RESEARCH REPORT

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SMART GROWTH PATHWAYS: BUILDING A GREEN PLATFORM FOR SUSTAINABLE ARUBA

THE CARBON WAR ROOM

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CARBON WAR ROOM

SMART ISLAND ECONOMIES

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Foreword by Prime Minister Mike Eman

Smart Growth Pathways

I am very pleased and proud that we have reached this important milestone—the first of many—in the partnership between the Government of Aruba and the Carbon War Room, as we embark together on a historic project to propel Aruba further on its path to smart growth.

Our goal is an ambitious one: to increase the social, environmental and economic resilience of Aruba through an efficient use of natural resources and an implementation of projects that will create and sustain high-quality local jobs for current and future generations. Ultimately, we hope that Aruba will become the model for a low-carbon, sustainable and prosperous economy that can be replicated in other island nations.

At the UN Rio+20 Conference on Sustainable Development, we formally announced our partnership with the Carbon War Room and launched the Smart Island Strategy for Aruba. Together, we made the commitment to transition our island to 100 percent renewable energy by 2020, increase housing choices and neighborhood quality, strengthen social cohesion, reduce traffic congestion and improve mobility, reduce obesity and improve public health, improve water conservation, and diversify an expanding island economy.

Since then, the experts from the Carbon War Room have been working closely with many Arubans in both the public and private sectors to analyze the various action areas and determine the preliminary strategy for moving forward.

Aruba has already made significant progress on the path to sustainability. The Vader Piet wind farm generates part of Aruba's electricity needs, and there is a second wind farm in development. We have planned additional projects, including an Airport Solar Park and a waste-to-energy plant. Arubans also are putting solar panels on residential and commercial buildings. When completed, these projects—together with Vader Piet—will generate a substantial percentage of Aruba's power needs. With the help of partners such as the Carbon War Room and its experts we are developing plans to go much further, however, to become one of the leading countries in the world in the use of renewable energy. This will not be easy. Wind and solar energy can only take us so far because of intermittency issues, but we will be looking closely at newer technologies for both energy production and storage as these become more reliable and cost-effective. We in Aruba are looking forward to achieving our first "green hour" of electricity completely generated by renewable energy, and then our first "green week", "green month" and so on until we have achieved our ultimate goal.

Smart growth addresses many areas beyond the transition to renewable energy. It also involves: the creation of world-class walkable destinations for tourists and residents; providing incentives for household retrofitting and commercial energy efficiency; implementing a sustainable approach to smart growth in the tourism industry to create an inspirational holiday destination; and creating an Agriculture sector in Aruba that makes the best use of water resources. One of the first steps on this path is to build a Green Platform to promote the transition to renewable forms of energy and to develop a land-use and urban planning component that supports this transition.

Smart growth will also be focused on the Built Environment. The land-use and urban planning component of our vision has the potential to contribute significantly towards the reduction of dependence on fossil fuel. As places are built in a more compact, diverse and complete manner, people will be encouraged to walk more and to drive less, thus reducing vehicle miles traveled and, subsequently, the CO_2 emissions per capita. And equally importantly, if not more so, these steps will promote greater social cohesion in our neighborhoods. A second separate report will focus on the built environment aspect of smart growth aimed at building stronger communities.

Consistent with Aruba's consensus-driven, policy-making approach of "social dialogue", we are now ready to share this initial strategy with Aruba's stakeholders. We look forward to obtaining their input and advice at the earliest stage possible in order to refine the "Smart Growth Pathways" document and to ensure that the final, definitive version reflects the views of the Aruban people. We will continue to develop and refine the plan after consultation with all of the stakeholders and extensive community participation, just as we have done in previous large projects.

I wish to thank all those that are contributing their valuable time and expertise to the improvement and refinement of the draft "Smart Growth Pathways".

Mike Eman
Prime Minister, Aruba

Foreword from Carbon War Room

Dear Friends of Aruba,

In March 2012, the Carbon War Room began a journey with the Government of Aruba. This journey began with us listening to the words of Prime Minister Mike Eman as he articulated his vision for the island of Aruba, a vision that has continued to enthuse and inspire us, a vision that declares that Aruba will become an island where "everything we do is sustainable."

An early step on this journey was the formation of a partnership, declared at Rio+20, where the Prime Minister voiced his remarkable aim for Aruba to become the first island nation to completely transition off fossil fuels. I was both delighted and proud to share the stage with Mike Eman at that moment, and to jointly strive for the achievement of this ambitious goal.

Since Rio, we have heard the Prime Minister speak of the moral responsibility we all have to our planet, and we have understood very clearly his intention, which he shares with his people, that Aruba is committed to playing its part in creating a sustainable tomorrow for all. This intention to secure the future of the island by increasing its resilience through a reduced dependency on imported fossil fuels and a holistic transition to sustainability is one that the Carbon War Room firmly supports.

Today, we take a practical step in demonstrating that support with the publication of **Smart Growth Pathways**—a discussion document that takes an initial view of the roadmap to sustainability for Aruba through a focus on low-carbon pathways as the keystone to sustainability and economic growth. While the document focuses more on the opportunity to transform the **Energy sector** from one that depends on fossil fuels to one that is fundamentally renewable, there is also consideration of the many sectors that rely on this energy system to create their livelihoods, and the livelihoods of others, on the island.

This document should hopefully be read as just one more step on this journey. and we recommend that it is read in conjunction with other documents focused on the development of Aruba's sustainable future, including efforts which are aimed at achieving the maximum social impact for the island by addressing spatial planning, health indicators and the well being of the population. We firmly believe that while transformation of the Energy sector is a near-term commercially viable opportunity, **all stakeholders in all sectors** should have a say in the outcome, as the results will have such widespread effects. For example, tourism and land use are vital threads that intersect with all components of a successful transition. We welcome the opinions of key stakeholders across the economy as we help to develop the thinking on the concrete steps to a sustainable Aruba.

Both the thinking, but most importantly the action, of a variety of friends of Aruba (domestic and international) will be required to make Sustainable Aruba a reality.

At the Carbon War Room, we see **our role** very clearly as working collaboratively with the Government of Aruba and other key partners to identify and implement commercial projects designed to transform the energy system, and to make efficient use of natural resources, aiming at strengthening the environmental, social and economic fortitude of the island. What will success look like? In short, a vibrant economy, with local job creation and a positive impact on the health and well-being of the population, all while significantly reducing CO_2 emissions and serving as an example to others.

This point about serving as an example is an important one, and a vital intended legacy of this project. Aruba and its partners, among them the Carbon War Room, are working towards the island's journey to sustainability to become a blueprint for others, and in so doing to enable the new pillar of the Aruban economy to flourish: **a pillar of knowledge**.

We are very keen to hear what you think about the options ahead, so we are looking forward to the continued partnership and engagement to come.

It is an honor to be partnered with the Government of Aruba and the people on such an important mission, and we gratefully acknowledge the huge efforts of the teams at WEB and Elmar, with whom we worked closely in producing this document. We look forward also to working closely with TNO in Aruba to demonstrate a proactive approach to more efficient use of energy and a reduction in the use of fossil fuels...

In short...we are looking forward to working together! After all...there is no Planet B!

José María Figueres
President, Carbon War Room

Introduction

The Challenge

Across the globe, populations are expanding, prices for food, water, and energy are rising, and climate change is creating increasingly fragile ecosystems. All of these trends pose particularly urgent threats to the futures of small island nations, which are struggling to balance the imperative for economic growth with the need for increasing resilience to a changing climate and energy price fluctuations. In Aruba, economic development is advancing at a greater pace than in most island states, driven mostly by a strong tourism and hospitality industry. However, in order to fuel this growth, Aruba must import ever-larger amounts of costly fuel and other resources each year—damaging its environment and ultimately hindering national development. This is the challenge that we face today: the continued pursuit of a low-carbon growth pathway for Aruba that reduces fossil fuel use in support of a healthy, prosperous, and secure future.

Background

At the United Nation's Rio+20 Sustainability Summit in June of 2012, Prime Minister Mike Eman affirmed the Government of Aruba's intention to develop a sustainability-centered national development strategy and jointly announced with the Carbon War Room a commitment to work together to transition the island off fossil fuels by 2020. In 2011, the Government of Aruba laid out its plans for revitalizing the national economy, including some broad goals for sustainable development and various policies to help achieve those goals, in a document entitled "Green Gateway". The Prime Minister has indicated the will and desire of his government to take the next step and examine how these current efforts and projects can be integrated and scaled up within a Smart Island Strategy that can attract new investment and place Aruba on the cutting edge of sustainability. The government's goals are both timely and visionary. The pathway for achieving these goals in coming years will encompass many interrelated sectors, as well as the various industries within stakeholder groups within these sectors.

Aruba has already begun the process. In the last two years, Aruba has conducted several very specific and critically important baseline assessments on waste streams, groundwater quality, and the refining industry. It has also conducted analyses of particular technologies, assessing their potential to support low-carbon development, and initiated pilot programs, such as the Smart Community Aruba project led by TNO (Netherlands Organization for Applied Scientific Research), where one of the many objectives is to study the use of microgrid solutions to overcome the supply and demand challenges. If implemented successfully, a low-carbon growth pathway will attract substantial investment to the island and will usher in a new era of prosperity for the country, allowing Aruba to realize its vision of sustainable economic growth and serve as an inspiration to other island economies, motivating them to pursue low-carbon development.

This Project

To help bring about its vision of sustainable prosperity,and low-carbon development, the Government of Aruba has partnered with the Carbon War Room, a partnership set in motion by the New America Foundation, an NGO that was already working to develop broader sustainability goals for Aruba. Inspired by the vision and commitment of the government, the Carbon War Room aims to facilitate the development and implementation of an integrated, multi-sector, sustainable development strategy for the Government of Aruba to pursue in partnership with the private sector and civil society. To help begin crafting that strategy, the Government of Aruba and the Carbon War Room have worked collaboratively to produce "Smart Growth Pathways: Building a Green Platform for Sustainable Aruba".

The Carbon War Room works with a vast network of global partners to nurture innovative, market-driven solutions to climate change. In particular, the Carbon War Room's Smart Island Economies Operation focuses on helping island economies reduce their dependence on fossil fuels, thereby insulating themselves from the price shocks and supply volatility associated with fossil fuels. The Carbon War Room has developed the Smart Growth Pathway to achieve the goal of accomplishing precisely such a reduction in Aruba's dependence on fossil fuels. In addition, the Smart Growth Pathway is part of a larger mission to develop a process that can be used by other national and sub-national entities that rely on imports of petroleum-based fuels for energy production. Working collaboratively with the Carbon War Room to develop a Smart Island Strategy, Aruba looks forward to positioning itself as a vital demonstration platform that attracts investment and demonstrates the success of solutions with an innovative measure of early entry advantage, raising the profile and brand of the island while providing critical skills and knowledge as a key pillar of its economy.

This is the challenge: the continued pursuit of a low-carbon growth pathway for Aruba that reduces fossil fuel use in support of a healthy, prosperous and secure future

Our goal is to present a process that is replicable in the many other island economies that are particularly vulnerable to climate change and that import more than 50 percent of their energy needs in the form of petroleum-based fuel. The Carbon War Room has begun this journey in Aruba, as it believes it is unique in its foresight and in the strength of its commitment to overcoming these vulnerabilities.

About This Report

Within this document, the "pathway" is Aruba's course towards achieving its vision of sustainable prosperity and successfully transitioning its economy off fossil fuels. To that end, this document provides an analysis of three key sectors, or "action areas", presenting both the most pressing current challenges and the greatest potential opportunities within those sectors, suggesting possible actions that would allow Aruba to realize its vision and provide a platform for the Carbon War Room to drive the commercial projects, helping to create tangible inward investment and implementation on the ground.

By setting out the initial pathways to sustainability, the "Smart Growth Pathways" document seeks to provide a framework for the delivery of solutions designed to maximize the social and economic returns on the island's natural resources, adopting an integrated and economy-wide approach to Aruba's sustainability strategy. The document also highlights some future opportunities, which include sectors that require long-term planning, as well as an analysis of technologies still under development.

