 40% lower than the maximum and occurs in Washington State west of the Cascade Mountains. In the USVI, the solar resource for PV is very good and is approximately 85% of the desert southwest's (tilt equivalent latitude comparison).

The intensity of solar radiation filtered through the earth's atmosphere with its accompanying clouds, moisture, and pollution is a maximum of about 1,000 W/m$^2$ and frequently interrupted by weather events. The solar resource is not available at night and varies seasonally. A challenge in working with the solar resource for energy applications is that the resource is variable, relatively diffuse, and un-concentrated. Further, the position of the sun in the sky is constantly changing. In the continental United States, the intensity of solar radiation during the middle 6–8 hours of the day is usually in the 500–1,000 W/m$^2$ range and less than 500 W/m$^2$ in the morning and evening hours or under cloudy conditions.

To facilitate climate comparison and predict system performance, the amount of solar radiation that falls on a surface throughout the day has been integrated to determine the amount of energy available each day (kWh/m$^2$/day). Figure A-12 and Figure A-13 (note that these two figures use different color scales) show total solar radiation on a horizontal surface for the continental United States and the USVI.
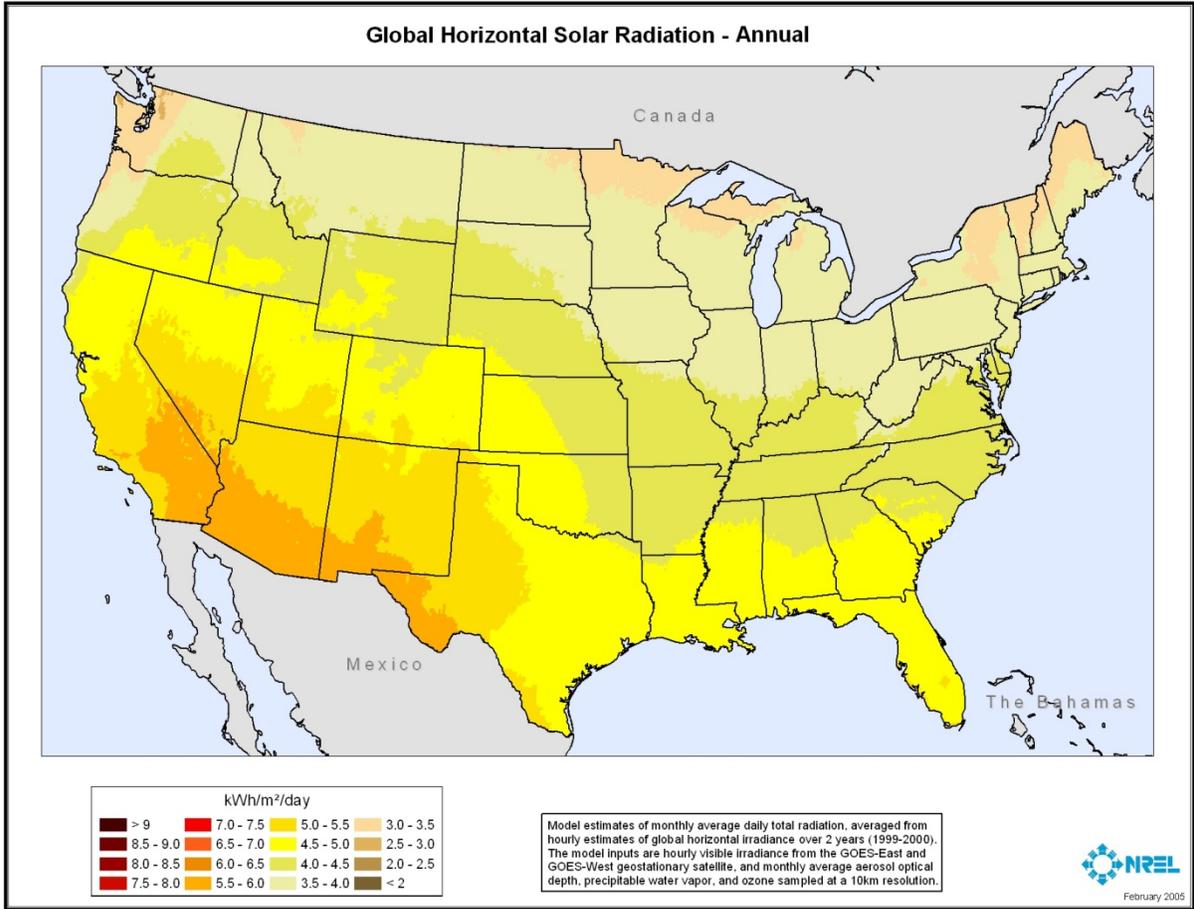
**Figure A-12. U.S. total solar resource**
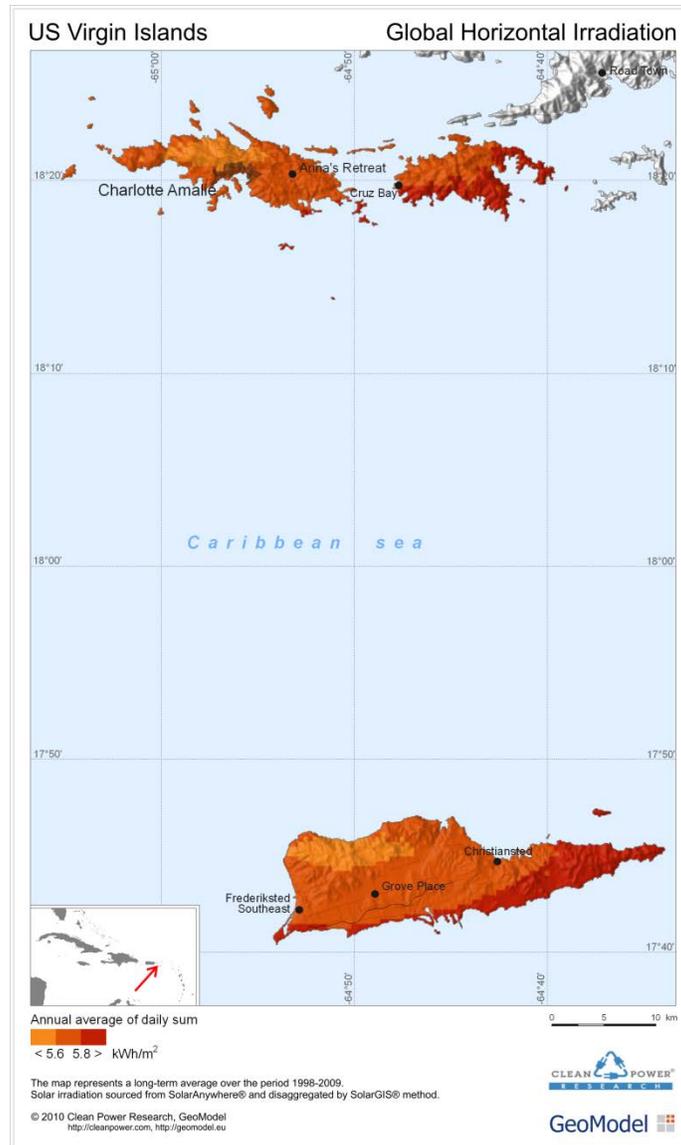
**Figure A-13. USVI total solar resource**

