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IN THE CARIBBEAN

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Abstract

Small island states, such as in the Caribbean, contribute only a small share to the global greenhouse effect, but they are the main victims of rising sea levels, change of seasonal climates and increase of tropical storms. In addition, they are heavily dependent on fossil fuels. Almost all Caribbean islands are aware of those negative effects and do consider to strive for use of renewable energy sources. Unfortunately, barriers like inadequate policies and strategies; lack of awareness, knowledge and confidence; inadequate capacity and lack of finance are still big hindrances. However, the potential for solar energy implementations in the Caribbean region is very high and it is possible to overcome the barriers. The case studies of Barbados, Grenada and St. Lucia show that local companies were able to establish a solar water heater and photovoltaic market. Through their strong commitment and governmental support, as well as a close cooperation with the utility, remarkable results have been achieved already. This master thesis shows under which conditions a solar water heater or photovoltaic market can be established and what is required for successful market penetration. Investigating and analyzing the drivers and obstacles, the generated frameworks shall help other islands to adopt the systems and help to extent the solar energy market. Governments, utilities and financial institutions will see how they can support the private sector and hence the consumer. Investors will learn what has to be considered when planning to enter the market, and donor agencies will get an idea how to further increase market growth. Finally, this master thesis discussed how to reach viability in terms of social, environmental and economic sustainability.

Key words: solar energy, solar water heater, photovoltaic, sustainability

Resumen

Los pequeños Estados insulares, como los del Caribe, contribuyen sólo una pequeña parte al efecto invernadero global, pero son las principales víctimas del aumento en el nivel del mar, los cambios estacionales del clima y el incremento de las tormentas tropicales. Además, son muy dependientes de los combustibles fósiles. Casi todas las islas del Caribe están conscientes de estos efectos negativos y los tienen en cuenta para luchar por el uso de fuentes de energía renovables. Lamentablemente algunas barreras como inadecuadas políticas y estrategias, falta de conciencia, conocimiento y confianza, capacidad insuficiente y la falta de financiamiento son todavía obstáculos grandes. Sin embargo, el potencial para implementar proyectos de energía solar en la región del Caribe es muy alto, y es posible superar las barreras. Los estudios de caso de Barbados, Granada y Santa Lucía muestran que las empresas locales fueron capaces de establecer un mercado de calentadores de agua solar y un mercado fotovoltaico. A través de un fuerte compromiso y el apoyo gubernamental, así como una estrecha cooperación con la empresa, notables resultados han sido ya alcanzados. Esta tesis de maestría muestra las condiciones en que puede implementarse un mercado de calentadores de agua solar o un mercado fotovoltaico y qué se necesita para una penetración exitosa en el mercado. Investigando y analizando las fuerzas motoras y los obstáculos, los esquemas generados deberán ayudar a otras islas a adoptar los sistemas y ayudar a extender el mercado de la energía solar. Por último, será examinada la forma de alcanzar la viabilidad en términos de sostenibilidad social, ambiental y económica.

Palabras clave: energía solar, calentador de agua solar, fotovoltaica, la sostenibilidad

Zusammenfassung

Kleine Inseln, wie die der Karibik, tragen nur einen geringen Teil zum globalen Treibhauseffekt bei, aber sie sind die Hauptleidenden der Folgen, wie ansteigender Meeresspiegel, saisonale Klimaveränderungen und die Zunahme von Tropenstürmen. Hinzu kommt, dass sie sehr stark von fossilen Brennstoffen abhängig sind. Fast alle Karibischen Inseln sind sich dieser Tatsache bewusst und streben nach einer Nutzung von Erneuerbaren Energien. Leider stehen sie immer noch Hindernissen, wie unangemessenen politischen Regelungen und Strategien, fehlendem Bewusstsein, Kenntnis und Vertrauen, sowie mangelnder Finanzierung gegenüber. Dennoch ist das Potential für Solartechnologien in der Karibik sehr hoch und es ist möglich die Barrieren zu überwinden. Die Studien in Barbados, Grenada und St. Lucia verdeutlichen, dass es lokalen Firmen gelungen ist, einen Markt für Warmwasserkollektoren und Photovoltaik aufzubauen. Durch ihre starke Einbringung und durch Hilfestellungen seitens der Regierung, sowie die enge Zusammenarbeit mit dem Versorgungsunternehmen, wurden bereits bedeutende Ergebnisse erzielt. Diese Masterarbeit zeigt unter welchen Bedingungen ein Markt für Warmwasserkollektoren und Photovoltaik in der Karibik aufgebaut werden kann und was für ein erfolgreiches Marktwachstum benötigt wird. Durch die Untersuchung von Anreizmechanismen und Hindernissen wurde ein Modell entwickelt, welches anderen Inseln bei einem Marktaufbau helfen soll. Darüberhinaus wird diskutiert, wie eine soziale, ökologische und ökonomische Nachhaltigkeit erreicht werden kann.

Schlüsselwörter: Solarenergie, Warmwasserkollektoren, Photovoltaik, Nachhaltigkeit

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List of Abbreviations

ADA	Austrian Development Agency
ECLAC	Economic Commission for Latin America and the Caribbean
BBD	Barbadian Dollar
BMZ	Federal Ministry for Economic Cooperation and Development
bbf	Barrel
BEP	Barbados Energy Policy
BL&P	Barbados Light & Power Company Limited
C	Celsius/Centigrade
CARICOM	Caribbean Community
CARIFTA	Caribbean Free Trade Association
CARILEC	Caribbean Electric Utility Service Corporation
CEIS	Caribbean Energy Information Service
CSFP	Caribbean Solar Finance Programme
GEF	Global Environment Fund
CHAT	Caribbean Hotel and Tourism Association
CIA	Central Intelligence Agency
CO ₂	Carbon Dioxide
GRENLEC	Grenada Electricity Services Ltd
GREN SOL	Grenada Solar Power Ltd
CREDP	Caribbean Renewable Energy Development Programme
ECD	Eastern Caribbean Dollar
EWH	Electric Water Heater
EU	European Union
F	Fahrenheit
GDP	Gross Domestic Product
GPSCU	Grenada Public Service Co-operative Credit Union
GTZ	German Technical Cooperation
GW	Giga Watt
GWh	Giga Watt hour
IDB	Inter-American Development Bank
kW	Kilo Watt

kWh	Kilo Watt hour
kWp	Kilo Watt peak
LAC	Latin America and the Caribbean
LUCELEC	St. Lucia Electricity Services
MW	Mega Watt
MWh	Mega Watt hour
NGO	Nongovernmental Organization
OAS	Organization of American States
OECS	Organization of Eastern Caribbean States
PV	Photovoltaic
R&D	Research and Development
RER	Renewable Energy Rider
SECCI	Sustainable Energy and Climate Change Initiative
SEP	Sustainable Energy Action Plan
SEPA	Solar Electric Power Association
SIDS	Small Island Developing States
SODIS	Solar Water Disinfection
SWH	Solar Water Heater
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
USD	United States Dollar
W	Watt
Wp	Watt peak