Overall, the pathway is a vision for how Aruba can, in the near term, economically achieve its goal of energy generation free from reliance on fossil fuels, whether it is for a minute, a day, or eventually throughout the year. Achieving this vision will allow Aruba to minimize its carbon dioxide emissions, will open new channels for environmentally sustainable economic growth and create local job opportunities, and will enhance the health and general well-being of the people of Aruba.

Energy Supplement

Since this report concludes that shifting to renewable energy sources presents the most economic and actionable solution for reducing fossil fuel imports in the near term, this is a primary focus of analysis. More information on the energy model discussed in the report is available upon request.

Analytical Approach

The Smart Island Strategy is intended to help reduce and potentially eliminate Aruba's fossil fuel consumption, providing new channels for economic development.

The Carbon War Room has assembled sector-specific teams of technical experts to examine the current status of Aruba with regards to the economic sectors responsible for a majority of the island's fuel consumption, and to offer a range of possible strategies for addressing the key challenges to sustainable growth in those sectors. This document gives an overview of the work that has been done to date by these technical teams to translate Aruba's goals into tangible plans of action.

The findings are based largely on desk research, together with data made available by the Government of Aruba and its relevant departments and agencies, benefitting also from rich and wide-ranging discussions on-island with key stakeholders. The Carbon War Room is very grateful for the generosity of time and insight that it has been shown.

The smart growth pathway is a vision for how Aruba can, in the near term, economically achieve its goal of energy generation free from reliance on fossils fuels

Key Conclusions

1 Current practices for generating electricity, for transporting residents and guests around the island, and for providing food, present a significant opportunity to increase efficiency and greatly reduce the reliance on expensive imported fossil fuels.

2 Implementation of the technologies outlined in the action areas will not only reduce fossil fuel use but will also deliver important societal benefits, including jobs, monetary savings, community engagement, health and well-being.

3 Aruba should focus its efforts on reducing fossil fuel use for energy generation through the implementation of renewable energy, which presents the most economic and actionable solution for reducing fossil fuel imports in the near term. This solution presents an opportunity for the island to invest in domestically produced energy resources, working towards the commitment made at Rio+20 Summit to transition the island off of fossil fuels and setting out pathways that could realistically meet 80 percent of domestic supply in the near term, and perhaps meet total demand during certain periods of time. This would be possible while keeping power costs at or below current levels.

4 A shift to a higher penetration of renewable energy will also require careful consideration of a wide variety of generation, storage, demand response, and systems control technologies. In order to move towards 100 percent renewable electricity, Aruba will also have to be at the cutting edge of smart grid innovations. Increasing energy efficiency will also be a key strategy for reducing fossil fuel use and will require a variety of technologies within a program, which will promote local job creation.

5 While the Transportation sector uses approximately 25 percent of imported fuel, it is likely that effecting change would require a phased approach, with initial steps taken to reduce emissions from the existing vehicle parc, and future efforts aimed at increasing the uptake of electrified transportation systems across private and commercial use.

6 Food imports play a minor role in the overall fossil fuel reliance of the island, and while there are no clear options for shifting the current status quo of nearly 100 percent imported food, the integrated approach to development shown by the government lends itself well to opportunities within the cross-cutting areas of agriculture, water and waste.

7 With 900,000 visitors to Aruba annually, and as a major driver of the Aruban economy, the tourism industry will be a key place to start addressing all of the action areas in concert.

8 Although Aruba contributes minimally to climate change, it will be affected, requiring an approach that also focuses on adaptation.

Action Areas

Aruba consumed around 8,000 barrels of oil per day in 2010. Roughly three-quarters of the country's fuel imports are used to generate electricity

Within the Smart Growth Pathway for Aruba, there are three action areas—Energy, Transportation, and the Built Environment—sectors representing almost all of Aruba's petroleum-based fuel consumption and emitting the bulk of its annual emissions. The three action areas discussed in this report were also chosen because they offer Aruba both the highest potential reductions in fossil fuel use and the greatest opportunity for generating low-carbon economic growth.

The first action area was an obvious choice, as a transition away from fossil fuels in Aruba necessarily requires a transition to other means of energy production, and so this paper mainly focuses on the feasibility of different renewable energy production options for Aruba, as well as some other changes that could be implemented to increase the efficiency of the Energy sector. As the other main way to reduce fossil fuel dependence is by reducing overall demand for energy, the sections on the Built Environment and Transportation sectors offer actions that will lead to progress in this respect, with a focus on increased efficiency and new low-carbon or low-fuel-consuming technologies.

ENERGY

Aruba relies heavily on fossil fuel imports for all activities in its society, and at a great price. Aruba consumed around 8,000 barrels of oil per day in 2010 (Central Intelligence Agency 2012). Roughly three-quarters of the country's fuel imports are used to generate electricity, nearly 90 percent of which is currently produced by the burning of heavy fuel oil (Langstaff & Gomez 2012). Given that petroleum prices have almost quadrupled over the last decade, it should not be surprising that electricity prices on Aruba are now twice what they were in 2001, averaging about 50 Aruban cents (28 US cents) per kilowatt hour (US Energy Information Administration 2012; Langstaff & Gomez 2012). In fact, an estimated 12 percent of Aruba's annual GDP is spent on fuel imports for electricity generation and transportation alone, with an average price of $100/barrel (Central Intelligence Agency 2012). Devoting this amount of annual GDP to fuel imports is a hindrance to economic growth and prosperity in Aruba.

The only way for Aruba to become less dependent on expensive fossil fuel imports is to significantly ramp up its production of domestically produced, renewable energy. The majority of Aruba's 230 MW total installed capacity is provided by steam turbines. However, renewables are not uncharted territory for the island. For example, the Vader Piet wind farm currently provides roughly 12 percent of Aruba's average power needs. In addition, as shown by Table 1, various public-private partnerships on the island are already planning a total of another 39 MW of installed wind, solar, and waste-based renewable generation capacity, which will bring the share of renewables up to just over 30 percent of Aruba's average current consumption (Langstaff & Gomez 2012). A shift to a higher penetration of renewable energy will also require careful consideration of a wide variety of generation, storage, demand response, and systems control technologies.

While the renewable capacity set to come online in the near future is an excellent starting point, the island will continue to rely heavily on fossil fuel imports for around 70 percent of its electricity needs. As sudden increases in fuel prices can have a devastating impact on both personal purchasing power and national growth potential, continuing to increase renewable energy production beyond just 30 percent of capacity must be made into the highest national priority for Aruba in both the short and the long term.

In order to manage diverse conventional and renewable generation, storage, and demand response technologies, the utility will have to invest in substantial upgrades to the power control systems. By making these "smart grid" investments, the utility should be able to completely shut down the fossil fuel generators for short periods when the wind and solar availability is high and demand is low. No place in the world with a wind/solar-based electrical grid nearly as large as Aruba's has yet been able to achieve these kinds of 100 percent fossil-free "green hours" or "green days". For example, such periods of fossil fuel-free generation might be achieved by running a combination of fixed resources (such as waste-to-energy) plus intermittent wind and solar, with sufficient battery and flywheel storage to cover any sudden drops in production, thereby allowing the fossil fuel generators to be temporarily turned off.

Table 1: Current and Planned Renewable Energy Projects[1]

	Max. Installed Capacity (MW)	%	Avg. Energy (MWh)	%
Aruba Average Load	100 MW*	100%	876,000 MWh	100%
Wind Park Vader Piet	30 MW	30%	105,120 MWh	12.0%
Wind Park Urirama	24 MW	24%	84,100 MWh	9.6%
Waste-to-Energy	5 MW	5%	43,800 MWh	5%
Airport Solar Park	4 MW	4%	7,300 MWh	0.8%
Residential & Commercial	6 MW	6%	10,950 MWh	1.3%
Total Renewables	69 MW	69%	251,270 MWh	28.7%

Source: Langstaff & Gomez, 2012.

[1] Average electricity use, not maximum installed capacity, which currently totals over 230 MW.

Once Aruba has demonstrated its ability to reliably manage this kind of complex system, it will have built the technical foundation for moving to 100 percent fossil-free electricity all of the time. The ability to operate solely with renewable sources without significantly raising costs to consumers will, however, depend on new technologies becoming commercially available. Some of those technologies (e.g., ocean thermal, geothermal) could provide baseload power on a year-round basis while others (e.g., hydrogen from wind, sustainably produced biomass from algae) could provide liquid or gaseous fuels for both baseload and standby power. Because the timing and costs of these new technologies are not predictable at this time, Aruba should monitor its development and position itself to take advantage of them as soon as possible.

Logically the process should proceed in several phases, as more renewables are added to the system. As the level of renewable penetration increases, it will become necessary to consider some institutional and regulatory strengthening. The following sections briefly summarize some of the key considerations that the various stakeholders in Aruba will have to take into account in deciding which pathways to follow in moving toward a fossil-free electricity future.

OPPORTUNITIES AND CHALLENGES

Natural Gas

The Government of Aruba is currently evaluating the potential for shifting to liquefied natural gas (LNG) from the heavy fuel oil currently used for generating electricity. It envisions LNG as a"transitional" fuel, pending availability of new renewable technologies, that would permit reaching the full 100 percent fossil-free goal. It will shortly be sending a term sheet to potential suppliers.

Based on the responses, it will then be in a position to determine whether the conditions of any potential contracts would be advantageous to Aruba in terms of reducing costs while avoiding the risks of getting locked into approaches that would reduce future flexibility. Carbon War Room agrees that natural gas may play a role in providing a solution to the intermittency of renewables, and in providing a alternative fuel option in the transport sector, but beyond this, investment in alternatives to all fossil fuels is the only smart growth pathway option.

Demand Management

In Aruba, the consistent year-round climate means that demand varies more over the course of a day than it does between different days over the course of the year. Lows in demand are in the mornings and late afternoons, as well as late at night, while the highest demand comes at midday. Luckily, in general, solar supply should also be highest during this period of peak demand. In any case, the island has opportunities to optimize its energy generation via "demand-side management", which are practices ensuring that periods of greater demand are mapped onto periods of greater supply in a wind/solar system. For example, Aruba relies totally on desalination for its fresh water, and its newer reverse osmosis desalination[2] equipment could be turned on and off occasionally to lessen the instances when demand must exceed supply. Over the longer term, ice-based air conditioning could be used to smooth demand, while the batteries of electric vehicles could be used as both a discretionary charging option as well as, eventually, a potential source of storage in a smart grid system. Both of these technologies will be discussed in greater depth in later sections.

Such demand-side management initiatives do create additional challenges for the grid operator. In order for WEB Aruba and Elmar to optimize the performance of the various renewable generation opportunities discussed here, **it will be necessary to invest in supporting smart grid and systems control technologies.** The TNO-run Smart Communities Initiative could serve as a pilot for demonstrating the benefits of implementing smart grid practices in a microgrid. This initiative is a sustainable energy neighborhood of 20 homes being designed and built with the cooperation of the government and a wide range of stakeholders to develop knowledge on the sustainable supply of energy.

The Carbon War Room is proposing to assist the Government of Aruba with similar, manageably sized projects, perhaps at the cruise port, the Free Zone, or other commercially oriented facilities. These pilots would give Aruba a diversity of experiences with smart grids and allow for an informed decision to be made about the possibility of an island-wide, smart grid program at some point in the future. A sophisticated smart grid would be required to fully implement demand-side management practices in Aruba.

> No place in the world with a wind/solar-based electrical grid nearly as large as Aruba's has yet been able to achieve these kinds of 100 percent fossil-free "green hours" or "green days"

Plan for Microgrids in the Future

At the residential level, TNO is managing a Smart Communities Initiative that will develop a microgrid for about 20 houses. These communities will test a variety of energy and water conservation technologies, construction techniques, smart metering technologies, and possible demand response options, as well as small wind turbines, rooftop solar, and local energy storage. Pilot projects such as these can provide highly valuable lessons for improving energy efficiency and expanding small on-site power generation across the island, and should demonstrate the potential benefits of closely linking energy efficiency to energy production through microgrids in a distributed energy system.