Illustration from Clean Power Research

The key parameters for determining cost-effective applications are highly influenced by other site-specific factors beyond solar resource alone, including local incentives and utility energy costs.

### Estimated Cost of Energy

Over the past two decades, significant improvements have been made in the efficiency of PV materials and manufacturing costs have been reduced, yet PV is typically still more expensive than conventional grid electricity in the United States. PV's cost effectiveness depends largely on local COE and local, state, or utility incentive programs coupled with tax-based incentives.

The cost of PV-generated electricity has dropped 15- to 20-fold in the continental United States over the past 25 years. Grid-connected PV systems currently sell for about $3.50/W to $8.00/W, including support structures and power conditioning.

The PV modules are the most expensive component of a system. The cost of PV modules depends on their size and type. Types of PV include: crystalline silicon, multi-crystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenium. Crystalline silicon is the oldest type of PV and has achieved the highest efficiency range of 14%–19%. The highest efficiency modules may have prices on the order of $2/W. Multi-crystalline is 13%–17% efficient; modules may cost $1.50–$2.00/W. The thin-film technologies are 6%–11% efficient. Cadmium telluride is not the most efficient and not the cheapest but represents a very competitive ratio of cost to performance.

Using high level solar resource data for the USVI and the estimated costs of PV panels in the region, analysts at NREL used CREST to estimate the cost of power in the territory. The NREL team estimated a 20-year PPA cost to range from $0.19/kWh to $0.36/kWh. The major variables that affect this price include:

- Price of installed system

- Expected debt and equity terms (i.e., financing costs)

- Debt service coverage ratio

- Value of electricity after 20-year PPA ($/kWh)

## Solar Water Heating
### Technology Overview
SWH systems consist of solar collectors to capture the sun's heat and tanks to store the heated water for later use. Operation is similar to a hydronic heating system, with the solar collectors as a heat source, heat exchangers to heat the water, pumps to circulate the fluid, expansion tanks, pressure-relief valves, flush and fill valves, and controls. Because there is no freezing risk in the USVI, direct water heating systems can be used, eliminating the need for anti-freeze fluid, heat exchangers, and possibly an additional tank. This greatly simplifies the system and lowers total costs.

There are three types of SWH collectors: unglazed plastic collectors for low temperatures, such as those needed for swimming pool heating; glazed, insulated flat-plate collectors for mid-temperature service hot water; and evacuated tube collectors with reflectors for high-temperature applications. A photo of a typical flat-plate system with integrated tank found in the USVI is shown in Figure A-14 (Walker 2011).

**Figure A-14. Direct heat with integrated tank SWH system**

Photo by Dan Olis, NREL

The fraction of a building's total hot water load that a SWH system provides is called the solar fraction (SF). SWH system efficiency depends on many factors, including SF, local solar resource, ambient temperatures, cold water inlet temperature, and time of use of hot water, also called water draw profile. Figure A-15 shows the general trend for efficiency versus SF for a modeled system operating in the USVI. Actual SWH performance will depend on system type and the application details. The graph only shows the general trend. System efficiency drops off very quickly as one tries to approach 100% SF. Typical SWH systems provide 40%–70% of water heating requirements.
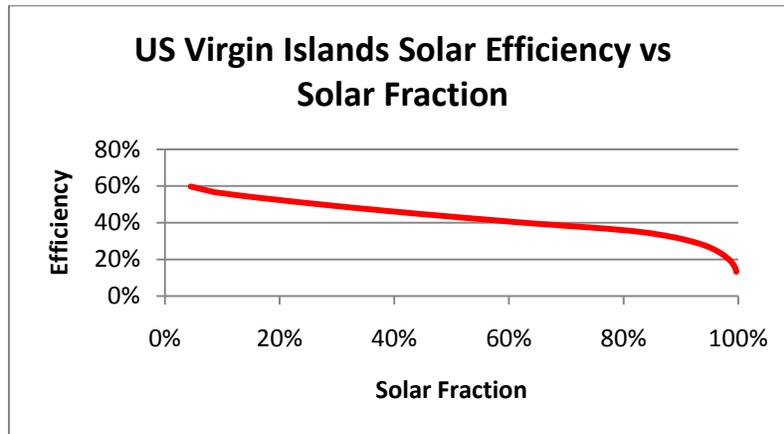


**Figure A-15. General trend of SWH efficiency versus SF**

Illustration by NREL

### *Barriers*
The main barrier to high penetration of SWH in the USVI is the initial investment. Current federal tax incentives and rebates offered by VIEO greatly improve life-cycle economics.

Additionally, a loan program offered by VIEO in partnership with WAPA eliminates this hurdle for eligible residential systems by providing low-cost loans and on-bill repayment.

### USVI Resource Availability
As shown in the section on PV, the USVI has a good solar resource for both SWH and PV applications. The temperate climate in the USVI can be included in addition to the total solar resource since it eliminates freeze protection schemes required in much of the continental United States, reducing system complexity and total costs.

### Estimated Cost of Energy
Table A-4 shows LCOE for hot water generated from SWH systems. SWH is cost effective in the USVI when competing against electrical heat systems.

**Table A-4. LCOE for SWH Systems ($/kWh$_{thermal}$)**

| LCOE | 15 year analysis | 20 year analysis |
|------|------------------|------------------|
| No Incentives | $0.34 | $0.28 |
| 30% Tax Credit Only | $0.24 | $0.20 |
| Tax Credit + 50% Rebate | $0.13 | $0.11 |

The results in Table A-4 are based on energy savings of 925 kWh annually, $3,500 total installed cost, 4% discount rate, and $20/year maintenance costs. The LCOEs provided in the bottom row include the 50% rebate currently offered by VIEO.