Exchange Rates

As of 30 June 2010

(Exchange rates in study are adjusted to corresponding dates in the past)

1 ECD = 0.37 USD

1 BBD = 0.49 USD

1 Introduction

Human well-being and global warming, both are closely linked with energy. Energy is needed for power generation, to fulfill basic living standards, for transportation and of course for economical development. Besides that, electricity production out of conventional energy sources such as hydrocarbons leads to grave resources cutbacks and pollutant emissions. One solution lies in the use of alternative energies which are renewable and do not harm the environment and furthermore help to be independent of oil prices.

There is a high potential for solar energy in the Caribbean region and its utilization could reduce the high dependency on fossil fuels and help develop many small island states. Despite the big potential, hindrances so far have been high prices for technologies, high costs for implementation, lack of knowledge and acceptance, missing financial incentives, volunteers, rules and regulations which are not easy to overcome. Nevertheless, some countries in the Caribbean already successfully integrated solar energies in their energy mix and started first implementations. But in most Caribbean countries this potential is still untapped and waiting to be discovered.

The key is to jump from theoretical knowledge to development and technical boots on the ground. Therefore, the Caribbean Renewable Energy Development Programme (CREDP) escorted this research study to analyze the potential solar energy market in the Caribbean region, considering the present situation, progresses and obstacles, possible improvements and how to adapt solar technologies to support Caribbean countries on their way to a diversification and security, ensure a sustainable development, health and well-being as well as economic growth.

A research was done in three markets – in Barbados as a show case for a successful solar water heater market, in Grenada as best example for photovoltaic implementations and in St. Lucia as location of the CREDP office as well as potential application market for both technologies. The aim was to evaluate how the solar markets were established, successfully developed and hence to create frameworks as guidelines for other islands.

1.1 The Caribbean as a Research Region

Located southeast of the Gulf of Mexico, east of Central America and to the north of South America is the Caribbean Sea, which forms the Caribbean region (Figure 1).

Figure 1: Caribbean Region



Source: Caribbean Cruises 2010

The Caribbean region is an archipelago called the West Indies. The region can be divided into the Greater Antilles and Lesser Antilles or as Western and Eastern Caribbean. The Greater Antilles comprise 4 big islands; Cuba, Jamaica, Hispaniola (Haiti and the Dominican Republic) and Puerto Rico, whereas the Lesser Antilles consist of many small islands. In 1981 seven Eastern Caribbean countries signed a treaty agreeing to cooperate with one another and promote unity and solidarity among the members, therefore establishing The Organization of Eastern Caribbean States (OECS). By now, OECS is comprised of the 9 member states Anguilla, Antigua & Barbuda, British Virgin Islands, Dominica, Grenada, Montserrat, Saint Lucia, St. Kitts & Nevis and St. Vincent. OECS is aiming to contribute to the sustainable development of its member states by supporting their strategic insertion into the global economy while maximizing the benefits accruing from their collective space (OECS 2010).

According to The World Bank (2010), Latin America & the Caribbean are classified as upper-middle income economies and hence developing countries. Above all, they are small island developing states (SIDS) which face special challenges (UN 2010). Most Caribbean countries are heavily dependent on fossil fuels. Their energy consumption is based on almost solely oil products which account for more than 97% of the energy mix. Only Trinidad and Tobago, as a net exporter of oil products, and Barbados, which covers some parts of its oil and natural gas requirements by own resources, are countries with significant proven fossil fuel resources. Mostly medium- and high-speed diesel generators are generating electrical power (ECLAC/GTZ 2004). Vulnerable to external factors such as fluctuations in energy prices, diseconomies of scale have a big impact on the costs of generating power on small islands (Ehrhardt & Oliver 2007). This results in high electricity prices, generally between 20 and 35 US cents per kWh, much higher than in the USA or Europe (Roper 2006).

Heavy economic burden of gasoline imports, political dependency, and the enormous untapped renewable energy potential, combined with failing investment costs for renewable energy projects, made governments and electrical utilities rethink and consider the use of renewable energy sources (ECLAC/GTZ, 2004). But despite the substantial wind, solar, hydropower and biomass resources, renewable energy still provides less than 2% of the region's commercial energy (CREDP 2009). In the English-speaking Caribbean Countries some attempts to invest in attractive renewable energy projects were made by regional and international private investors but these initiatives were turned down due to restrictive energy legislation unfavorable for independent power producers (ECLAC/GTZ, 2004).