Microgrids and related technologies will be a viable and important part of Aruba's Smart Growth Pathway. Currently, there is an untapped opportunity for developing a commercial or industrial microgrid pilot project that parallels the Smart Communities Initiative. One option would be to pilot this solution at either the cruise ship port or the cargo port/Free Zone.[3] Another would be to form a group of hotels to pilot the project, but the prospects for on-site energy generation here would probably be less than at the port sites.

The addition of a large number of distributed generation resources, along with added storage capacity and demand response technologies, would place a heavy burden on the utility to simultaneously orchestrate all the parts of the system at all times while maintaining grid reliability and stability (frequency and voltage) on a second-by-second basis. In order to seamlessly integrate the conventional and renewable generation, storage, and demand response devices, the utility will have to quickly begin implementing a sophisticated power control system that can be scaled up as the renewable penetration level increases.

A number of large and specialized smaller energy companies are developing these kinds of smart grid power control systems, but it has to be recognized that the technology is still in its infancy. **In order to move toward 100 percent renewable electricity, Aruba will have to be at the cutting edge of this aspect of smart grid innovations.** The approach to implementation should be experimental and incremental in order to gain the necessary experience and to stay as flexible as possible, as the best ultimate solutions are still unclear. Any contracts with suppliers, therefore, should be structured to put most of the performance risk on the vendor and not on the utility.

Solar power typically requires less than 10 percent of the area needed for comparable wind capacity, and solar panels can be located on rooftops or other structures

Wind and Solar

Aruba has excellent wind and solar resources. Wind speeds are fairly constant over the course of the day on and around the island, which means that wind could, in theory, provide most of Aruba's required baseload power,[4] while Aruba's sunny climate means that solar panels could, in theory, meet most of its daytime peak demand.

In practice, the situation is a bit more complicated. Of the renewable energy production technologies available in the world today, large-scale, on-shore wind is the most cost-effective in the near term for Aruba. However, substantial amounts of open land are required for most wind projects, and open land is something of which the small island of Aruba does not have large expanses. It is possible that the island may already be reaching its limits for on-shore wind developments, between the existing Vader Piet site and the planned Urirama facility. Aruba still needs to determine exactly how much land is available for wind farms, but **initial assessments by this report suggest that Aruba's energy needs will not be met by on-shore wind projects alone**, and so its renewable energy strategy will have to look towards solar and more costly off-shore wind projects.

Although a similar in-depth feasibility study on this option is also required, this report finds that, at present, Aruba likely has only limited potential to deploy off-shore wind. Wind farms using today's technologies need relatively shallow water. Water depths drop off quite sharply fairly close to the Aruban coast, so any off-shore wind would have to be placed close to the shore.

[2] An alternative to energy-intensive multi-stage flash distillation that is widely used throughout the world, RO desalination pressurizes water through special membranes in order to filter salt, large molecules, and other contaminants out of seawater and groundwater in order to produce potable water.
[3] Free Zones are special commercial districts that avoid tariffs and import duties on anything processed in the zone and re-exported or brought into the country from the zone.
[4] Baseload power is the minimum amount of power required to meet ongoing, or constant, demand.

In the future, Aruba may be able to benefit from pilot projects underway to develop floating wind turbines for deeper waters further offshore. For now, assuming that more in-depth assessments confirm that wind options in Aruba are subject to the limitations anticipated here, Aruba's transition to renewable energy will have to rely heavily on solar energy. Solar power does not face the same space or location restrictions as wind power, it typically requires less than 10 percent of the area needed for comparable wind capacity, and it can be located on rooftops or other structures, preventing it from encroaching on other land uses.

Rooftop solar, in particular, offers an excellent opportunity for both households and commercial establishments to save money on their own electric bills and even generate new forms of revenue by feeding back into the grid. With costs for solar power continuing to decline at such a rate that it is becoming competitive with HFO-generated power, the barriers to entry for building owners are low. The Airport Solar Park, for example, is an innovative development that will be both a source of renewable energy and a showcase for Aruba's commitment to sustainability. This 3.3 MW facility, established using a power purchase agreement financing structure, could prove to be a model for future developments.

Consistently Meeting Demand with Renewables

Even with the limitations outlined above, **Aruba is fortunate to have world-class wind and solar resources compared to other regions.** However, it lacks good geothermal, biomass, or hydro-electric resources, limiting the options available to the island for transitioning away from fossil fuels. To oversimplify, this is because renewable energy systems can be one of two types:

- "Firm" sources of generation, such as geothermal, biomass, hydro-electric, or waste-to-energy, which are generally available 24/7 and can be dispatched to meet variations in demand.
- "Intermittent" sources of generation, such as wind and solar, that depend on how strongly the wind is blowing and the sun is shining, and which require other sources of energy to be available on a standby basis to make up for fluctuations in these intermittent sources.

Given its resource dispensation, Aruba will be heavily dependent on intermittent wind and solar sources of renewable energy for the foreseeable future. Correspondingly, increasing Aruba's renewable production capacity will be more complicated than merely increasing its number of wind farms and solar parks. In order to maintain a consistent power supply in an energy system based on intermittent renewables, grid operators have to precisely balance the amount of power being generated against the amount being used, and some form of standby supply must be built into the system. Again simplifying, a system based on intermittent renewables faces essentially three different types of challenges:

- **Very short-term changes in supply or demand (seconds to minutes):** Sudden fluctuations in wind speeds or solar insolation (often due to rapid cloud movements), along with sudden spikes in demand, mean that grid operators must always maintain sufficient and substantial reserve on-line capacity. They can do this by running generators at low loads (i.e., maintaining spinning reserves[5]) or by using short-term storage technologies (e.g., batteries or flywheels[6]) to provide power until either the wind or solar supply increases or back-up generators can be started and brought up to speed.

Aruba is fortunate to have world-class wind and solar resources compared to other regions

[5] Spinning reserve is the capacity still available in a rotating power generator (unused capacity). This available capacity can quickly respond to load variations.
[6] Flywheels are a type of spinning reserve that store rotational energy by running a motor at a very high speed, such as when the renewable source is strong, and then extracting that energy when the renewable source weakens. Currently they are only good for providing larger-scale, short-term energy storage, but R&D is underway for longer-term flywheel storage.

- **Medium-term changes in supply or demand (hours):** Demand also varies over the course of the day, while intermittent renewable supply varies with wind speeds and weather systems. These kinds of fluctuations can be met by firing up peaking generators, though these provide energy at a high price and from a fossil fuel source, commonly diesel or natural gas. Medium-term fluctuations can also be addressed with storage technologies that hold larger amounts of energy, such as flow batteries, pumped hydro-electric storage, thermal storage for concentrating solar power, or compressed air. Flow batteries, in particular, could be suitable for larger, grid-scale projects such as those needed in Aruba, and these technologies are still improving. In general, out of all of these, pumped hydro-electric storage is the most cost-effective if local topology is suitable for it, and a feasibility study is currently being undertaken to determine the possibility of installing pumped hydro-electric storage capacity in Aruba.

- **Longer-term variations in supply or demand (days to weeks):** Wind speeds not only vary over the course of the day, they also vary across different seasons, tapering off considerably during the late summer and early autumn. Solar intensity can undergo similar seasonal variations. The shorter-term storage technologies mentioned above will not be able to ensure that supply cost-effectively meets demand during these periods, and substantial back-up capacity, in the form of a dispatchable power[7] source, is required. Fossil fuel-based "peaking plants" typically provide this. Currently, the only renewable option for longer-term storage is large hydro-electric reservoirs.

Aruba's Near-Term Potential

As Aruba moves towards higher and higher levels of renewable penetration, meeting these three types of challenges will require investment in increasingly large amounts of storage capacity, sophisticated control systems, and back-up sources of energy generation. Aruba's existing steam turbine and reciprocating engine generators will be capable of back-stopping, or supplementing, their renewables for the short-term supply disruptions discussed above. But the longer-term storage technologies that would allow Aruba to run on renewable energy sources 100 percent of the time are still in only the early stages of development and commercialization. As these new storage technologies evolve and their related costs decrease, they should be reconsidered for integration into Aruba's power generation system.

For the moment, increasing renewables in Aruba will require the continued use of generators, along with some new storage technologies and advanced systems controls. The necessity of taking an incremental approach to the renewable transition in Aruba should in no way be seen as a suboptimal outcome—merely being able to "turn off" fossil fuel use in a system the size of Aruba's for any small amount of time will be a huge achievement.

This is because, to move from the 80 percent threshold to a 100 percent renewable system, renewables will have to replace even the dispatchable generation serving to back-stop the system during medium- and long-term supply fluctuations. To maintain a constant energy supply in that scenario, it becomes necessary to greatly overbuild renewable generation and storage capacity in order to meet demand in periods of unusually low inputs, and much energy will consequently be wasted during periods of higher inputs.

An incremental approach should in no way be seen as a suboptimal outcome—merely being able to "turn off" fossil fuel use in a system the size of Aruba's for any small amount of time will be a huge achievement

[7] Dispatchable power is generating capacity that can be turned on and off on relatively short notice (e.g., in contrast to nuclear or steam plants that take hours or days to come up to speed).

Based on a preliminary model using HOMER software, the Carbon War Room has identified the general direction that Aruba should follow in adding significant increments of renewable energy to the levels already planned. The model takes into account the interdependencies among multiple generating and storage technologies and allows for estimates of the least-cost combinations and the returns on investment in them. In order to perform the analysis, it was necessary to make many simplifying assumptions. The most important assumptions are: (1) that only currently available technologies are used and their costs do not change over the period of the calculations; (2) that biofuels are not used as substitutes for fossil fuels for the back-up reciprocating engines. The projections should be regarded as preliminary and "directional" rather than definitive. The Carbon War Room will provide more definitive projections as soon as the necessary information becomes available.

With caveats as to the preliminary nature of the results, the model suggests that electricity generation costs (i.e., exclusive of transmission and distribution costs) decline slowly but fairly steadily up to a penetration level of about 40 percent. Costs increase slightly between 40 percent and 80 percent, at which point generation costs are roughly equal to current costs. Beyond 80 percent, costs rise, but the Carbon War Room and Aruba will be continually assessing newer, more cost-efficient technologies as these become available.

The most likely actions for reaching this 80 percent threshold, as well as some future possibilities for surpassing it, are considered in more detail in the following section, which gives an overview of the process of scaling renewable energy in Aruba.


ISLAND PRINCESS
HAMILTON

THE PATH TO 100% RENEWABLES

As outlined above, Aruba is fortunate to have world-class wind and solar resources, but does not have good geothermal, biomass, or hydro resources. As a result, for the foreseeable future, Aruba will depend heavily on intermittent wind and solar as the foundation of its renewable energy mix. This means that as the island moves to higher and higher levels of renewable penetration, it will have to invest in increasingly large amounts of storage capacity and sophisticated control systems to manage its intermittent wind, solar, and storage technologies. For illustrative purposes, this paper divides the pathway to complete fossil fuel independence into several phases.

Phase 1: Low Renewable Penetration

Aruba has already achieved a low level of renewable penetration with its existing 30 MW Vader Piet wind farm and its 3.3 MW Airport Solar Park slated to go come online in 2013. This level of penetration, which amounts to roughly 12 percent of Aruba's current average consumption, has required only minimal changes in grid operations but has added volatility to the energy supply because the renewable projects are all based on intermittent sources (wind and solar). Also, because the current renewable projects do not include any storage, all the spinning reserves and peaking capacity are provided by existing fossil fuel generators, which use expensive heavy fuel oil, run inefficiently at low loads, and are slow to come up to speed (up to 15 minutes) from a cold start.

Figure 2 illustrates the current situation and shows that, with the current energy mix, there will never be periods when the fossil fuel generators could be shut off if supply is to remain consistent.