## Wind Power
### Technology Overview
Wind energy is an abundant resource across many parts of the globe. More than 30 years of technology development and operational experience have reduced land-based wind energy costs by a factor of five (EWEA 2009; IEA 2009). Modern wind turbines are theoretically capable of capturing up to 59% of the available potential in the wind; however, today's state-of-the-art commercial equipment typically captures about 45% of the available energy in the wind at maximum efficiency. In spite of this, wind power is often among the lowest cost renewable energy technologies and as a result, has seen significant global growth over the past 15 years (GWEC 2011). The energy in the wind increases with the cube of the wind speed. A doubling in wind speed results in an eight-fold increase in energy production.

Turbines today are characterized by the three-bladed, up-wind (i.e., turbines that are oriented into the prevailing wind flow) configuration. Mechanical blade pitch control, coupled with modern power electronics, also allows variable speed operations, which increases efficiency, smoothes output power, reduces drivetrain torque, and in some cases provides the ability to supply ancillary grid services. Turbines may be equipped with a three-stage planetary gearbox, a single-stage medium-speed gearbox, or a direct drive generator (this latter alternative does away with the gearbox altogether). Typical machine capacities range from 1–3 MW with some equipment exceeding 3 MW. Tower heights and rotor diameters of 80–100 m are common in the world's mature markets. Developing markets may be characterized by smaller equipment in terms of capacity, rotor diameter, and tower height.

Offshore wind plants today utilize a basic onshore turbine adapted to the marine environment. Offshore projects today employ fixed-bottom foundations (e.g., mono-pile, jackets, or gravity-base). Floating offshore turbines, which could be tethered to fixed spots on the ocean floor, exist today only in prototype and concept stages of development.

### *Installed Capacity*

Wind technology began to gain traction as a source of commercial power generation in the United States in the late 1970s. Aggressive policy helped to drive the first wind plant installations in the United States in the early 1980s. Buoyed to some extent by activities in Europe as well as continued technological advancements, a lull in growth during the late 1980s and early 1990s was followed by the emergence of the modern wind industry. Since the mid-1990s, wind power has emerged as a mainstream power generation technology and a significant contributor to electricity use in many countries (e.g., Denmark 26%, Portugal 17%, Spain 15%, Ireland 14%, and Germany 9%) (Wiser and Bolinger 2011). Continued improvement in technology is also opening up new areas for development. Sites that previously did not have adequate wind are in some cases now viable candidates for commercial investment.

The total installed capacity in the United States exceeds 40,000 MW (AWEA 2011; Wiser and Bolinger 2011). The expected contribution to annual electricity generation from installations through 2010 is estimated at nearly 3% (Wiser and Bolinger 2011). Over the past five years, wind has been at least 18% and as high as 43% of annual new electric power capacity in the United States (Wiser and Bolinger 2011). Average annual industry growth in the United States between 2001 and 2010 has been 25% (Wiser and Bolinger 2011). Capacity in the United States is spread throughout the continental United States with leading states including Texas, Iowa, California, Minnesota, and Washington (Wiser and Bolinger 2011).

Globally, through year 2010, installed capacity was estimated at more than 190,000 MW (GWEC 2011). Global growth has exceeded 20% every year since 1996 with a number of years where cumulative growth exceeded 30% (GWEC 2011). Development around the world has been concentrated in western Europe, North America, and Asia. However, emerging markets including eastern Europe and Latin America have recently observed significant new development (GWEC 2011).

There are no offshore wind facilities installed in North America; however, a number of projects are in various stages of planning and development (Wiser and Bolinger 2011). The primary market for offshore wind globally is in Europe where a total of nearly 3,000 MW were installed at year end 2010. Outside of Europe, only China has successfully completed an offshore wind project (GWEC 2011).

### *Barriers*

Despite its emergence as a mainstream energy resource, wind power continues to face an evolving set of barriers and hurdles. Of significant concern are access to adequate transmission, maintaining and achieving general power sector competitiveness, permitting and regulatory approval for projects, understanding and minimizing wildlife impacts, and addressing aesthetic and nuisance effects.

Access to adequate transmission is critical because developable wind resources are often not in close proximity to demand or load centers. High value wind sites with adequate transmission are becoming fewer and continued widespread wind energy development is generally expected to require significant new investments in transmission. However, planning and developing new transmission lines can take years.

Under certain markets and policies, wind power is competitive with wholesale power markets (Wiser and Bolinger 2011). However, transmission constraints and supply chain bottlenecks, among other factors, coupled with reduced natural gas prices and a general decline in electricity consumption (as a result of the recent U.S. recession) has made it more difficult for wind to compete. In order to maintain consistent growth, there is increasing pressure on wind energy to become more competitive economically.

Siting and permitting individual projects can also be a challenge. Regulators and host communities may be concerned about an array of potential aesthetic, nuisance (e.g., noise and shadow flicker), and wildlife impacts. In some cases, policies have been set forth that effectively prevent new wind development from occurring. Finding technical and policy solutions to these challenges is likely to open up new areas for development in locations where projects are not currently feasible.