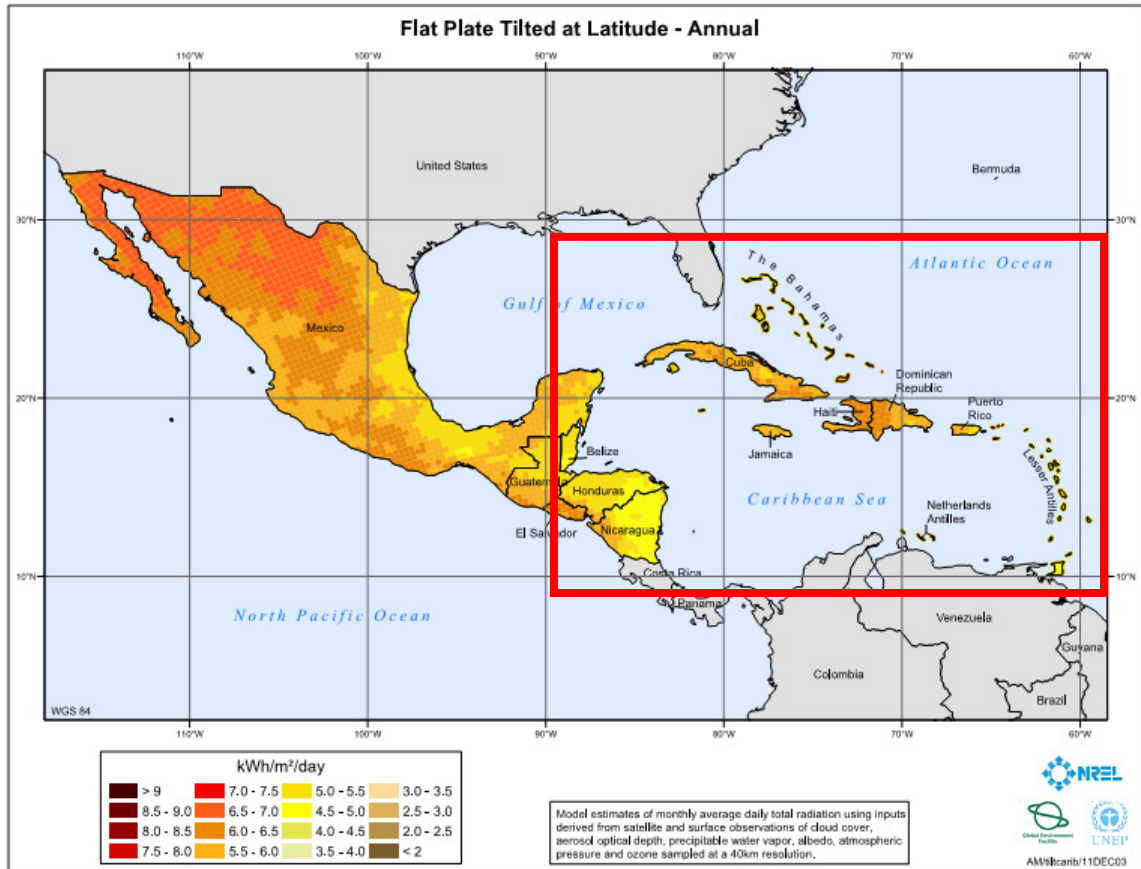
The main characteristics of Caribbean countries are:

- Small scale economies and thus energy markets
- Relatively high GDPs (e.g. Trinidad, Barbados, Grenada)
- Extremely dependent on oil import (except Trinidad and Tobago)
- Longstanding private electrical utility monopolies
- Extensive electric power coverage, up to 99%
- Some of the highest electricity tariffs on the globe
- Readily available, but mainly untapped renewable energy potential

(ECLAC/GTZ 2004, Loy & Farrell 2005)

As Figure 2 shows, the average solar insolation in Caribbean region is between 5 and 6 kWh/m²/day, which is very favorable for solar energy applications.

Figure 2: Caribbean Solar Insolation



Source: SWERA 2010

Besides the above mentioned characteristics, the Caribbean region is heavily affected by climate changes. The observed global warming over several decades shows abundant evidence that the large-scale hydrological cycle is strongly impacted by climate change. This has wide-ranging consequences for human societies and ecosystems. It heavily affects sub-tropical areas and is especially dangerous for small islands in the Caribbean. Droughts are getting more severe, precipitation as well as diseases increase, sea levels are rising and the occurrence and severity of climate related disasters like hurricanes increases. This has also impacts on biodiversity. A study showed that coral cover on the Caribbean reefs decreased by 17% on average in the year following a hurricane (Bates et al. 2008).

For example beginning of 2010, several Caribbean countries battled a severe drought. Prolonged low rainfall negatively affected residents and economic sectors. St. Lucia even declared a water-related emergency. Drought-like conditions are not uncommon but the situation has been exacerbated because low rainfall began in October 2009, which is usually the wettest month in the sub-region (BBC 2010). During droughts, countries face an increase water stress and it is unlikely that the water demand will be met during those seasons.

With a 0.5m rise in sea level, up to 38% of the total current beach could be lost, most vulnerable to lower narrower beaches. This reduces turtle nesting habitats by one-third. Beach erosion and coral bleaching, affected by climate change has furthermore negative impacts on the beach-based tourism industry and the marine-diving ecotourism industry (Bates et al. 2008). Small island states contribute only a small share to the greenhouse effect, but they are the main victims of sea level rise and change of seasonal climates and the increase of tropical storms.

1.2 Caribbean – High Solar Potential versus Low Implementation

As mentioned before, Caribbean countries are heavily dependent on fossil fuels. Trade balance and domestic economies are highly vulnerable to fluctuations of oil prices. Up to 50% of their export earnings, including revenues from tourism, are spent to import oil products. Besides that, the Caribbean region will also be heavily affected by consequences of global climate change, particularly rising sea levels and the increased danger of hurricanes. As a result, the Caribbean energy sector is facing main challenges: energy security, economic growth and sustainable development (ECLAC/GTZ 2004).

On the other hand, solar radiation in the Caribbean region is high, which is very favorable for various kinds of solar energy implementations. The most common and significant solar technology so far in the Caribbean is solar thermal for solar water heating which is applied for domestic and industrial use, in hotels and hospitals (ECLAC/GTZ 2004). Photovoltaic technology was primarily used for security lightning and stand-alone systems in areas far from the grid, for example to pump water for irrigation (CCST 1999). However, nowadays with grid coverage of almost 100% in all islands, improved technology and decreasing costs, photovoltaic systems are getting

more and more interesting for reducing electricity also in urban areas. Some countries like Barbados and Grenada already successfully integrated renewable energies in their energy mix and started solar thermal and photovoltaic implementations. Nevertheless, this is a very small share compared to the huge, still untapped potential waiting to be discovered.

According to Loy (2007), reasons for the extraordinary low usage of solar energy and renewable energies in general are mainly the unfavorable political and legal conditions bringing up many barriers, for example monopolies of national utility companies and missing incentives for usage or sanctions for non-usage of renewable energies. Due to those political, regulatory and market uncertainties the barrier of perceived investor risk in developing countries is high. Furthermore, renewable energy projects often failed because of inconsistent government interventions, poor technology as well as missing planning and maintenance capacities (ISES, 2005).

Another problem for the low implementation is the scarce information about renewable energy integration (Huacuz 2003). Regarding solar energy, as a crucial barrier also high technology costs (Margolis & Zuboy 2006) as well as fear of hurricane damages were mentioned (CCST 1999). Summarizing, the barriers for renewable energy implementations are related to:

- Lack of adequate policies and strategies
- Lack of finance for investments
- Lack of capacity of governments and utilities
- Lack of awareness, knowledge and confidence

Source: following CREDP 2009

1.3 Hypothesis and Objectives

Based on the above problem statement, this thesis postulates the following hypothesis:

There is a potential market for solar energy systems implementation and use in the Caribbean Islands, and it is possible to define and quantify this market, as well as to justify it in terms of social, environmental and economic sustainability.