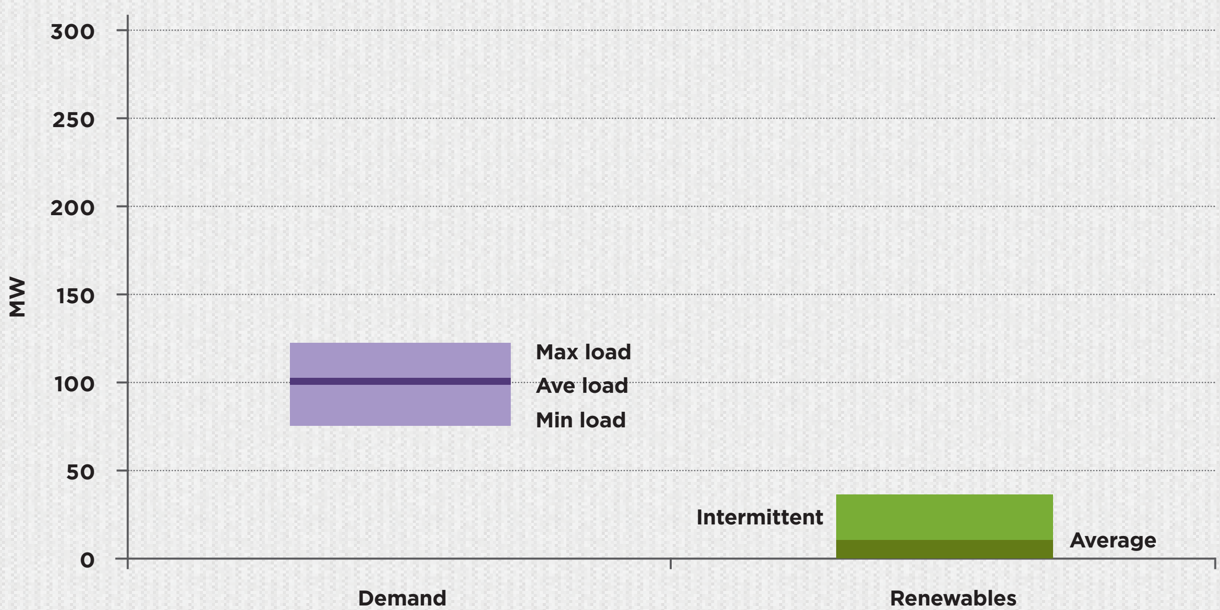
Phase 2: Medium Renewable Penetration

Aruba has identified approximately 40 MW of potential existing and under-development renewable capacity in addition to the that covered in Phase 1. This includes another 24 MW of wind at the planned Urirama facility, 5 MW of waste-to-energy (WTE) capacity, and 6 MW of additional solar projects, all of which could be online by 2016.

The total, 69 MW, of existing, under-development, and planned renewable capacity would represent roughly a 29 percent penetration level, given wind/solar intermittency. Though the WTE plant would provide a small base of firm supply, the overall renewable mix would still be from intermittent sources.

Preliminary analysis indicates that it would be cost-effective for Aruba to add around 20 MW of storage into its renewables plan for the next three years, consisting of 15 MW worth of flywheel-based storage that would provide some grid stability for short- and medium-term intermittency, and 6 MW (10 MWh) of flow batteries that would supplant inefficient diesel generators providing spinning reserves.

Figure 2: Low Renewable Penetration



Source: HOMER Energy, 2013.

Figure 3 illustrates that the planned 40 MW of additional renewable power gives Aruba enough capacity to make it possible that, for at least a few hours of the year, the amount of peak renewable supply might exceed demand. The possibility is slim, since solar generation would be "off" at night, when demand is usually at a minimum, but it would be a huge accomplishment to be able to turn off the fossil fuel generators completely in a system the size of Aruba's even for a few hours. **This paper finds that, thus far, no wind/solar system of comparable size and complexity has ever even come close to running with conventional generators totally off.** In order to hit such a milestone by 2016, the water and power utility WEB Aruba and the power distribution company Elmar would have to invest in more sophisticated power controls than Aruba currently has, but it would be a worldwide achievement to demonstrate any such truly "green hours" or "green days".

The first-phase additions of wind (Vader Piet) and solar (Airport) can be incorporated into the grid without having to rely on smart grid power controls or changes in organizational or policies. These first two projects have been structured as private power projects selling electricity to WEB and Elmar under power purchase agreements (PPAs). As the level of penetration increases, however, it will become more difficult to integrate substantially more private power projects into the grid under these types of relatively simple PPAs.

The difficulty arises largely because the utility and the private operators of intermittent wind and solar projects will find their interests diverging as more and more intermittent power (or fossil fuel generation) has to be curtailed during periods of high wind and insolation. As a result, there will be increasing pressures to consolidate the operation under a single entity that can balance the competing interests of baseload/dispatchable versus intermittent power without having to resort to highly complex contract arrangements. **Once the grid reaches a sufficiently high level of penetration, it would probably make sense to consolidate ownership in either a government-owned utility or in a fully privatized one.** There are sound arguments for either alternative, but if responsibility for providing the service were turned over to a private provider, it would be necessary to develop a strong regulatory regime to ensure that the public interest is protected.

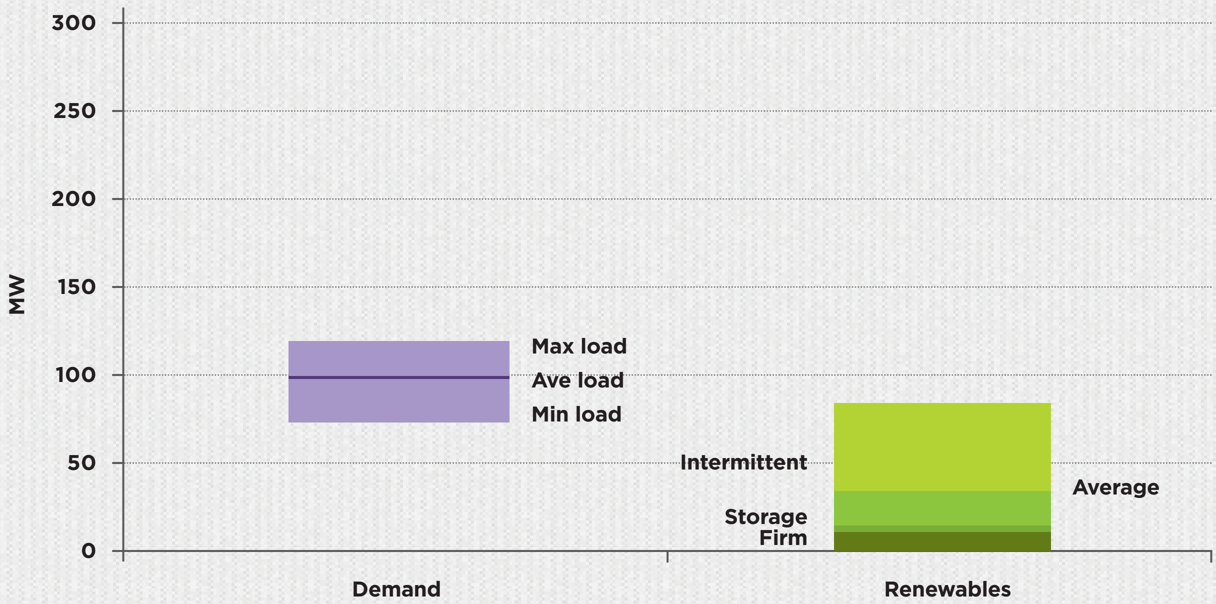
Phase 3: High Renewable Penetration

As mentioned earlier, **our preliminary analysis indicates that it should be possible to achieve around 80 percent renewable penetration (based on actual energy use) while keeping power costs at or below current levels.** Increasing renewable capacity up to this level would dramatically reduce Aruba's vulnerability to fossil fuel supply disruptions and price fluctuations. In order to realize this ambitious goal, Aruba will have to add another 30 MW of on-shore wind, which is the most cost-effective renewable source. It also assumes that 50 MW of off-shore wind can be built, along with 180 MW of solar and 5 MW of WTE sources, to reach a total of 265 MW of additional capacity over and above the 75 MW already discussed. Finally, around 160 MW of various storage technologies (totaling 200 MWh of energy in storage) would need to be added to meet the 80 percent threshold, which could be accomplished cost-effectively. Though this is a massive undertaking, it could be accomplished by the end of the decade.

Figure 4 illustrates the aforementioned constraint holding Aruba to the 80 percent penetration threshold—the fact is that Aruba will necessarily be overwhelmingly reliant on intermittent wind and solar sources of energy, and so it must substantially overbuild its capacity in order to provide power during low wind and solar periods. Were fossil fuel elimination Aruba's sole objective, it would be possible to simply substitute biofuels for the fossil fuels used by the steam turbines and reciprocating engines that are required to support the wind/solar system. However, from a holistic perspective, many biofuels have a significant carbon footprint in their own right, and as they would have to be imported just like fossil fuels, they would not reduce Aruba's vulnerability to price and supply disruptions.

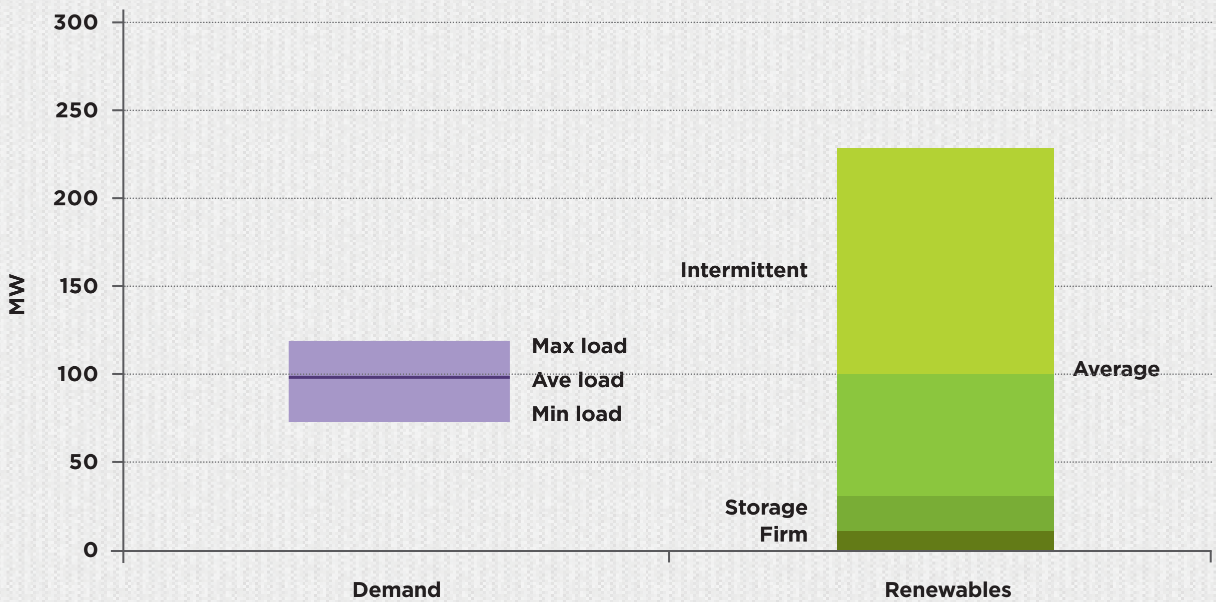
> Through discussions and information-gathering work on-island, it will be possible to expand, refine, and select the most promising projects

Figure 3: Medium Renewable Penetration



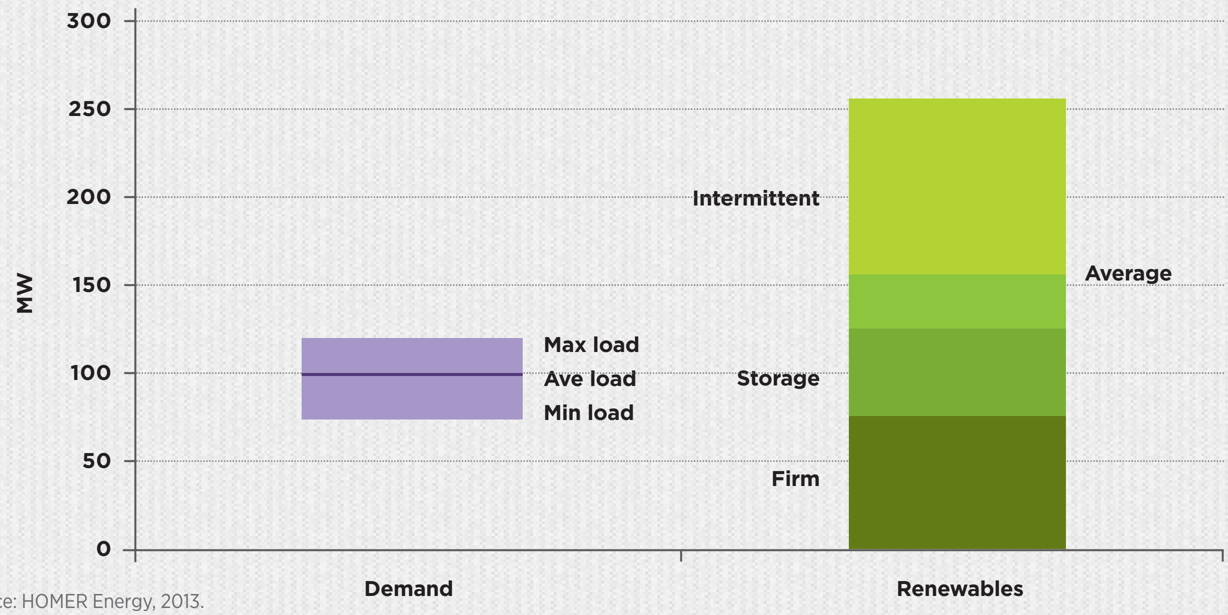
Source: HOMER Energy, 2013.