### USVI Resource Availability
Developable wind resources have been identified on many of the exposed ridges and in coastal areas of the USVI (Elliot 2008) (Figure A-16). Specifically, the southern shore of St. Croix and Bolvoni Point on St. Thomas have each been identified as potentially viable sites for utility-scale wind energy production. Other sites with sufficient exposure to the prevailing easterly tradewinds may also provide wind development opportunities.
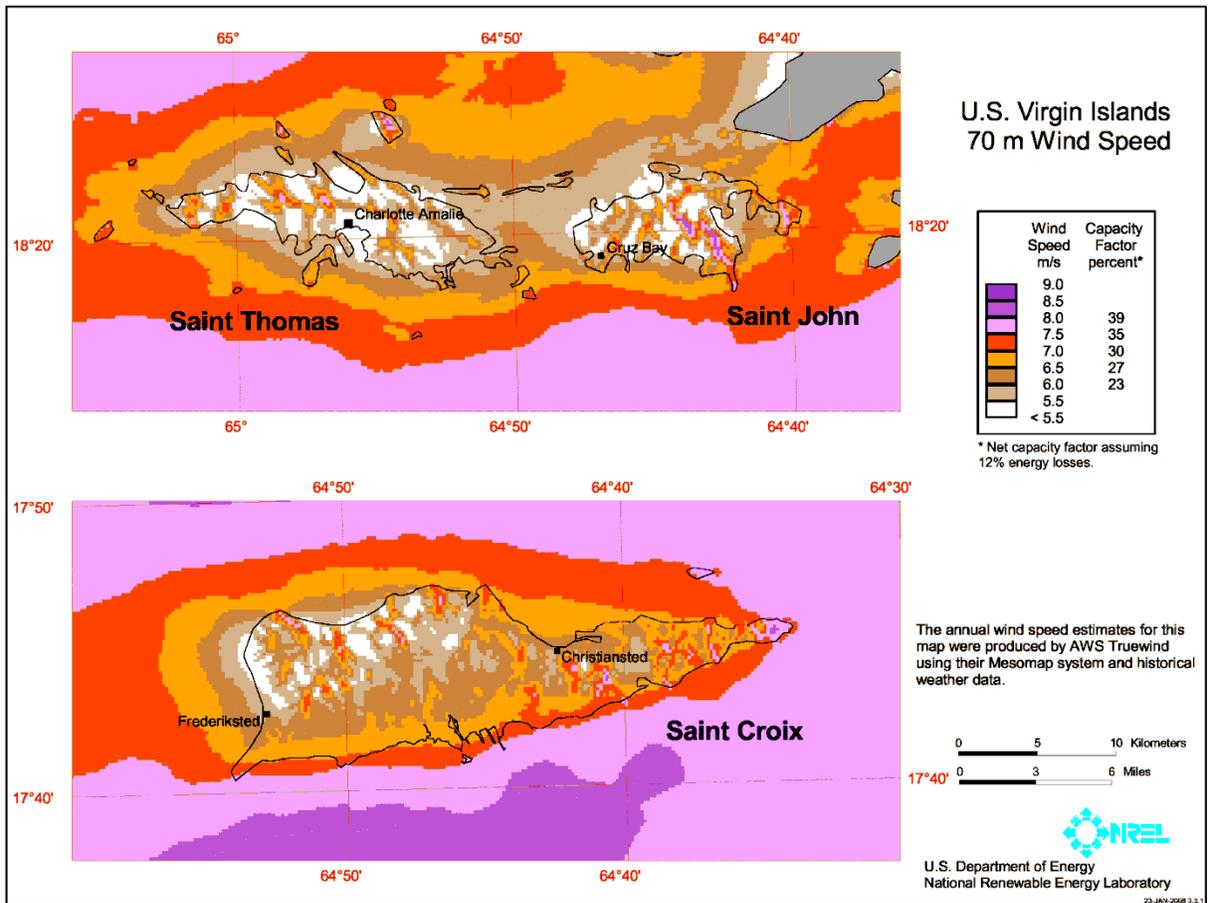
**Figure A-16. Wind resource potential in the USVI at 70 m**

In order to better assess specific sites in the USVI, VIEO has solicited bids to install meteorological towers at specific sites on the islands. Installing meteorological towers and collecting site-specific wind speed data for a period of 1 to 2 years will provide VIEO with the ability to better quantify the value of adding wind at those specific project sites and may help encourage interest from project developers. Some sites with viable wind resources may not be feasible for development as a result of inadequate site access (i.e., to steep or mountainous) or proximity to homes and other occupied buildings.

### *Estimated Cost of Energy*

The cost of wind energy has declined dramatically over the past 30 years. Research and development investment, learning, production volume, and economies of scale have helped reduce installed costs by a factor of five (EWEA 2009; IEA 2009) since the early 1980s. In addition to increasing energy capture, scaling from turbines of less than 100 kW to turbines greater than 3 MW has also allowed for reductions in the required supporting infrastructure, such as roads and underground cabling, and helped to decrease time spent moving heavy equipment (e.g., cranes) between turbine sites. More recently, project installed costs have increased but so too has project performance offsetting, at least in part, on some of the increases in installed costs observed over the past five years (Wiser and Bolinger 2011).

Looking back over the past decade indicates that the cost of wind energy has been generally in line with that of wholesale power markets around the United States (Wiser and Bolinger 2011). The years 2009 and 2010 represent some reversal of this trend; however, recent prices have been inflated as a result of turbine and power production contracts that were signed prior to the financial crises in 2008. Power prices in 2010 for projects installed between 2007 and 2010 have ranged from about $0.03/kWh to more than $0.12/kWh (Wiser and Bolinger 2011). On average, prices have increased from about $0.032/kWh in 2002–2003 to $0.62/kWh in 2009 to as high as $0.073/kWh in 2010. In removing state and federal policy incentives, the International Energy Agency estimated the cost of wind energy in seven different countries to range from $0.085/kWh in Denmark to $0.167/kWh in Switzerland and established a representative average reference case at $0.095/kWh (Schwabe et al. 2011). The Intergovernmental Panel on Climate Change recent *Special Report on Renewable Energy Sources* estimated wind energy to range from well below $0.10/kWh to more than $0.20/kWh (IPCC 2011). Offshore wind energy costs are generally expected to fall into the higher end of the range suggested by the IPCC. In fact, in the United States, power sales contracts have been signed that suggest prices on the order of $0.18/kWh to $0.24/kWh (Wiser and Bolinger 2011).

Power prices for wind energy in the USVI are generally expected to be somewhat higher than those in the mature markets of North America and Europe; nevertheless, they are likely to fall within the range highlighted by the IPCC. As one reference point, the Kodiak Electric Association's Pillar Mountain Wind Farm, also located in a remote island setting, estimates their COE to be about $0.12/kWh (KEA 2011). Jamaica's Wigton Wind Farm installed cost is estimated at about $2,800/kW (JIS 2010), which, when using standard industry assumptions and including no incentives, is estimated with CREST to be on the order of $0.15/kWh.

Into the future, many studies expect wind power costs to continue to decline (e.g., DOE 2008; Lemming et al. 2009; EPA 2009; EREC GPI 2008; EWEA 2009). In addition, evidence suggests that after many years of price increases, prices have peaked and are now falling once again (Wiser and Bolinger 2011). Falling prices coupled with continued technological and performance improvements suggest that wind power is likely to remain competitive as a mainstream power resource into the future.

### *Barriers*
Apart from costs that sometimes exceed conventional generation resources and its variable output nature, barriers to wind energy projects are typically in the form of wildlife impacts, land use, aesthetics, and nuisance impacts (on individuals living in close proximity to projects).