Along goes the main objective:

Analyze the potential of solar energy use in the Caribbean region and define the conditions under which its implementation has viability in terms of social, economic and environmental sustainability.

The specific objectives are:

- a) Gain an overview about the present solar energy situation in general and in the Caribbean Islands in particular.
- b) Establish possible scenarios and the corresponding attempts to approach the solar market.
- c) Analyze the viability in terms of social, economic and environmental sustainability for selected case studies.

The next part after hypothesis and objectives is the conceptual framework, giving an overview about solar energy implementations in developing countries and what are the drivers for renewable energy reforms. This is followed by the methodology, explaining what kind of research method was used to obtain the necessary data and information for this study. Within the methodology also the research project will be explained in detail. Thereafter, three island states will be examined as case studies. This can be found under chapter 4, with a summary under 4.4, and refers to the first objective. The second objective is answered in chapter 5.3 and 6.3 compiling scenarios for a successful market penetration for solar water heaters and photovoltaic technologies. Those scenarios are accompanied by an overview of barriers and drivers for the markets as well as some important economical, environmental and social facts. Chapter 7 is dedicated to the third objective, the viability in terms of social, economic and environmental sustainability. The conclusion and recommendations are closing this master study.

2 Implementation of Solar Energy in Developing Countries

There are three basic natural sources 1) tidal energy, originated by the movement and gravitation of planets 2) geothermal energy, heat stored and released by the earth and 3) solar radiation, energy radiated by the sun (Kaltschmitt, Streicher & Wiese 2007). Of those three, the most important renewable energy source is solar radiation. Coal, crude oil and natural gas are all transformation products of biomass, whereas biomass is a direct or indirect product of natural photosynthesis – a transformation of sun light into a biological usable energy form (Michel 2008). Approximately 1000 kilowatt hours (kWh) reach on each square meter of earth surface per year, this equates to an energy amount of 100 liter of oil. The biggest part of solar radiation is heating the oceans, huge amounts of water vaporize, high and low pressure areas develop and dissolve, which creates wind currents, and ocean streams and river systems are moved. Together with the daily freshly produced biomass of the photosynthesis, this creates enormous natural energy storage (Simon 2008).

Solar energy can be used passively by converting solar radiation into heat by using the building envelope as absorber and the building structure as heat storage. This utilization is therefore often referred to as passive solar architecture (Kaltschmitt, Streicher & Wiese 2007). It is important to be considered especially in terms of shading, but due to the architectural background, this aspect will not be included in this paper.

Harnessing active solar energy is done by using technical devices. Rather low-tech forms are for example solar water disinfection (SODIS) or solar distillation, solar cookers and solar dryers. More technological applications are listed in Table 1.

Table 1: Common Solar Technologies

Method	Description
Solar Thermal Heat Utilization	converting solar radiation into heat by using absorbers (e.g. solar collectors)
Solar Thermal Power Plants	thermal energy is transformed into mechanical energy by an engine and then converted into electricity
Photovoltaic Power Generation	solar energy is directly converted into electrical energy

Source: Kaltschmitt, Streicher, Wiese 2007

Solar evaporation for salt production and direct solar drying for processing crops are well established applications in developing countries (Agency for International Development 2009). Solar drying is one of the oldest techniques. Nevertheless, solar dryer same as solar water disinfection and solar cooker are non-commercial and therefore seen as marginal products. Not to say those are less important technologies though. They do have significant health aspects and in addition, the positive effect of saving energy.

Another technology is solar desalination. Regular desalination processes like brute-force distillation or reverse osmosis are very energy intensive and thus expensive. Using solar energy would be an attractive alternate solution, especially to offset the current and projected water shortages. There are several technologies under development and hopefully soon also applicable for developing countries.

Solar water heaters are widely used in developing countries and nowadays also solar refrigeration and solar cooling, another form of thermal heat utilization, finds growing interest, especially in hot countries. However, solar cooling as well as solar thermal power plants are still too expensive and a big challenge for developing countries (Agency for International Development 2009). Photovoltaic technologies were generally used for small applications in remote areas of developing countries and were also judged as too cost-intensive but find more and more acceptance lately. Therefore, this paper will focus on low temperature solar thermal heat utilization (referred to as solar water heater) and photovoltaic technologies for small system sizes in the residential market.

2.1 Renewable Energy Markets in Developing Countries

To promote renewable energies, lots of policies came up in the last years and many developed countries have adopted feed-in policies. Also, developing countries have greatly accelerated their renewable electricity promotion policies, enacting, strengthening, or considering a wide array of policies and programs. Many developing countries are interested in using renewable energy technologies to provide electricity to rural and remote areas as a cost-effective alternative to grid supply. Already some rural electrification programs are explicitly incorporating large-scale investment in solar home systems and governments are recognizing geographic rural areas that are non-viable for grid-extension, and enacting explicit policies and subsidies for renewable energies in

these areas to supplement line-extension electrification programs (REN21 2008). However, in some developing countries electricity coverage is already very high and renewable energies, such as photovoltaic technology, can be connected to the grid and help to diversify the energy mix.

To successfully proceed in the renewable energy market, individual countries will need to agree on and adopt their own targets. Prerequisite for the process of technology adoption towards the successful and sustainable internalization of renewable energies can only be fulfilled when all elements such as policy, institutional framework, technology stocks, financing schemes and sustainable local industry infrastructure are properly established and harmonically put in place (Huacuz 2003).

Key drivers for renewable energies in developing countries are basically poverty eradication, risk avoidance and protection of natural life supporting systems (Holm 2005). Poverty eradication goes along with an amplification of electricity supply, which could be seen as economic and/or social aspect. Risk avoidance instead is a mainly economical factor. Hence, it seems more appropriate to refer to the main drivers for renewable energy policies according to van Dijk et al. (2003), as seen in Table 2: economic, environmental and social drivers. The same drivers are mentioned by Dubash (2002) but further mentioning that electricity reforms are tremendously motivated by macroeconomic crises and the need to establish financial health rather than the provision in an environmentally sustainable manner.