Figure 4: High Renewable Penetration



Source: HOMER Energy, 2013.

Figure 5: 100% Renewable Energy



Source: HOMER Energy, 2013.

Phase 4: 100% Fossil Fuel-Free Energy

For Aruba to be able to rely on renewable energy sources for 100 percent of its generation capacity, it would be necessary for the island to have a much higher capacity of firm renewable sources, as well as sufficient storage to meet annual peak demand. Given both the limitations of existing technologies and the island's renewable resources base, at present it is simply not possible for Aruba to meet energy demand using only with renewable energy. Over time, new "firm" renewables technologies are likely to become available that would provide power 24/7, such as Ocean Thermal Energy Conversion (OTEC) and deep-well geothermal energy, as well as technologies that could locally and sustainably generate either gas fuels (wind-to-hydrogen) or liquid biofuels (algae) to allow conventional generators to be used for back-up power (see the section on Advanced Energy Technologies).

Figure 5 illustrates the levels of firm renewable power and storage capacity that would be required for Aruba to one day meet its energy needs entirely using renewables.

The four scenarios above assume that demand remains constant over the entire period. However, it is possible that demand could significantly increase in coming years due to likely changes in Aruba, such as providing more shore power to cruise ships or requiring charging power for electric vehicles. On the other hand, Aruba has many options for improving its energy efficiency, thereby reducing demand. Some options for demand management have been discussed already in this paper, while other options for improving the efficiency of energy use will be discussed in later sections.

NEXT STEPS

In order to increase the likelihood of success, key research questions that assess the relative viability and priority of the various energy production options discussed thus far in this paper will need to be considered.

Does Aruba have sufficient land resources for renewables? Although this paper has found that an 80 percent level of renewable penetration is likely to be the optimal level for Aruba to cost-effectively obtain in the short term, under current economic and technical feasibility, and largely achieved through wind and solar resources, it is still unclear whether reaching this level is practically feasible. Again, much of the capacity required to reach that 80 percent threshold will depend on the availability of land for on-shore solar and wind power generation, and more research is required to determine whether or not using available lands will prove feasible.

Should biofuels be part of the solution? The ability to use biofuels as an interim measure or stepping stone on the path to true sustainability faces logistical, technical, and financial challenges in Aruba. These issues need to be explored with potential suppliers in order to understand whether displacing fossil fuels with biofuels would be environmentally sustainable at all, and whether it would make economic sense for Aruba. Exploring these issues may present opportunities to utilize existing local skills and land availability for refining purposes.

What are the specific steps in the transition to renewable energy production? Moving forward, the technical team will need to hold stakeholder meetings that systematically evaluate the anticipated impact and feasibility of a variety of specific projects and compare those projects to one another. Through discussions and information-gathering work on-island, it will be possible to expand, refine, and select the most promising projects for implementing Aruba's transition away from fossil fuels and to determine the best sequence for doing so.

BUILT ENVIRONMENT

Currently, Aruba experiences relatively high per capita electricity use, with an annual average of around 8,000 kWh used per person in recent years (Central Intelligence Agency 2012). As a comparison, the United States average was just over 12,000 kWh per person in 2010, but the State of California, which has implemented substantial energy savings initiatives, averaged less than 7,000 kWh per person that year (California Energy Commission 2010). In Aruba, residential areas account for about 40 percent of all electricity consumption, followed by hotels and resorts, which use 25–30 percent (Langstaff & Gomez 2012). Desalination activities account for another large portion of usage, while commerce and industry accounts for most of the rest. Household energy use accounts for 34 percent, small business 29 percent, and large business 35 percent. The remaining 2 percent is used for street lighting and social entities (schools, churches, etc.).

While renewable energy production strategies make the energy supply more sustainable, reducing the demand for energy is equally important to the goals of saving money and mitigating environmental concerns. "Energy efficiency" involves both maximizing the efficiency of existing energy use and encouraging changes in behavior that reduce consumption. Given that electricity (including desalination) accounts for about three-quarters of Aruba's total energy consumption, improving the efficiency of its electricity usage should be a major focus of the country's efforts to reduce fossil fuel use in coming years (Langstaff & Gomez 2012).

Currently available proven technologies and practices could allow Aruba to further increase its energy efficiency and reduce waste. Lights left on in empty rooms and air conditioners chilling empty buildings do nothing to improve living standards, and other technologies exist that can help to ensure all structures and appliances are utilized in the most efficient manner possible. Both Aruba's electricity generation and distribution utilities, WEB and ELMAR respectively, have promoted energy efficiency campaigns. Such programs should be examined to see how they might be expanded to achieve even greater gains in this area.

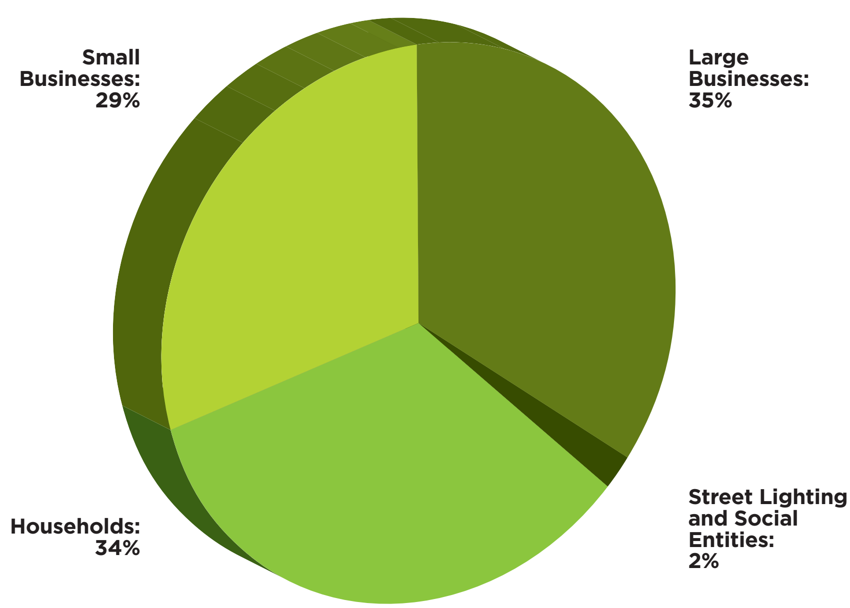
OPPORTUNITIES AND CHALLENGES

Demand Projections

Future demand projections for Aruba are subject to considerable uncertainty. On the one hand, there are several possible developments that could significantly increase demand in coming years, though the positive benefits of these initiatives outweigh the simple negative of increased electricity usage. For example, the addition of electric vehicles (EVs) to the Aruban vehicle fleet would entail a substantial increase in electricity demand for battery charging—25 percent penetration of EVs on the island would create an additional estimated peak demand of around 37 MW. But smart grid technologies could ensure that most of this charging occurs during non-peak periods, so investment in EVs would not significantly increase peak capacity requirements as long as certain smart grid investments are made in parallel. The potential benefits and challenges of EVs are discussed in more depth in the section on the Transportation sector.

The "green port" initiative is another example of increased demand with positive benefits from within the Built Environment sector. This initiative could provide shore power for at least two of Aruba's five cruise ship berths, thereby enabling them to shut down their much more environmentally damaging diesel engines when in port. Each ship would require roughly 7–10 MW of capacity to connect, and it would add that demand during the day when overall power demands are at the highest, complicating the task of daily demand management in a system based on intermittent renewables (Alphonso Boekhoudt, Port Director 2012). However, the peak demand period of cruise ships would occur largely from November through April, when electricity demand overall is lowest, and when wind resources are greatest, which adds to the feasibility of this project.

On the other hand, **TNO's Sustainable Aruba working group estimates that existing efficiency measures will achieve a 25 percent decrease in electricity consumption between now and 2020.** Regardless of these projections, there are several purposeful steps Aruba can take to increase the efficiency of its building stock, greatly reducing costs and increasing the prospects for renewable energy to meet demand.



Improving Efficiency

Around the world, improving the energy efficiency of buildings is consistently identified as one of the best opportunities for profitably reducing humanity's dependence on fossil fuels. Many interventions into the energy efficiency of the Built Environment save much more money in fuel and energy costs than they cost to purchase and install. Employing proven energy efficiency technologies, not only in the design of new buildings but also in the retrofit of existing buildings, is a cost-effective, job-creating, and profitable way to achieve immediate and substantial reductions in energy use.

The Carbon War Room has found that, on average around the world, every US dollar spent on energy efficiency can return $3 in energy savings. With some commercial building operators currently spending 30 percent of their budget on their energy bill, and fossil fuel prices continuing to rise, Aruba will benefit greatly from investing in new technologies and other upgrades to its Built Environment.

Energy efficiency is also a lucrative growth market, not only for companies with energy efficiency products and services, but also for the finance industry and for building owners themselves.

Aruba's move towards greater reliance on renewable energy can create a significant number of jobs, whether in the production of energy itself or in the retrofitting of the existing building infrastructure to accommodate renewable energy systems and the installation of energy efficiency and conservation measures and systems. The job-generating capacity of renewable energy is well documented by several sources, including in a recent working paper by the International Renewable Energy Agency (IRENA), "Renewable Energy Jobs: Status, Prospects & Policies". In addition, as Aruba progresses in its efforts to transition off fossil fuels, it will serve as a model for other island nations. Along with the Carbon War Room, Aruba and its renewable energy professionals will be able to "export" the knowledge and lessons gained in Aruba to the other islands envisioned in the UN's Ten Island Challenge, which was issued to, and accepted by, the Carbon War Room in 2012 at the UN Rio+20 Summit. In addition, Aruba hopes to attract visitors seeking to witness first hand Aruba's accomplishments, and the island will continue to host its annual Green Energy Conference and related activities. All of this direct and indirect job-creating activity is consistent with the goal of the Government of Aruba to promote a new knowledge-based pillar of the economy.

The Government of Aruba can play an important role in driving improvements in the Built Environment sector, assuming some of the financial risk associated with implementation time frames and performance, and creating the proper political climate. The following approaches present Aruba with an opportunity they should pursue to improve the energy efficiency of its Built Environment.

The Carbon War Room has found that, on average around the world, every US dollar spent on energy efficiency can return $3 in energy savings

Target Air Conditioning

As shown in Table 2 below, air conditioning is responsible for about 55 percent of household and hotel/resort electricity use, making it the largest consumer of electricity in most buildings. Targeting air conditioning by investing in new and more advanced technologies therefore represents a significant opportunity for carbon reduction.

Table 2: Distribution of Residential and Commercial Electricity Use

Source of Household Electricity Use	% of Electricity Use
Air Conditioning	55%
Lighting	11%
Electronics	9%
Refrigeration	8%
Washers & Dryers	8%
Other	9%

Source: Alfred Rafine of Utilities Aruba NV, 2012

At least two proven technologies are particularly well suited for adoption in Aruba. First, seawater-based air conditioning (SWAC) is an option for hotels or other closely connected areas of sufficient size to warrant district cooling systems.[8] SWAC systems use the naturally cold temperatures of the deeper strata of the ocean as heat sinks, performing along much the same principles of heat exchange as a conventional air conditioner. However, **not only does SWAC technology substitute seawater for the ozone-depleting refrigerants found in conventional air conditioners, it uses 90 percent less energy** for the cooling process.