Historically, there have been instances of large numbers of avian and bat fatalities at wind energy projects (Orloff and Flannery 1992). Today, however, modern technology coupled with detailed pre-construction wildlife studies has dramatically reduced the number of avian and other wildlife fatalities occurring at operating wind energy projects. Presently, risks to birds tend to be to individuals rather than populations. Meanwhile, the industry continues to fund research to further reduce avian and bat fatalities. Concerns are also present regarding habitat fragmentation and its impact on other wildlife, but little evidence, either supporting these concerns or refuting them, is currently available.

With regard to land use, wind energy plants typically cover relatively large amounts of land due to turbine spacing requirements. A typical rule-of-thumb is an estimated 5 MW/km$^2$. Turbine arrays are generally designed to minimize production losses but must also factor in local terrain, predominant wind direction, turbine size, property lines, setback requirements, and other landscape features (e.g., roads). As a result, actual land requirements vary somewhat from 1.0 MW/km$^2$ to 11.2 MW/km$^2$ (Denholm et al. 2009). Of this land, only about 3%–5% is generally required for actual infrastructure, including the turbine, electrical equipment, and potentially an operations and maintenance building.

In addition to land requirements, turbines represent a conspicuous presence in the landscape. For some they are symbols of technological advancement but for others they may represent the unwanted industrial development. Project neighbors and host communities are sometimes concerned about the aesthetic or viewshed impacts from wind energy projects. Aesthetic concerns must be taken seriously and addressed early. Failing to adequately portray aesthetic impacts with modern video or photo simulations can result in diminished public confidence and ultimately in increased costs and delays. In addition, it is important to identify areas with particularly high cultural or aesthetic value and exclude those from potential development while at the same time explicating seeking out and exploiting those areas that are more amenable to landscape alteration (e.g., preexisting industrial sites or landfills).

Other concerns include sound and shadow flicker. The latter issue tends to be of greater concern in localities with much greater latitude than the tropical USVI but can easily be predicted and mitigated with proper siting studies. Sound is somewhat more complex as reaction to wind turbine sound is often highly subjective. Although allegations of health impacts resulting from wind turbine noise have been made (e.g., Pierpont 2010), they have not been verified outside of a few unique case studies, and noise guidelines in place in most localities have generally been developed to protect the public from acute health impacts (McCunney and Meyer 2007). Nevertheless, annoyance resulting from wind turbine noise persists even at very low levels. It has been proposed that wind turbine noise is more bothersome because of elements of wind turbine noise that are not typically present in other sources of community or environmental noise. For example, amplitude modulation, which may be experienced as audible pulsing, has been shown to increase annoyance among individuals proximate to rail yards (Kanteralis and Walker 1988). However, annoyance from wind turbine sound has also been found to be correlated with unrelated factors including prior attitude toward wind turbines, the visibility of the turbines, and whether or not individuals receive direct financial payments from a project (Pedersen and Waye 2007; Pedersen et al. 2009).

# Appendix B: Analysis of End-Use Efficiency Potential

This appendix focuses on opportunities for implementing cost-effective end-use energy efficiency measures. Broadly speaking, end-use energy refers to the energy supplied to and used by customers and includes energy associated with street lights, industrial processes, commercial buildings, residential buildings, and essentially all energy-using devices within these buildings. This analysis focuses on the energy use associated in the residential building sector. Residential buildings in the USVI total approximately 44,000 customers and represent approximately 35% of the building sector electrical energy use on the islands. This sector has the largest number of accounts and represents the greatest consumption of any single sector (Table B-1).

**Table B-1. 2009 Building Sector Energy Use**

| Sector Description | Accounts Served | Annual Electrical Use (MWh) | Building Sector Electrical Energy (%) |
|---|---|---|---|
| Residential | 43,972 | 248,227 | 35% |
| Commercial | 8,402 | 116,192 | 16% |
| Government | 649 | 121,700 | 17% |
| Large C&I | 982 | 227,025 | 32% |
| Total | 54,005 | 713,144 | 100% |

Source: RW Beck 2010; VIEA 2010

## Background

The USVI are located approximately 18 degrees north of the equator. The tropical environment presents unique challenges and opportunities for increasing energy efficiency. Figure B-1 provides a snapshot of some of the factors associated with these opportunities: dry bulb temperature, relative humidity, and prevailing wind.
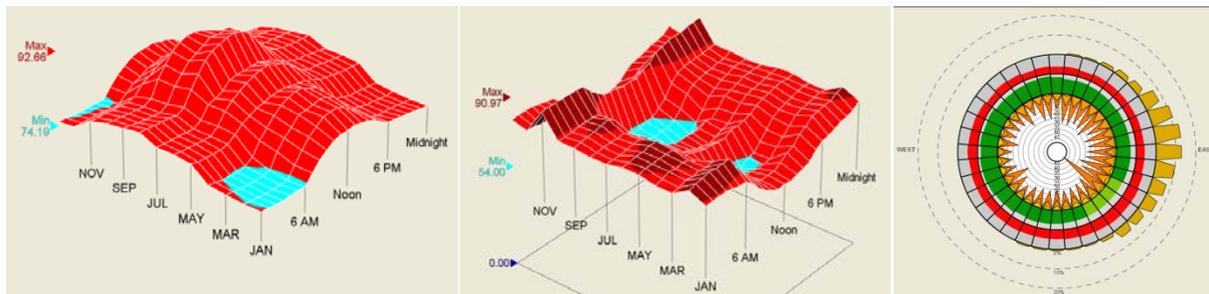


**Figure B-1. Annual temperature, humidity, and wind profiles**

Illustration by NREL

In 2009, the International Energy Conservation Code (IECC) was adopted by the USVI. Today, the territory is working to modify the IECC to incorporate tropical energy features. This work is supported by grant funding from DOE. Enforcement of new building standards such as those that were recently adopted and are under development will support energy efficiency in new construction projects throughout the islands. However, existing buildings offer immediate opportunities to increase energy efficiency.