Table 2: Drivers for Renewable Energies

Economical Drivers	Environmental Drivers	Social Drivers
Economical Optimization (small off-grid energy supply often cheaper than connection to a power grid)	Reducing Emissions (no direct or limited emissions from renewable energies)	Employment (direct and indirect employment will be generated)
Security of Supply (decrease dependency on fossil fuels)	Reducing Climate Change (implementation of renewable energies helps to prevent Climate Change)	Public Support (people asking for more attention of alternative energies as part of their sustainable way of live)
Leading Industry (increase of market share and business opportunities)	Protect Natural Life (no cut-backs of natural resources)	Social Economic Cohesion (possible development in areas formerly economically less attractive)

Source: following van Dijk et al. 2003

Several case studies showed that due to the financial emphasis, actors shaping reforms are mainly technocrats and politicians from energy agencies and finance ministries whereas representatives for environmental and rural development authorities are almost excluded (Dubash 2002). Economic liberalization and integration therefore seem to be the primary drivers of power sector reforms. In this context it could be understood that renewable energies then would work properly just by putting them on the market without any interventions. But as Mallon (2006) states, markets are good servants but poor masters and the government has the responsibility to establish the market conditions.

Because economies of scale still favor fossil fuels, policymakers need to intervene in energy markets to accelerate the dispersion of renewable energies. Economies must encourage competition in their energy markets through effective policy measures to draw domestic and foreign investments. Reducing fossil fuel subsidies is a significant issue. "Reducing or eliminating subsidies provides internal revenues for investment, improves the prospects of attracting direct foreign investment, and improves the financial capacity of governments to pursue other development objectives" (Johansson & Goldemberg, 2002, p.57). Furthermore, external costs as global carbon emissions could be decreased (Larsen & Shah 1992).

But there are many more options for governments to intervene and harness the benefits of renewable energies. The critical role is to use legislation and market dynamics to leverage private sector investments into renewable power projects and industries (Mallon 2006). Recent studies (Dubasch 2002; Johansson & Goldemberg 2002; Mallon 2006) suggest that the best solution for developing nations for policy change and strengthening reforms must balance financial, social and environmental sustainability, all together starting with the initiating process. Achieving financial stability has to go along simultaneously with an active promotion of public benefits shifting them closer to the mainstream of political concerns. Once reforms have been undertaken it is difficult to retrofit them (Dubash 2002).

The White Paper of ISES (2005) is stating 5 categories of relevant policy mechanisms for a promotion of renewable energies in the developing world:

- Regulations governing market and electric grid access as well as quotas mandating capacity and generation (e.g. feed in tariffs, pricing systems)

- Financial interventions and incentives (e.g. tax reliefs, rebates, low interest loans)
- Industry standards, planning permits and building regulations
- Education and information dissemination
- Public ownership and stakeholder involvement

The crucial step between installing renewable capacity and getting the generated energy to the customer, is having the incentive mix directly attached to the actual production of energy (Mallon 2006). What is also important besides and after the setting, governments have to take care of proper function and maintenance of the policies. This can be achieved by long-term commitment, targets and consistency; good laws and consistent enforcement; by developing reliable, predictable market conditions; redress failures and by choosing the most successful and suitable feed-in systems (Holm 2005). “The problem is that, for governments, one parliamentary term is about four years, two policy terms is guesswork, 10 years is a long time and 20 years is somebody else’s problem” (Mallon 2006, p. 25).

Mallon (2006) is summarizing ten key features of successful renewable energy policy: transparency; well-defined objectives; well defined resources and technologies; appropriate applied incentives; adequacy; stability; contextual frameworks; energy market reforms; land use planning reform; equalizing the community risk and cost-benefit distribution. Qurashi & Hussain (2005) is stating this shorter as a 3A strategy:

- Accessibility (provide clean energy at affordable prices)
- Availability (reliable source and security)
- Acceptability (public attitude, social and cultural circumstances)

The 3A strategy is basically reflecting all key features mentioned by Mallon but seems to be more appropriate and applicable because of the clear, short statement.

2.2 The Caribbean Solar Energy Market

Benefits of renewable energy accrue at different levels – globally talking about pollution mitigation, nationally regarding inward investment, regionally when it has to do with manufacturing and employment creation and on a local level also in case of employment

(Mallon 2006). Within this research study, this clustering will be adjusted to the Caribbean region. Three levels can be defined; the state level for each Caribbean island state, the CARICOM level for all its member states and international level. The next paragraph gives a definition for CARICOM to better understand this aggregation, followed by the definitions of the stakeholders of the solar energy market.

In 1958 the West Indies Federation, comprised of ten territories, had the aim of establishing a political union among its members but the Federation collapsed in 1962. So The Caribbean Free Trade Association (CARIFTA) was founded in 1965. CARIFTA was intended to unite economies and to give them a joint presence on the international scene but although a free-trade area had been established, CARIFTA did not provide for the free movement of labor and capital, or the coordination of agricultural, industrial and foreign policies. So it was decided to transform the Caribbean Free Trade Association into a Common Market and to establish the Caribbean Community, of which the Common Market would be an integral part. Thus, in 1973, CARIFTA became the Caribbean Community (CARICOM) and later a single market and economy in which factors move freely as a basis for internationally competitive production of goods and provision of services. Now CARICOM has 15 member states and 5 associate states: Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, Montserrat, St. Lucia, St. Kitts and Nevis, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago (CARICOM 2010).

CREDP

In 1998, different Caribbean countries agreed to work together under CARICOM and together with UNDP to support the use of renewable energy and thereby foster its development and commercialization. Based on this, the Caribbean Renewable Energy Development Programme (CREDP) was launched with the overall goal of the reduction of the Caribbean region's dependence on fossil fuels and the contribution to reduce green house gas emissions (CREDP 2009).

Governmental Institutions

Governments are playing a very important role in renewable energy reforms, implementation and enforcement. They have to keep the whole process running in all three dimensions – economically, environmentally and socially. Because they are the decision-makers, they are responsible for how all other stakeholders are affected (Mallon

2006). Government policies are interacting at a variety of levels. At the highest level legislation starts with international agreements, such as the Kyoto Protocol for example. On the CARICOM level there are energy/environmental policies, industry development plans as well as planning and zoning legislation. The last level is the local government decision-making (Mallon 2006).

Donor Agencies

Significant effort in reform comes from donor agencies, for example in leading countries toward making political difficult decisions and initializing reforms. Nevertheless, a continued heavy hand in consolidating reforms is appropriate, like a more subtle strategy of engagement with borrower countries, so Dubash (2002). In case of renewable energy implementations in developing countries, donor agencies will basically come from the international level. A donor agency in the Caribbean region for example is the Inter-American Development Bank (IDB).