This makes the systems cost-effective, particularly given that hotels currently spend a major fraction of the 10–12 percent of their gross revenue that goes to utility costs on running air conditioners nearly year round in the Caribbean (Ecopower International Capital Cooling 2012; Langstaff & Gomez 2012). Developers are currently exploring the possibility of installing a SWAC system for a group of hotels on the northern part of the island, and this project could also serve as a pilot for other such SWAC-based district cooling systems on Aruba.

Ice-based air conditioning is another technology that could affordably reduce current electricity demand on Aruba, and it has the added potential to provide grid stabilization benefits. Ice-based cooling systems typically produce ice during the night when electricity demand is low and then use it in lieu of energy-intensive, refrigerant-based compressors for cooling during the day when demand (and temperatures) are higher.

Using ice-based air conditioning to ameliorate some of the fluctuations inherent to intermittent renewable energy sources requires only a relatively simple alteration to its operations. Instead of making ice at night and powering air conditioners in the afternoon, these systems would need to be programmed to make ice when there is more renewable power than the system could handle and stop making ice in moments when the renewable power decreased suddenly. For example, the system might make ice in the afternoon when the sun is shining strongly and generating larger amounts of energy, but it might stop when a storm rolls through. Hotels and larger government buildings are prime candidates for switching to ice-based air conditioning. Household air conditioners could eventually also be upgraded to this technology.

Change the Way Water is Processed, Heated, and Used

Alongside air conditioning, water heating and desalination processes are major sources of electricity demand in Aruba. And as with air conditioning, Aruba has many promising options for reducing the amount of electricity demanded by the required daily processes of heating or treating water. Conversion to Seawater Reverse Osmosis (SWRO) desalination[9] is already under way on the island and should be pursued to the furthest extent possible. Since electricity is used by the desalination process that produces all of the island's fresh water, programs should also be developed to promote investments in simple and quick-payback water-saving fixtures, such as low-flow shower heads, faucet aerators, or low-flow toilets.

For some water uses, gray water recycling and water capture practices, discussed in greater detail in the Agriculture section of this paper, offer low-energy alternatives to desalinated water. Certain hotels have already begun to use recycled gray water for watering and irrigating landscapes, and methods for replicating such practices in communities and residential areas should be explored. Aruba could also develop an island-wide program to promote the installation of solar hot water heaters by households and hotels. Solar water heaters are among the most cost-effective renewable energy investment opportunities and could drastically reduce a major source of electricity demand.

Encourage Short-Term Efficiency Upgrades

A wide variety of technologies are applicable in Aruba that could increase the efficiency of the Built Environment without requiring any expensive or difficult feats of construction or engineering. Among these so-called "plug and play" energy efficiency options, homeowners and commercial real estate owners could invest in the following:

- Replacing incandescent light bulbs with compact fluorescent (CFL) bulbs or LED lights, which are more expensive upfront but also last much longer
- Upgrading to more efficient conventional air conditioning units
- Installing electric timers on pool pumps
- Adding room occupancy sensors that automatically switch off heating, ventilation, and air conditioning units when rooms are empty
- Converting to higher-efficiency motors for pumps and air handling units
- Basic improvements in insulation.

Moving forward, Aruba should keep building on the methods that are already in place and develop new methods for financially incentivizing efficiency investments in order to promote the widespread adoption of these and other similar technologies.

To advance uptake for commercial real estate, the government should also provide relevant information to selected business leaders on specific project examples, e.g., upgrading air conditioning units or converting lighting systems to LEDs.

Facilitate Medium-Term Efficiency Improvements

Over the medium term, Aruba also has significant opportunities for improving the energy efficiency of its buildings. Properly insulating and sealing buildings to help prevent leakage of heated or cooled air greatly lowers the electricity required to maintain comfortable indoor temperatures. Further savings can be achieved by installing more efficient large appliances, as well as more advanced equipment for managing household/building utilities, such as "smart" thermostats. These options can be retrofitted into existing buildings, and some exploration of undertaking them in Aruba is already underway.

These options and more are also relevant to new construction. **Based on current figures, Aruba will gain more than 12,000 new residents by 2020,** and this growth will create significant demand for new housing units (Central Intelligence Agency 2012). Therefore, instituting energy efficiency standards for new buildings on the island is imperative. Smart building design for new units and the retrofitting of existing buildings will also create new local jobs.

[8] District cooling is the counterpart to district heating, which involves linking a series of users together to achieve economies of scale.
[9] SWRO desalination is a process for generating potable water from the sea, with low energy requirements.

THE TOURISM INDUSTRY

As the largest source of economic activity in Aruba, the tourism industry is a particularly important focus for energy efficiency efforts. **Almost three-quarters of Aruba's gross national product is earned through tourism or tourism-related activities, drawing in almost 900,000 visitors to the island annually** (Aruba Tourism Authority 2012).

As the centerpiece of Aruba's economy, integrating sustainability efforts across the tourism industry will be vital to the country's aim of transitioning off fossil fuels. Furthermore, by demonstrating its far-reaching commitment to sustainability, the tourism industry in Aruba can differentiate itself from its island neighbors while insulating the island's economy from price fluctuations in the cost of imported fuels.

Tourism and Energy Use

There are a number of ways that the tourism industry in Aruba can reduce its energy use while also providing positive returns on investment. Determining the dollar amount saved will require energy audits to establish a baseline level of performance from which to measure, monitor, and manage change for individual businesses. The following specific energy efficiency and water savings plans will help to inform future strategies:

- Conduct energy audits, including property and utility data analyses, to determine the characteristics of the energy systems and patterns of energy use; establish baselines for property energy use to develop best-case models of existing energy use and operating conditions; evaluate energy-saving measures; and list energy conservation measures, alternative energy solutions, etc.

- Retro-commission the mechanical systems in hotels and other tourism-related facilities to ensure that they are running properly and not wasting energy. Caribbean hotels of 200 or more rooms that retro-commission and switch to energy efficient measures save approximately 30 percent of their electricity (Duffy-Mayers 2011).

- Transition to SWAC or ice-based cooling systems, reducing the largest source of energy consumption.

- Use key cards in guest rooms to activate heating, ventilation, air conditioning (HVAC), and lighting. This prevents these systems being left on when guests are not in the room and saves energy without compromising guests' comfort. Switching to key cards can lead to 45 percent savings in energy expenses (Hotel Online 2012).

- Switch from traditional incandescent light bulbs to Compact Fluorescent Lamps (CFLs) or Light Emitting Diode (LED) light bulbs in both non-guest and guest rooms. This can reduce overall lighting expenditure by up to 35 percent. CFLs also last longer than traditional light bulbs, minimizing the number of bulbs a property needs to purchase (Hotel Online 2012).

- Decrease demand for more energy-intensive desalinated water by installing water-conserving hardware in showers, faucets, toilets, etc., recycle gray water, and harvest rainwater for laundry/irrigation.

Aruba should also consider encouraging the development and implementation of Global Sustainable Tourism Council-aligned hotel and tour operator standards, using a certification program featuring incentives and benefits from the Aruba Tourism Authority.

Current Aruba Tourism Authority/Aruba Hotel & Tourism Association Energy Programs

Green Globe is the worldwide benchmarking, certification and performance improvement system that assists the travel and tourism industry to attain sustainability and respond to the major environmental problems facing the planet, including climate change, waste reduction and non-renewable resource management.

Areas covered in the Green Globe 21 certification process are corporate social responsibility, conservation, and environment and energy (reuse, reduce and recycle).

Of the 57 Green Globe-certified hotels in the Caribbean area, seven are in Aruba. Aruba has successfully completed Phase One in the process of having Arashi, Mangel Halto and Baby Beaches become Blue Flag certified, an international certification program of eco labor that upholds quality standards in four main areas:

- Water quality

- Safety, services and facilities

- Environmental education and information

- Environmental management.

Tourism and Energy Production

The tourism industry can also be a significant driver of change in the transition towards renewable energy. The following are additional steps that should be incentivized and closely fostered through collaboration between the government and the tourism industry:

- Install solar panels on hotels and resorts (such as the project at the Aruba Hyatt) to serve some of the power needs, allowing them to contribute directly to the goal of transitioning from fossil fuels to renewable energy sources.
- Promote sector-wide purchasing of renewable energy from clean energy sources, including exploring long-term power purchase agreements.
- Install ice-based air conditioning systems that can serve a load balancing function as the island scales up its use of wind and solar resources.
- Create opportunities to contribute to waste-to-energy production though waste streams.

NEXT STEPS

In order to increase the likelihood of success, key research questions assessing the relative viability and priority of the options discussed thus far in this paper for making Aruba's Built Environment sector and tourism industry more sustainable will need to be considered.

Which Strategies Are Most Appropriate?

Effective implementation of strategies to reduce energy use will rely on a wide variety of actors, some of whom might be resistant to participating and may require additional information or incentivization. For instance, it may be difficult to encourage household consumers to make energy efficiency investments given the relatively high upfront costs of such technologies.

Commercial actors may require evidence of the longer-term contributions to their bottom lines that they can hope to achieve by adopting energy efficiency strategies. Therefore, campaigns to encourage efficiency will have to be tailored to specific groups (such as those already started by Elmar, WEB, and Utilities NV). The government can continue to take the lead on modeling the importance of adopting efficiency-enhancing measures at a broader level through initiatives like the LED street lighting program. It can also encourage or support more advance pilot projects, such as for microgrids.

What Information Is Needed to Move Forward?

As with energy production, the systematic gathering and analysis of information will need to be undertaken to assess the relative costs and viabilities of individual strategies for increasing energy efficiency. Again, stakeholder meetings, other on-island information gathering, and consultations with organizations like TNO and the developers exploring SWAC conversion with some hotels should all serve to generate better knowledge of factors such as the relative financial costs and benefits, scale of activity, technical viability, capacity of local supplier, and likelihood of adoption for any given strategy.

Commercial actors may require evidence of the longer-term contributions to their bottom lines that they can hope to achieve by adopting energy efficiency strategies

TRANSPORTATION

Reducing overall emissions and fuel consumption levels will require Aruba to address the fuel use of its transportation system, which accounts for roughly a quarter of its fossil fuel imports (Langstaff & Gomez, 2012). However, transitioning to electric vehicles, the primary approach available to Aruba for doing so, poses significant challenges of cost, consumer choice, and the technical issues associated with the increase in electrical demand. Overcoming these impediments would require significant government action. With these challenges come opportunities—**significant penetration of EVs, at levels of 25–50 percent or more, could serve a valuable load-balancing function** and could strengthen Aruba's ability to transition its energy generation systems towards renewable sources. **Load balancing** refers to the use of various techniques by electrical power companies to store excess electrical power during low-demand periods for release as demand rises. The storing of energy in the batteries of EVs at night (lower power-demand period) for release during the day is one example.

Private car ownership is high on the island, but it seems to have peaked and leveled off at around 50,000 vehicles, or one car for every two inhabitants

Within this action area, the Carbon War Room seeks to provide information that will inform future efforts to examine the potential for effecting change within this important sector, and to offer several immediate steps to improve the efficiency of the current vehicle stock.

Composition of Aruba's Vehicle Fleet

A broad breakdown of the existing vehicles on the road in Aruba based on government statistics finds that the vast majority of vehicles on the island are privately owned passenger cars. Therefore, near-term efforts must focus on either a transition to EVs or on retrofitting for natural gas. Future efforts could also focus on increasing availability of public transportation options and better urban planning (discussed in later sections).

Table 3: Vehicles Registered in Aruba by Type

Vehicle Type	Number of Vehicles (2011)
Passenger Cars	49,984
Irregular Transportation Cars	149
Trucks	901
Buses	116
Tour Buses	173
Taxis	373
Rental	3,620
Government Vehicles	448
Other Cars	23
Motorcycles (Incl. Mopeds)	1,791

Source: Central Bureau of Statistics, 2011.