## Methodology

As noted in Section 5.4, three residential building types were evaluated in this analysis, a single 900 ft$^2$ design with and without air-conditioning and a fully air-conditioned 3,000 ft$^2$ vacation or large residence (Figure B-2). DOE-2 with the eQUEST interface was used to develop the building energy models that have been used. The baseline construction assumptions are summarized in greater detail Table B-2.
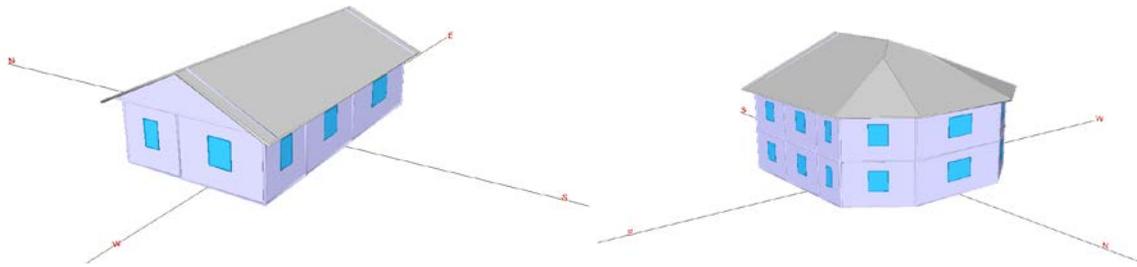
**Figure B-2. Building model geometry**

**Table B-2. Baseline Construction and Load Assumptions**

| Component | 900 ft$^2$ | 3,000 ft$^2$ |
|---|---|---|
| Wall Construction | Uninsulated 8" concrete block with stucco exterior and gyp interior, effective R-3 | Uninsulated 8" concrete block with stucco exterior and uninsulated 4" furring gyp interior, effective R-5 |
| Roof Construction | Wood-framed, uninsulated metal roof. Effective R-5 assembly. | Wood-framed, uninsulated clay tile roof. Effective R-5 assembly. |
| Windows | Single pane | Single pane |
| | 0.47 – Shading Coefficient | 0.47 – Shading Coefficient |
| | 0.72 – Glass Conductance | 0.72 – Glass Conductance |
| | 0.85 – Visible Transmittance | 0.85 – Visible Transmittance |

| Lighting (W/ft$^2$) | Baseline Value | ECM Value | Baseline Value | ECM Value |
|---|---|---|---|---|
| Living | 0.6 | 0.4 | 1.0 | 0.4 |
| Bedroom | 1.0 | 0.5 | 1.5 | 0.8 |
| Kitchen | 1.3 | 0.5 | 1.2 | 0.6 |
| Bath | 1.3 | 0.5 | 1.5 | 0.8 |

| Equipment (W/ft$^2$) | Baseline Value | ECM Value | Baseline Value | ECM Value |
|---|---|---|---|---|
| Living | 0.4 | - | 0.6 | - |
| Bedroom | 0.2 | - | 0.4 | - |
| Kitchen | 0.5 | 0.35 | 0.5 | 0.35 |

The American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 55, *Thermal Environmental Condition for Human Occupancy*, addresses six primary variables related to human comfort:

- Metabolic rate (occupant activity)

- Clothing insulation

- Air temperature

- Radiant temperature

- Air speed

- Humidity.

Air temperature, air speed, and humidity are variables most often identified as relating to comfort. Passive means such as cross-ventilation can provide an increase in occupant comfort with an associated opportunity for decreased energy consumption. Kao Design Group, along with graduate students from Harvard University, recently completed an analysis to quantify the impact of utilizing natural ventilation as a means to enhance occupant comfort while minimizing energy use in residential buildings. Their report suggested opportunities and the associated impact on energy use from utilizing passive ventilation strategies (Holms and Kao 2010).

This analysis focuses primarily on the opportunities for reduced energy consumption through measures relating to building envelop enhancements and equipment within or used in conditioning existing homes comparable to those described by Holms and Kao (2010). While these opportunities can most easily be realized when planned and integrated into a new building, such opportunities are available for existing buildings. ECM evaluated for each building type are shown in Table B-3 and described below.

**Table B-3. ECM Matrix**

| Model | ECM-1 | ECM-2 | ECM-3 | ECM-4 | ECM-5 | ECM-6 | ECM-7 | ECM-8 |
|---|---|---|---|---|---|---|---|---|
| Small-No Air-Conditioning | | | | | | X | X | X |
| Small-Air-Conditioning | X | X | X | X | X | X | X | X |
| Large-Air-Conditioning | X | X | X | X | X | X | X | X |

## ECM-1: Air-Conditioning Efficiency

Compressor-based air-conditioning is an energy-intensive process that consumes even greater amounts of energy as a result of the elevated humidity levels in tropical environments.[35] Due to the high COE, many island residents do not utilize air-conditioning within their homes. An ongoing residential energy use consumption survey is intended to provide a greater understanding of actual air-conditioning penetration and use within homes. However, for this

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[35] High humidity environments require additional energy to remove moisture from the air that is ultimately supplied to conditioned spaces.

analysis, the use of air-conditioning and the impact of improvements to air-conditioning equipment have been investigated to illustrate the potential implications of using air-conditioning and upgrading to more efficient equipment. For air-conditioning units in the conditioned building models, the baseline efficiency has been assumed to be 13 SEER. This ECM increases air-conditioning unit efficiency to 16 SEER.

## ECM-2: Cool Roof and Insulation

Minimizing loads within a building enhances environmental thermal conditions and reduces the need for mechanical cooling to provide comfort to occupants. This measure looks at the effects of high-emissivity cool roofs and roof insulation to help minimize these loads.

The baseline roof construction for all models was assumed to be an uninsulated weathered metal roof with an assumed solar reflectance of 0.21 and no radiant barrier. This ECM increases the roof insulation to R-30 and radiant barrier per section 402 of the 2009 IECC with increased solar reflectance to 0.48.
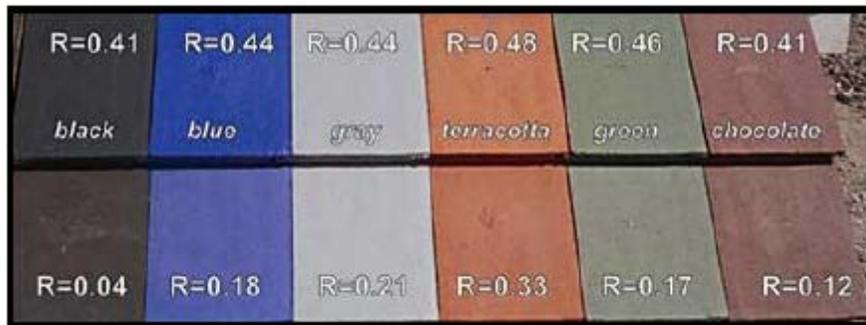


**Figure B-3. Cool roof options**

Source: EERE Building Technologies Program; http://www1.eere.energy.gov/femp/pdfs/coolroofguide.pdf.