NGOs

Non-governmental organizations (NGOs) range from non-profit organizations, environmental groups, to commercially oriented industry organizations (Mallon 2006). They can be local, regional, national or international. Dubash (2002) is pointing out that in their case studies NGOs rarely participated actively in the design of reforms and international NGOs mainly act upon and influence international environmental negotiations. The Caribbean Solar Alliance (CSA), for example, is devoted to help country leaders, regulators and utilities (CSA 2010). On international level, there is the Solar Electric Power Association (SEPA) non-profit resource for information about solar technologies, policies, and programs for electric utilities and all businesses that have an interest in solar electricity (SEPA 2010).

Utility Company

Energy production and energy transport sometimes are separated. If the grid management is separate from the electricity production, entities ought to be neutral regarding renewable energies. However, they are not happy about intermittent supply and can place onerous barriers (Mallon 2006). Nevertheless, in the Caribbean region usually longstanding private electrical utility monopolies handle generation, transmission and distribution (ECLAC/GTZ 2004). Thirty three electric utilities are members of the Caribbean Electric Utility Service Corporation (CARILEC), established in 1989. The

association strives to enhance communication among its members and to serve as the focal point for general and technical information. It produces a number of information products and provides a range of services to members, such as training, conferences, information services, disaster management, technical studies and surveys as well as major publications (CARILEC 2010).

Regulatory Agencies

These agencies or ministries are responsible for decisions regarding energy, natural resources, pricing, investments and the utility companies. They are in charge of implementing and controlling governmental policies. Regulatory Agencies exist only in some Caribbean markets and can be an indicator for more liberalized electricity markets.

Financial Institutions

Generally, big finance companies are engaged in the renewable energy industry. They are likely to be early movers and they have significant influence also in government circles (Mallon 2006). Another cooperative financial institution is a credit union. It is owned and controlled by its members and provides credit at reasonable rates and other financial services to its members. Credit unions are widely spread within the Caribbean region and preferred to provide smaller loans for people with low salaries. Commercial Banks instead, seem to be more in charge of cars and house mortgages. A big commercial bank is the First Caribbean International Bank. It is the largest, regionally listed bank in the English-speaking Caribbean (FirstCaribbean 2010).

Consumer

Some people will enjoy the global environmental benefits and others the localized project effects. They can act with great influence locally, regionally or nationally basically through participation (Mallon 2006). Consumers can be the energy users, people providing space and land or even employees working in the renewable energy business.

Investors

Investors range from individuals who are likely to be highly motivated, well educated and connected to large institutional investors who can send strong signals by making a decision about investing in renewable energies (Mallon 2006). Investors could come from all levels – international, national and local.

Manufacturers

Manufacturers or producers could vary from domestic to foreign companies. Local knowledge is very helpful but according to Mallon (2006) usually only larger companies have the ability to invest heavily to open up new markets. This can vary from country to country, but it is essential that local knowledge must be coupled with international experience. Manufacturers are at the same time investors, especially when establishing a new business.

Distributor

A distributor is an independent trader who is entrusted, often on an exclusive basis, by the manufacturer to satisfy the demand of the product in a particular territory. He purchases at his own risk and resells at his prices, terms and conditions. Out of his margin, the distributor is providing extra benefits such as repair and servicing (Christou 2005). Distributors function as linkage between manufacturer and installer.

Installer

The installer buys the components from the distributor and installs the system on behalf of the customer. In small markets, a distributor might not exist and the installer is working directly with the manufacturer.

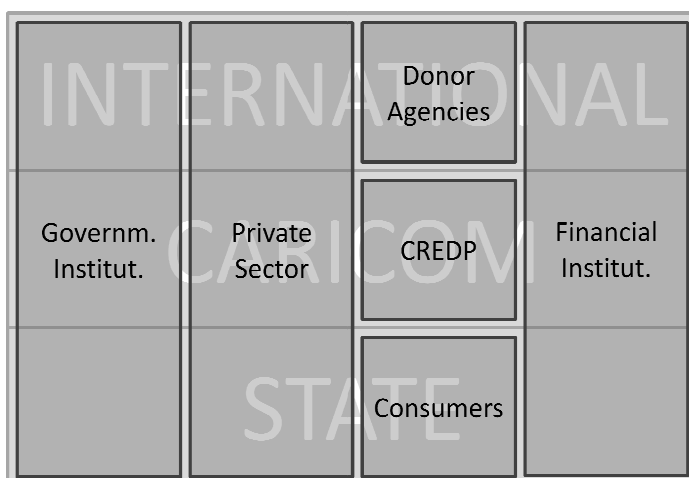
Because in a small market the manufacturer, distributor and installer may be one entity, or some intermediates are skipped, it is often difficult to differentiate and have a clear definition. For better understanding it will be classified as the private sector. Furthermore, as there are solely smaller individual, private investments and no involvement of big banks or other institutions yet, also investors will be clustered under the term private sector.

Stakeholders will face economic, environmental and social impacts. Economic impacts of renewable energies can be positive in the sense of profit making or can be negative in case of loss of market share or increase of energy bill, for example. Environmental impacts are physical changes to biological activity and diversity. Social impacts affect the human interaction in the sense of aesthetic or social change, for example improved health conditions (Mallon 2006).

2.2.1 Actors Framework for Solar Water Heaters

A framework for the solar water heater market in the Caribbean could look like illustrated in Figure 3. Solar water heater technology is quite simple and could be easily manufactured domestically. Because of the small islands market sizes, most manufactures also occupy the field of installers and directly contact the consumers. Government can help in developing this sector by tax concessions, deductions and incentives, and this can be supported by donor agencies and CREDP. Financial institutions get involved when people are planning on buying solar water heaters and are looking for credits.