As shown in Table 3, private car ownership is high on the island, but it seems to have peaked and leveled off at around 50,000 vehicles—one for every two inhabitants. Of these, approximately 45,000 run on gasoline and 5,000 on diesel. There are currently five electric cars and two hybrids on the island (Langstaff & Gomez 2012).

Beyond these broad figures providing a breakdown on vehicle type, very little data is available on the composition of the vehicle fleet, including the ages and conditions of the vehicles.

Vehicle-Use Rates

Although specific figures on vehicle annual mileage in Aruba were not available at the time of writing, there are ways of approximating this information. For example, it is possible to estimate average per capita vehicle miles traveled (VMT) by analyzing the key centers of population and employment. Over half (58 percent) of the population lives within the four residential districts of Noord (20 percent), Oranjestad East (14 percent), Oranjestad West (13 percent) and Paradera (11 percent). This puts them all within 6.2 miles of the three main employment destinations: Eagle/Paardenbaai (25 percent of trips), Palm Beach/Malmok (12 percent) and Main Street Oranjestad (10 percent) (Central Bureau of Statistics 2012). These locations are illustrated in Figure 6.

Based on this information, the majority of people have a daily commute of 12.5 miles or less, and probably much less in many cases. The longest trip possible on the island is approximately 21 miles. The Carbon War Room estimates an average vehicle use of 5,000 miles per year.

Figure 6: Map of Aruba Showing Key Population and Employment Centers

Fuel Use and Emissions

Total daily consumption of gasoline and diesel fuel on Aruba in 2011 is 1,284 and 533 barrels respectively (Langstaff & Gomez 2012). Using this information and data received from the Aruban government, US Bureau of Transportation Statistics figures for vehicle mpg, and reasoned assumptions for daily VMT, the Carbon War Room has developed a bottom-up model to estimate the energy consumption of the Transportation sector based on available data and cross-referenced against these consumption totals. This model also takes into account the commuting patterns discussed above.

The only significant change made to the base data was to modify the fuel consumption (mpg) figures of US vehicles by dropping the mpg by 30 percent in order to account for the fact that, given the small size of Aruba, the average vehicle will spend little or no time in "highway driving". It also assumes that the use of air conditioning will be higher than the US average, and that this will contribute to a small loss of efficiency.

Table 4: Vehicle Fuel Use in Aruba and Related GHG Emissions

Vehicle Type	Number of Vehicles	MPG (US Gallons)	Fuel Type	Average Daily VMT	US Gallons Per Vehicle Per Day	Total Gallons Per Day	GHG Emissions: Tons CO_2e/day
Passenger Cars – Sedan	24,991	16.66	Gasoline	12.5	0.75	18,751	193.96
Passenger Cars – Light Truck	17,493	12.18	Gasoline	12.5	1.03	17,952	185.70
Passenger Cars – Light Truck (Diesel)	4,806	17.4	Diesel	12.5	0.72	3,453	41.54
Trucks	901	5.18	Diesel	70	13.51	12,176	146.49
Buses	116	4.8	Diesel	120	25.21	2,924	35.18
Tour Buses	173	4.8	Diesel	50	10.50	1,817	21.86
Taxis	373	14.42	Gasoline	120	8.32	3,104	32.11
Rental	3,620	19.25	Gasoline	30	1.56	5,642	58.36
Government Vehicles	448	19.25	Gasoline	20	1.04	465	4.81
Motorcycles (Incl. Mopeds)	1,791	30.2	Gasoline	12.5	0.41	740	7.66

Comparing the actual figures for daily fuel consumption to those estimated by Table 4 suggests that, although these figures require verification, they are likely accurate enough to make broad predictions about the emissions savings that could be achieved by various fuel-saving measures for the different vehicle types.

Based on this initial assessment of the vehicle fleet, including these estimates of annual miles driven and these extrapolations on both fuel use and emissions, passenger cars are clearly the obvious target for strategies looking to create a more sustainable transportation system in Aruba. Passenger cars represent by far the most vehicles on the road in Aruba and account for the majority of emissions.

Heavy vehicles like trucks, buses, and tour buses merit attention as well because of their relatively high per vehicle fuel use, which also makes them significant contributors to the country's estimated emissions. But data on the duty cycles, vehicle models, engine sizes, and engine efficiencies of the commercial and heavy-duty fleet are still quite limited, so this segment of vehicles will require further analysis as data become available.

CHALLENGES AND OPPORTUNITIES

Although current estimates suggest that vehicle use on Aruba is relatively low in terms of daily mileage, there are opportunities to avoid growth in the number of miles traveled and even to reduce current vehicle use, as well as to reduce emissions by shifting to more sustainable transport modes and by improvements in the efficiency of vehicles.

Unfortunately, few of these approaches could be implemented in the near term or have major impact. In the near term, the most promising approaches will revolve around car sharing, and policies requiring higher vehicle efficiency for new cars on the road. Other approaches will require more long-term planning—shifts to electric vehicles and additional public transportation.

Shift to Sustainable Transport Modes

Efforts to improve the experience of bus passengers through fleet upgrades and the creation of dedicated, fast-moving bus lanes could potentially increase the appeal of using this mode of public transportation—which has much lower per capita fuel use than personal cars. Other public programs could promote the use of bicycles or walking for shorter trips, but this would require long-term shifts in urban planning.

Reduce Vehicle Use

Encouraging mass transit will certainly reduce the use of personal vehicles, but not necessarily the numbers of miles traveled. In the short term, Aruba can promote things like car sharing among households and trip pooling among neighbors or co-workers, However, over the long term, land-use planning could have the ability to minimize vehicle usage and miles traveled through optimized spatial design, i.e., increasing the proximity between where people live, where they work, where they conduct their commercial transactions, and where they participate in leisure activities, which will allow people to drive shorter distances, or even to walk or bicycle between their daily destinations.

Reduce the Emissions of the Vehicle Fleet

While reducing the number of miles traveled and shifting to more sustainable transport modes will reduce the emissions of the Transportation sector, there are also ways to reduce the emissions produced by any mile traveled by any type of vehicle, including by encouraging the adoption of new technologies and simply encouraging drivers and passengers to make smarter choices. The ultimate goal for Aruba should be to achieve high penetration levels of EVs.

Emissions from heavy-duty vehicles are harder to address. There is unlikely to be a significant opportunity to reduce the miles traveled by these vehicles, as bus miles will actually need to increase if the less efficient car miles are to be reduced. Furthermore, electrification is not a practical option for any but the lightest of these vehicles, as the weight and cost of the batteries that would be required are prohibitive.

NEXT STEPS

Important gaps in information must be filled in order to properly judge the relative merit or viability of any strategy for reducing the emissions and fuel dependence of Aruba's transportation system. Additionally, the government must carefully weigh the costs and benefits of an effort to incentivize individuals and businesses to purchase EVs, which will require significant investment in charging infrastructure, and, from the perspective of reducing emissions, must be accompanied by the addition of renewable energy generation capacity. Otherwise, since the EVs would be charging from a grid supplied by generators burning heavy fuel oil, the benefits would be minimal at best.

What is the detailed breakdown of the vehicle fleet?
Beyond the numbers for broad categories of vehicles, very little information on the breakdown of the vehicle fleet is available. The breakdown of the bus, tour bus, and truck fleets in particular will need to be identified by future work. For example, it is known that the Arubus bus fleet mainly consists of Brazilian-built Volvo buses, but the age and emissions profile of these vehicles still needs to be assessed.

How accurate is the transport model?
Further research is also required to verify the assumptions and results of the model presented in this paper. More information is needed on vehicle utilization across a number of variables, including the true length of average commutes, how many people actually need to commute daily, and whether certain populations or vehicles drive longer distances and more frequently than others.

What are the best strategies moving forward?
With a better idea of how, why, and by whom all types vehicles are currently being used on Aruba, it will be easier to generate specific strategy recommendations. Stakeholder consultations will be the other key input into generating locally relevant action plans that identify specific actors for implementing recommendations, thereby increasing the likelihood for uptake and success.

There are ways to reduce the emissions produced by any mile traveled by any type of vehicle, including by encouraging the adoption of new technologies

Future Opportunites and Considerations

The sections above endeavor to outline the sectors and specific action areas within them that Aruba must focus on in the near term to achieve its vision for a low-carbon future. In addition, the Carbon War Room has evaluated the potential that future technologies and strategies may have for Aruba to continue to reduce its dependence on imported fossil fuels and for reaching broader sustainability goals.

Capitalizing on the opportunities presented in this section will require both the passage of time, as technologies that are in the early stages reach maturity, as well as careful long-term planning. In no way does this mean Aruba must sit on the sidelines while others work to develop these technologies. The island can play a significant role by being a leader in the piloting of new energy technologies and taking immediate steps to incentivize the long-term potential for locally producing food, thereby reducing imports and planning urban growth in a way that will ensure that more sustainable modes of transportation will be attractive to the islands residents and visitors.

AGRICULTURE

Aruba Is Almost Totally Reliant on Imported Food

As with fuel, Aruba's scarcity of domestically produced foods has resulted in a reliance on imports. Nearly 100 percent of the food consumed daily by the more than 102,000 residents and more than 900,000 annual visitors is imported from the US, Europe, and Central and South America (Aruba Tourism Authority, 2012). Its almost complete dependence on imported food undermines the island's food security by creating a vulnerability to potentially volatile supply flows and to world food prices, which have risen dramatically over the last decade. In recent years, the Ministry of Agriculture, through the Department of Agriculture, Fisheries and Husbandry, has made a concerted effort to support local farmers and fisherman and to promote local food production. In particular, there has been some success on a small scale with the growing of vegetables for commercial sale. The Aruban government should continue to investigate the potential for further developing local food production capacity through sustainable agriculture practices.

Currently, Aruba's Agriculture sector does not supply enough production to have any significant impact on the local economy or the marketplace for food, nor does it currently have the capacity to do so. Agricultural production represents 0.4 percent of the GDP of Aruba (Central Intelligence Agency 2012), and only a small percentage—approximately 10 percent as of 2008—of the land area is currently arable and/or being used for agriculture (UN Statistical Division, 2011). Historically, aloe was grown on much of the island after being introduced in 1840 and continues to be the primary domestic agriculture product grown in Aruba (Central Intelligence Agency 2012).

Nearly 100 percent of the food consumed daily by the more than 102,000 residents and more than 900,000 annual visitors is imported from the US, Europe, and Central and South America

Beyond aloe production, some livestock is raised and produce is grown for local consumption. Produce-wise, Aruba has some seasonal rain-fed cultivation using dry-land farming practices, as well some production of local fruits and vegetables grown via irrigated horticulture on 0.5–1-acre plantations (Santa Rosa 2012). However, beyond these generalities, reliable agricultural statistics on the small producers of the island are few and hard to come by.

Unfortunately, **Aruba's land resources and climate are not conducive to supporting large amounts of traditional land-based agricultural production**. Aruban land area is limited and the soils have low fertility and quality for growing, while the climate is semi-arid with seasonal rain patterns that would necessitate irrigation for year-round production, which is currently not commonly practiced. Groundwater resources on the island are also limited and of poor quality, and access to potable water is entirely dependent on energy-consuming desalination processes.

But despite these challenges and the minimal agricultural output of the island to date, there are a number of possible strategies for increasing on-island food production at various levels. Bearing in mind that the feasibility and possible scale of such strategies will require further research, there are several steps Aruba can begin to explore:

- Advanced farming practices represent Aruba's best chance at improving its local agricultural production. For example, controlled environment agriculture (CEA) provides alternative options for food production on the island through the use of techniques such as aquaponics or greenhouse-based farming, if suitable water sources are available. Similarly, low- or zero-discharge controlled growing systems can be explored as possibilities for reducing water consumption for food production while drastically increasing yield and the number of production cycles.

- Both gray water recycling and water capture provide some basis for irrigating agricultural spaces on all levels without creating more demand for desalinated water.

- With regard to improving soil quality, the composting of organic waste can help to improve soil texture, moisture retention, and fertility, ultimately resulting in increased yields and decreased water and fertility requirements, without having to rely heavily on expensive imported fertilizers. Households and businesses could undertake waste separation and composting programs aimed at supporting agricultural production.