## ECM-3: Wall Insulation

Minimizing loads within a building enhances environmental thermal conditions and reduces the need for mechanical cooling to provide comfort to occupants. This measure looks at the effects of increased wall insulation to help minimize these loads. Two wall construction types were used in the baseline building analysis. The baseline wall insulation for all models was assumed to be uninsulated. This ECM provides R-13 to exterior walls per section 402 of the 2009 IECC.

## ECM-4: Glazing Improvements

Minimizing loads within a building enhances environmental thermal conditions and reduces the need for mechanical cooling to provide comfort to occupants. This measure looks at the effects of improved glazing performance to help minimize these loads. For all models, the baseline glazing characteristics were assumed to be single pane clear glazing. This ECM represents double-pane glazing with characteristics described in Table B-4.

**Table B-4. Glazing Characteristics**

| Component | Baseline | ECM-4 |
|---|---|---|
| Shading Coefficient | 0.47 | 0.33 |
| Assembly Conductance | 0.72 | 0.35 |
| Visual Transmittance | 0.85 | 0.35 |

## ECM-5: External Shading

Comparable to glazing improvements, this measure looks at the effects of external shading to help minimize these loads. All baseline models are assumed to have no shading on south windows. This measure adds 3′0″ external shading devices to all south windows.

## ECM-6: Lighting Power

Lighting within buildings accounts for a significant portion of a typical building's energy use. Electricity used directly to power these lights is also converted to heat, which can impact thermal comfort leading to the need for mechanical cooling to provide comfort to occupants. Lighting power densities for spaces within each building and space type are described in Table B-5. It is intended that the residential energy use consumption survey will help provide a greater understanding of this opportunity and its associated impact

**Table B-5. Lighting Power Densities**

| | Living (W/ft$^2$) | | Kitchen (W/ft$^2$) | | Bath (W/ft$^2$) | | Bedroom (W/ft$^2$) | |
|---|---|---|---|---|---|---|---|---|
| | Base | ECM | Base | ECM | Base | ECM | Base | ECM |
| Small | 0.6 | 0.4 | 1.3 | 0.5 | 1.0 | 0.5 | 1.3 | 0.5 |
| Large | 1.0 | 0.4 | 1.5 | 0.8 | 1.2 | 0.6 | 1.5 | 0.8 |

## ECM-7: Refrigerator

The expected life of a refrigerator is 19 years. An ENERGY STAR refrigerator consumes only 30% of the energy that a similar or even smaller-sized refrigerator nearing the end of its useful life and only 50% of a refrigerator purchased just 10 years ago. This measure looks at the effect of a reduction in energy use by implementing ENERGY-STAR-rated refrigerators. This ECM assumes a conservative 30% reduction from the baseline equipment power density. This reduction equates to a reduction from 0.5 W/ft$^2$ to 0.35 W/ft$^2$ in equipment load density. The residential energy use consumption survey is expected to provide greater understanding of this opportunity and its associated impacts.

## ECM-8: Solar Domestic Hot Water

This measure evaluates the effect of incorporating a SWH system to provide domestic hot water (DHW) to residences. While ACT 7075 mandates that a building is to have 70% of its domestic water heating provided by solar, the opportunity for water conservation and system efficiency measures such as tank and pipe insulation are easily implemented. This measure assumes 90% of the DHW load is being offset with the solar system.

Although SWH is included here as a potential energy saving opportunity for residential buildings, this opportunity is actually broken out separately in the 60x25 road map. Including

this opportunity represents a more complete picture of actual building energy savings potential. However, to assess precisely how these results compare with the targeted reductions outlined for residential energy efficiency above, the percentage reduction in energy consumption, excluding those savings realized from shifting to SWH, should be examined.

## Results

Figure B-4, Figure B-5, and Figure B-6 show the energy end-use and savings potential for the ECMs described above. Note that the savings shown for each measure build on the savings from the previous measure. These results suggest that on average, energy reduction targets included in the clean energy road map outlined above are reasonable for the residential building sector.[36]
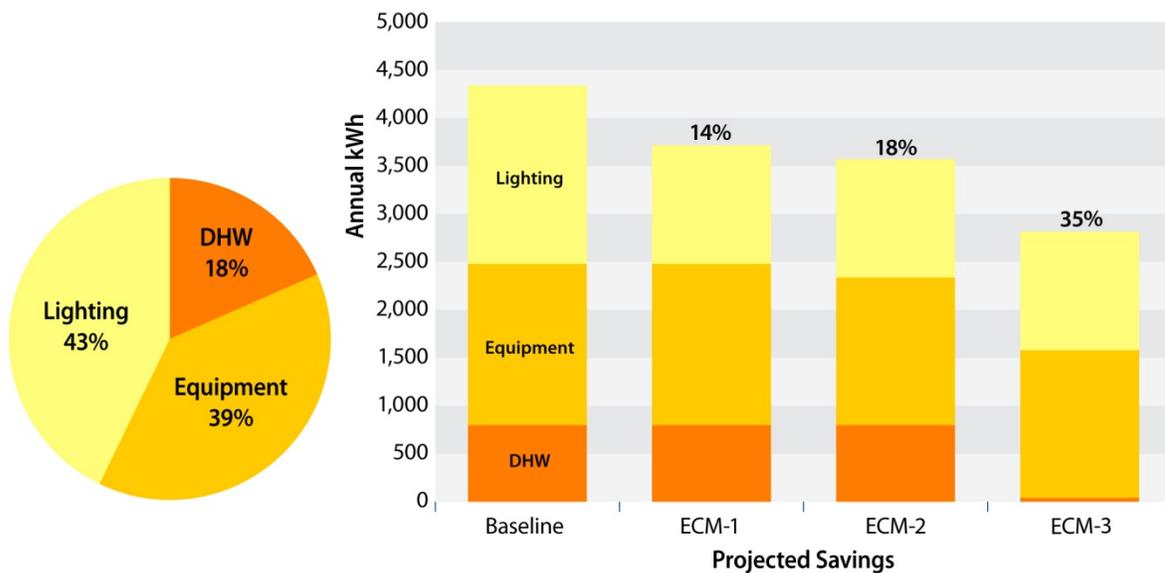


**Figure B-4. Energy end-use and savings potential—900 ft$^2$, no air-conditioning**

Figure B-4 illustrates the three primary energy end uses within the 900 ft$^2$, no air-conditioning building type. By excluding the impact of shifting to SWH, the energy savings potential in this building is only about 18%, slightly below the targeted 20% to 30%. However, additional efficiency gains in those residences with air-conditioning above 30% easily offset the slightly lower savings potential observed here. As such, a sector-wide estimate of 20% to 30% reduction in end-use energy consumption is not likely to be negatively affected by moderately lower savings potential in the most basic residential buildings.