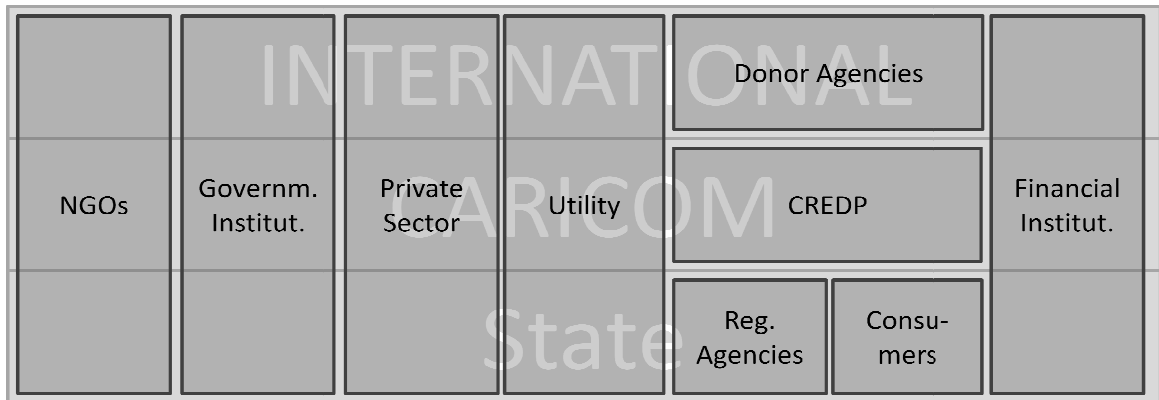
Figure 3: Solar Water Heater Framework



2.2.2 Actors Framework for Photovoltaic Technologies

As seen in Figure 4, the basic structure of the photovoltaic market is the same as for solar water heaters but when talking of grid-connected systems, more actors, such as utility companies and regulatory agencies, are involved. Because of higher sophisticated technology, it requires international interaction and products are imported. In case of photovoltaic technology, the distributor is generally also the installer as well as the system designer. Due to the high up-front costs, financing is very important and financial institutes can vary from international to local. Policies have to be set and maintained by the government. To get familiar with the photovoltaic technology, NGO's have a consultancy and advisory role.

Figure 4: Photovoltaic Framework



3 Methodology

This master thesis study is a result of a research project together with the Caribbean Renewable Energy Development Programme (CREDP), located in St. Lucia, for three months, from the end of February until the end of May 2010. The focus of CREDP is to remove barriers to renewable energy and energy efficiency uses in the Caribbean. The respective project proposal with an initial period of five years was approved by the Global Environment Fund (GEF) Council in 2002 and was joined in 2003 by the German Technical Cooperation (GTZ) project. The first UNDP/GEF part of CREDP ended in December 2009 but the German Government approved a second phase of the German contribution over a period of 4 years, taking place from April 2008 until March 2012. This GTZ project (CREDP/GTZ) is a financially and organizationally separate project of CREDP/UNDP (CREDP 2009). The project provides Technical Assistance to Caribbean countries through international and regional renewable energy (RE) and energy efficiency (EE) experts and through capacity building measures in RE and EE for staff members of energy ministries and electric utilities. Project countries are CARICOM member states and the Dominican Republic (CREDP 2009). The aims of the project are “Improved political, regulatory and institutional framework conditions and the development of specialist technological and economic competencies favorable to invest in RE/EE within the Caribbean region” (CREDP 2009, p 2).

3.1 Market Research for Development Projects

Development projects work like other projects. They are based on a continuous decision-making process. Information, as the essential foundation of decisions, is forming the basis of the project direction and control. Project managers have to be integrated into a decision-making process which relies on fundamental information. Those are reinforced by the expertise and evaluation skills of the project manager and on the other hand, on formal information (Kinnear & Taylor 1996). The better the available information is, the better the decision-making. The goal of a research process is the improvement of the relevant information.

Market research is the function which links the stakeholders through information. This information identifies and defines opportunities and problems; generates, refines, and evaluates actions; monitors performance; and improves the understanding of the process. Market research specifies the information required to address these issues; designs the method for collecting information; manages and implements the data collection process; analyzes the results; and communicates the findings and their implications (Kinnear & Taylor 1996).

The formal market research process can be seen as a procedure as illustrated in Figure 5, following Kinnear & Taylor (1996) and Berekoven (2001). First, the information needs had to be determined based on the problem, and from here, research hypothesis and objectives were deduced. This was done in chapter 1.2 and 1.3. Next step, covered in the following chapter, was to define appropriate data sources and how to collect them. The decision about the research frame is summarized before the case studies under chapter 4. Once the data was recorded, it was processed and analyzed. Presenting the results is the main part of this study, ranging from chapter 4 to 8. They are basis for the solution of the defined problem.

Figure 5: Steps of the Market-Research-Process



Source: following Kinnear & Taylor 1996 & Berekoven 2001

3.2 Information Sources and Research Method

Information can be generated out of secondary and/or primary market research. Secondary research is the extraction of information out of already existing data material. This can be research studies previously performed by government agencies, chambers of commerce, trade associations or others. If appropriate data sources are found, the researcher has to evaluate their accuracy. If there are no sources available, new data has to be collected by interviews or observations. This extraction of original data is called primary research (Berekoven 2001, Kinnear & Taylor 1996). A research to gather primary or secondary data can be qualitative or quantitative. Quantitative research is the study of numbers with the aim to find numerical patterns in responses to survey questionnaires or observed behaviors. Results then indicate the magnitude of people's decision and behaviors and how these are distributed across a study population (Gorbach & Galea 2007). The qualitative market research focuses more on the related experience, social and cultural factors. The basic direction is to trace theoretical questions in a certain context and help to develop a theory (Arnould & Thompson 2005).

Qualitative market research offers effective paths for the development of so far undiscovered circumstances and processes, with the main characteristics - increase of discovery, accessibility and complexity. It gives a solution to push the awareness process in a direction of more profoundness, better quality and higher degree of recognition (Buber & Holzmüller 2007). Secondly, it is very useful to capture private thoughts and feelings, preconscious factors (intuitive associations, self-evident, habitual and cultural derived attitudes) as well as emotions in complex conditions. A special strength of this method is its ability to reduce constraints of verbalizing (Ereaut, Imms and Callingham 2002). Thirdly, qualitative methods offer high effectiveness when generating insights and cognition. Because of the open, emphatic, interpretative and comprehensive approach, individual and social processes can be developed; which are extremely important for the market action (Arnould & Thompson 2005). The goal of this study was to define the solar market in the Caribbean as well as analyze its viability and thereby a qualitative market research was considered as the most suitable.

Qualitative approaches allow comprehensive research about individual affective feelings or cognitive patterns and processes, as well as the resulting behaviors. They are also very useful to collect and understand reactions to marketing actions, attitudes in markets

and against suppliers, mechanisms of long-term relationships as well as prognoses about future attitudes and therewith future reactions to supplier activities. Same applies also to group aspects in the market, for example what role certain groups play in the development of new market structures and in influencing other consumers or which mechanisms are remarkable for the purchase decision. Furthermore, qualitative methods are indispensable to get insights and knowledge about the whole market system (Buber & Holzmueller 2007). To gain those market insights, to understand the reactions, attitudes and mechanisms and thus to give a market prognosis was the key subject of this study.