RESEARCH QUESTIONS

Many questions remain about the feasibility of reducing food imports through increasing sustainable agriculture on-island, and about how such drastic changes could be implemented and supported. Additionally, questions remain about the economics of such shifts. Based on further analysis of the potential feasibility and potential scale, further research will be required to ascertain whether such changes would result in significant reductions in emissions.

What are the basics?
The information used for this summary analysis was limited and needs to be supplemented by an assessment of the realities within Aruba. There is a need for a more complete inventory of the existing food sector and the scope and elasticity of the demand for local food. Although anecdotal information was available, it is imperative to have a more complete understanding of the prospective customers for island-grown products.

Can local food production contribute to a low-carbon development pathway?
At a general level, considerably more information is also required to determine whether local agriculture makes sense as a component of Aruba's integrated strategy to reduce fossil fuel use. Therefore, a critical next step would be to attempt to contextualize the potential impact of local food production on fossil fuel dependence by generating estimates of fuel use and emissions for Aruba's current food imports in general and disaggregated estimates for those food imports that could possibly be replaced by local food production (e.g., fruit and vegetables). Knowing more about where different parts of Aruba's food supply are coming from and how they are being produced and transported will help to better gauge whether, and how much, local food production could actually contribute to a low-carbon development pathway.

How much potential is there for local agriculture in Aruba?
Detailed further investigation will be needed to assess how much local food production will be possible and how feasible it will be for local food production to impact the demand for food imports. Key determinants of the feasibility and possible scope of local agriculture that will require further investigation include land use and urban planning and advanced energy technologies.

Aruba's long-term sustainability and economic growth are reliant in many ways on smart island development and urban planning

LAND USE AND URBAN PLANNING

Aruba's long-term sustainability and economic growth are reliant in many ways on smart land development and urban planning. Aruba is moving forward on this important issue. The Ruimtelijke Ordenings Plan (ROP), a long-term strategy for spatial arrangement, has been operating since 2009. This and other efforts, such as the Nos Aruba 2025 Integrated Strategic Plan,[10] demonstrate the community's and the government's forward-thinking efforts on this issue.

Although these efforts are promising, the challenges are formidable. Aruba will need to choose between remaining on the path of car dependency or opting for sustainable settlement patterns that are walkable, compact, and diverse. This is not an easy decision to come to, and one that will require the most consultation and consensus from the community of any of the ideas put forth in this vision.

As the government and people of Aruba discuss these questions, they must also consider the implications of these decisions for the following action areas:

- **Energy:** The questions of whether or not land is available on the island for more on-shore wind projects and of where that available land is located will impact the viability of such projects. Similarly, land-use planning will play a key role in determining how much solar capacity can be installed in Aruba, as will the square footage of rooftops or other prospective locations for solar panels in the built environment.
- **The Built Environment:** The amount of energy used, the efficiency of its usage, and the opportunities for savings are all enormously impacted by where and how buildings are constructed and by how indoor space is used, distributed, cooled, heated, insulated, and managed. Considering future development from a land-use and urban planning perspective will be an important driver of increasing energy efficiency.
- **Transportation:** Both land use and the built environment will impact the allocation of traffic patterns and the locations of different types of destinations, which in turn affect what types of vehicles are favored and how much they are used. All of these factors together determine the fossil fuel consumption levels of the Transportation sector.

The Need for Strategic Land Use and Planning

Decisions about land use and planning will have to be closely coordinated between leading actors in each of the three different action areas in order to ensure that the best possible use is made of the limited land available on the island. Therefore, a key first step in Aruba's low-carbon transformation will be to create a detailed, up-to-date map of current land use and land availability. Available lands should then be assessed for their potential to support different types of projects, and priority should be given to projects that are likely to have the greatest low-carbon, high-growth impact. This assessment process will need to be an ongoing one, as land use and demands for land are constantly evolving.

ADVANCED ENERGY TECHNOLOGIES

Along with some of the potential improvements in batteries, flywheels, pumped hydro-electric energy storage, and the deep-water or floating wind turbines outlined previously, other emerging technologies present opportunities for Aruba to advance along its pathway to a low-carbon future. Technologies are constantly improving in all three action areas (Energy, the Built Environment, and Transportation), along with advancements in air conditioning systems to electric vehicle technologies. In the future, the development of these technologies may hold the potential for Aruba to truly become fossil fuel free.

In addition, Aruba can help with the development of some of these technologies and derive benefit from them today on a small scale, even if they are in the development or demonstration stage.

Biofuels

Biofuels have the great advantage that they can be used in existing reciprocating and turbine engines with minimal modification and, therefore, could provide flexibility in offsetting lulls in wind and solar production. However, Aruba has very little arable land available for growing the necessary feedstock for production of biofuels (e.g., biodiesel, ethanol). As a result, any significant amounts of biofuel would have to be imported from abroad. On balance, the importing of biofuels would leave Aruba vulnerable to essentially the same risks of price increases and supply disruptions as the importing of fossil fuels. Additionally, the current generation of biofuels is produced primarily from feedstock that competes with food production (e.g., corn, soy, palm oil) and usually involves at least partially offsetting land-use changes and adverse environmental impacts, including large indirect carbon emissions.

As a result, there is little to be gained until a "third generation" of biofuels becomes available. In the future, advanced biofuels such as cellulosic ethanol, or new processes for the direct conversion of carbon and hydrogen into liquid fuels, using renewable energy for the conversion process, may become a viable option for providing back-up power or even primary generation in Aruba, as well as fuel for vehicles. The direct conversion technologies, for example, are still in the R&D phase. In any case, for Aruba to cost-effectively produce its own biofuels domestically, most likely from algae feedstock, will require technologies that are currently unproven and that cannot be realistically expected to become commercially available any time before 2020.

[10] The goal of Nos Aruba 2025 is the institutionalization of an integrated and strategic planning process in which the coordination between the relevant stakeholders is encouraged, taking into consideration guidelines for sustainable development.

Waste-to-Energy

Some waste-to-energy (WTE) capacity is already planned in Aruba, but the potential for this type of renewable energy generation will always be limited by feedstock availability. There is only one main source of potential biomass fuel on the island: the organic portion of municipal solid waste (MSW), which also includes commercial waste. This biomass source needs to be segregated, collected, transported, and, if necessary, pre-treated and/or stored before it can be converted to energy through any one of a variety of processes.

Aruba currently has several waste collection services, the two main ones being the government-owned SERLIMAR and the private Ecotech. Ecotech runs a modern waste separation plant that produces a low-quality refuse-derived fuel (RDF), and also separates and exports recyclable materials from the general waste stream, such as paper, plastic, ferrous metals, and aluminum. Aruba has the potential to produce about 200 tons per day of RDF, which would provide suitable fuel for a more advanced waste-to-energy (WTE) system. This amount of feedstock input could save the equivalent of roughly 200 barrels per day of oil—only a small fraction of Aruba's total imports. The government is preparing to issue an Request for Proposal for a WTE plant of this design.

OTEC

While wave power may not be the answer, as Aruba does not possess significant tidal activity, the oceans may still prove to be an invaluable resource for Aruba in the future. A potentially significant opportunity for renewable energy generation is a technology under development called ocean thermal energy conversion (OTEC). OTEC uses the temperature differential between the cold deep waters and relatively warmer surface waters of the ocean to generate electricity. While there are no commercially proven OTEC applications at this time, considerable research into this technology is underway around the world and several sub-commercial-scale pilots are likely to be launched shortly, though the technology will not become cost-effective for some time.

Solar Thermal

Concentrating solar is on the verge of becoming a mature technology. Its big advantage is that it has built-in storage so it can extend service into the evening hours, but it is only cost-effective on a utility scale. The system economics are best if tied to existing steam turbines, which may be a possibility if enough space is available near WEB facilities. It is, however, water intensive.

Geothermal

Although some islands in the Eastern Caribbean have excellent geothermal resources, Aruba does not lie in a region with volcanic activity, so today's geothermal energy technologies are not a promising option for the island. However, future geothermal technologies may warrant investment. Ongoing development of single-well enhanced geothermal systems (SWEGS) reveals an opportunity that may soon be available to extract renewable, geothermal energy beyond regions with specific geologic conditions, such as the existence of brine pools and those sitting over tectonic plates.

SWEGS utilizes a closed-loop system and a heat exchanger, drilling deep into the ground to reach hot rocks. This approach is also much more sustainable, as current geothermal requires pumping fluid into the earth (hydrofracking), which can result in seismic disruption, disruption of groundwater, and often corrosion of equipment.

Development of SWEGS geothermal could be a major breakthrough for Aruba, as this source of renewable energy is able to provide firm, consistent power for decades.

Development of SWEGS geothermal could be a major breakthrough for Aruba, as this source of renewable energy is able to provide firm, consistent power for decades

Looking Ahead

By reducing fossil fuel use, Aruba can buttress its economy and society against oil price and supply volatility and redirect savings on import spending

By reducing fossil fuel use, Aruba can buttress its economy and society against oil price and supply volatility and redirect savings on import spending to other productive purposes. Along the way, the individual processes involved in increasing renewable energy production, decreasing energy use, and improving the efficiency of the transportation fleet all have the potential to create a significant number of jobs and to otherwise improve the quality of life of the island's residents. One of the biggest potential contributors to and beneficiaries of Aruba's success in pursuing low-carbon growth will likely be the tourism industry, the heart of the island's economy.

Thanks to the strong platform laid down by its pioneering and visionary leadership, Aruba has shown strong early progress on the path to true sustainability, putting it on course to show the world how a low-carbon transformation does not need to hinder the pursuit of an improved quality of life and a healthier economy, but rather that it can power sustainable economic development.

There are specific, significant, and interlinked opportunities in Aruba to dramatically reduce energy demand through air conditioning and energy efficiency improvements, coupled with the potential to take renewable energy to the next levels of implementation, from wind and solar to potentially pioneering new methods of renewable baseload generation.

This document provides an initial assessment of some of the challenges and opportunities ahead as Aruba develops its strategy for ending its dependence on fossil fuel imports and for laying a solid foundation for sustainable prosperity and growth into the future. Drawing on available information and expertise, the Carbon War Room has produced baseline assessments of Aruba's Energy, Built Environment, and Transportation sectors, along with samplings of the types of mature technologies available to reduce fossil fuel consumption in each of these three action areas. This report presents neither a comprehensive review of these sectors nor in-depth action plans for advancing change within them, but rather outlines the potential and the technologies that can be used to reach it. In order to bolster the likelihood of achieving this vision, a next phase of on-the-ground research and development of strategies for implementation is required.

The next phase should focus on filling important gaps in information on-island. Through observation, stakeholder dialogues, and consultations with local experts and officials, we will gain a more comprehensive and nuanced understanding of baseline conditions in Aruba and of the feasibility of the different projects. In particular, **determining feasibility will require the consideration of a range of factors, including economic costs/benefits, political feasibility, availability of land and other resources, technical capacity, existing programs or opportunities on which to build, and available technological solutions.** With such information in hand, the Carbon War Room will work with the Government of Aruba and other partners to narrow the list of possible projects in each action area and to add more detail to the most promising, working with the commercial opportunities already identified in the vision outlined in this document, and to begin to engage with the private sector that shares our optimistic view of transforming Aruba into a low-carbon society.

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ABOUT THE CARBON WAR ROOM

The Carbon War Room works on breaking down market barriers to the flow of capital into entrepreneurial solutions to climate change by employing a sector-based approach focusing on the solutions that make economic sense right now. It targets the movement of institutional capital into a working marketplace and the elimination of market inefficiencies (in the form of insufficient information and high transaction costs, among others). Policy and technology are necessary conditions to the solutions but they are neither sufficient nor the bottleneck to progress.

The Carbon War Room's vision is to see markets functioning properly and clean technology successfully scaling to promote climate wealth, business and economic growth. In the role of a climate wealth catalyst, the Carbon War Room focuses on areas where a sector-by-sector approach to climate change can be applied to generate gigaton-scale carbon savings. It seeks to complement existing efforts and organizations, leveraging its convening power, its market-driven, solutions-oriented focus, and its powerful global network to develop and implement catalytic change.

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