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[36] The estimated base case reduction in end-use consumption in the residential sector is a 25% reduction in 25% of homes. This estimate excludes the possibility of moving to SWH, which is included in these results. Nevertheless, even when excluding the impacts of shifting to SWH, the potential end-use savings exceeds the 25% reduction in all cases except the 900 ft$^2$, no air-conditioning analysis. There, the savings potential without factoring in SWH peaks at 18%. However, because this represents only one of three basic building types and those buildings with air-conditioning have an energy savings potential that easily exceeds 25%, in aggregate, it is shown that reduced consumption targets of 20% to 30% across the residential sector are generally feasible.
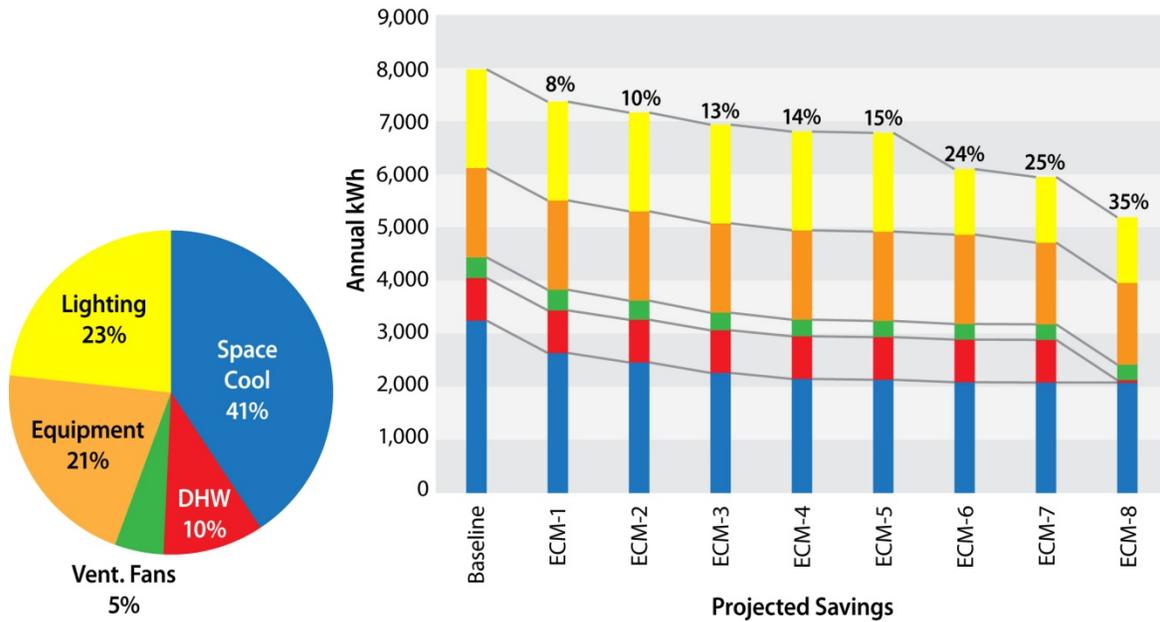
**Figure B-5. Energy end-use and savings potential—900 ft$^2$, with air-conditioning**

Figure B-5 illustrates the five primary energy end uses in the 900 ft$^2$ building type with air-conditioning. As shown, the opportunity for increased energy efficiency in this building type without factoring SWH potential is about 25%, including the savings resulting from shifting to SWH; the total potential reduction is estimated at 35%.
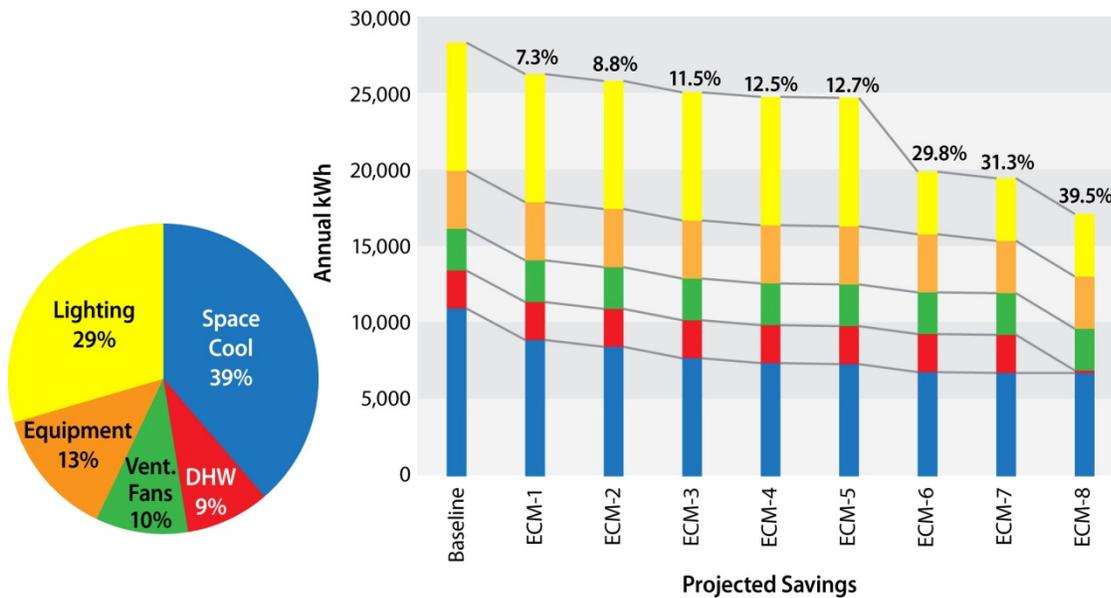


**Figure B-6. Energy end-use and savings potential—3,000 ft$^2$, with air-conditioning**

There are also five primary energy end uses within the 3,000 ft$^2$ with air-conditioning building type. The opportunity for increased energy efficiency in this building type exceeds 30% without factoring in the potential impact of SWH; with it, the potential savings is nearly 40% (Figure B-6).

This preliminary modeling work shows that opportunities for increased energy efficiency in the residential building sector are available. Analyzing additional information on building construction, occupancy schedules, end-use energy consumption and estimated costs with respect to these specific ECMs could offer more site- and context-specific information regarding impacts in actual buildings. Similar building modeling work could also be extended to commercial buildings as well as with the island hotels and resorts to help identify cost-effective ECMs to meet the energy-reduction goals for these building sectors.