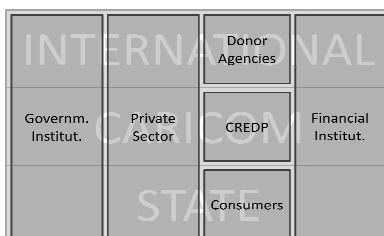
It is unlikely to find those features already documented, they have to be gathered and qualitative interviews are a very useful tool. The qualitative interview intends to get another quality of information which means the ascertaining of attitudes, images, behavioral patterns, barriers and blockades (Schub von Bossiazky 1992). The main application of qualitative interviews is to create confidence with the interviewee thus resulting in a higher willingness to respond, spontaneous comments, and accordingly manifold insights of different ways of thinking, sensing and acting. The ability to individually adapt expressions and the sequence of the questions increases the chance also to appeal half conscious or delicate problems (Berekoven, Eckert, and Ellenrieder 2001). There exist various forms of qualitative interviews. In this research paper the focus is set on expert interviews, within explorative conversations. Expert interviews were chosen among all important stakeholder groups of the solar water heater as well as the photovoltaic market. The very good connections of CREDP to the private sector, utilities and governments helped to nominate the experts and get key interviews in all desired research parts. A list of the interviewees can be found in the appendix.

In the data collecting process first, already existing data was collected by mainly literature review, online research and internal project documents. Secondly, new data was produced by primary research with the help of qualitative interviews. The expert interviews were primarily face-to-face interviews, supported by telephone and Email correspondence, to generate the primary data as well as confirm and discuss the secondary research results. Because of the individuality of the interviews and the gathered information, a qualitative approach was also chosen to process and analyze the data, gathered in the secondary and primary market research.

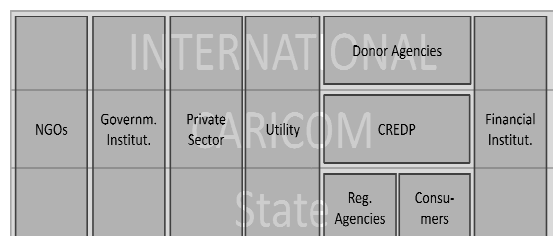
The analyzing process of the qualitative market research follows the iterative access through hermeneutics. Hermeneutic means the study of cognition; to meaningful interpret a phenomenon in a certain context and to decode and reconstruct it thus to understand the meaning (Knassmueller & Vettori 2007). A very important instrument to continually approach the meaning is the hermeneutic circle. It characterizes the process of comprehension based on previous knowledge. Through an iterative process of formation and examination of assumptions about the text, modification and advancement of this knowledge shall be reached (Heidegger 1927/1995). General knowledge and theoretical expectations will serve as orientation and shall increase the awareness of relevant aspects (Witzel1982). Due to the professional background of the researcher, through ex-ante secondary research and conversations with CREDP project colleagues, a certain necessary market understanding was assured.

To reach cognition, a combined deductive-inductive approach was used. In literature this method is also called qualitative content analysis (Mayring 2000). First, in a deductive step, already known theoretical concepts were identified and summarized in a preliminary category scheme. This categorization by stakeholders of the Caribbean solar market was done in chapter 2.2 and by establishing corresponding frameworks for solar water heater and photovoltaic technologies under 2.2.1 and 2.2.2, displayed below. Thereafter, this starting scheme was expanded step by step with the help of the gathered information in an inductive process until all elements of the qualitative data material were allocated in the category scheme. Frameworks for a market establishment can be found under chapter 5.1 and 6.1. By the gradual adaption based on the empirical information, new insights and findings were gained and thus amended frameworks for a successful market penetration are illustrated under chapter 5.3 and 6.3. This method postulates openness – the willingness to rethink and adapt already existing concepts (Srnrka 2007).

Solar Water Heater Framework



Photovoltaic Framework



The qualitative content analysis is an evaluation method of fixed communication (e.g. texts). With the help of categories it works systematically, rule and theory-oriented and is measured by quality criteria. The qualitative element is the development of categories and the content analyzed systematization of the allocation of the categories to text fractions. Fixed communication contents can be divided in two types of texts; already existing text material or within the research project produced material. The produced material has to be fixed by audio or video taping, ideally transcribed and enriched with comments. There exist different techniques for the qualitative content analysis. They can be text summarizing (reductive), explaining or structuring (Mayring & Brunner 2007). Most expert interviews were audio taped and afterwards transcribed. In rare cases, when audio taping was not possible, notes were taken and later supplemented as a comprehensible text. All text materials, gathered in the secondary and primary market research, then were iterative structured, systematically sorted and analyzed by the categories. Thereby, the stakeholder categories were reviewed under social, economic and environmental aspects.

The main questions to be answered among this research are summarized below. The questionnaires which served as rough interview-guidelines can be found in the appendix.

1. Objective: Gain an overview about the present solar energy situation

- How is the actual status of the solar market?
- How is the renewable energy share and what are the targets?
- Are there any governmental policies supporting or hindering the market?

2. Objective: Establish possible scenarios and corresponding attempts

- How did the solar water heater and photovoltaic market develop?
- Were or are there any incentives for solar technologies?
- What are the barriers and hindrances and how could they be overcome?
- What is the position of the utility towards photovoltaic technologies?
- What solar programs are offered by financial institutions?

3. Objective: Analyze the viability in terms of sustainability

- What are the main drivers and how is the awareness of social, economic and environmental aspects?
- Are the market mechanisms properly implemented to secure a sustainable development?
- How is the transferability to other markets?

To increase validity and reliability of a qualitative research method, four approaches have to be met; conformability, credibility, transferability and dependability. Conformability stands for neutrality and objectiveness and evaluates if the interpretation of the results was accomplished in a logical and unbiased way and if the conclusion is reflecting the most logical possibility. The credibility or validity can be increased by the evaluation and approbation of the research results by the interviewees, colleagues and experts. The aim is to demonstrate that the research was undertaken in a credible manner. Transferability is analog to the representativeness, which is high in case of similar results among different interviews and it is possible to generalize it. Dependability or reliability serves to indicate the level of stability and coherence of the measures (Riege 2007).

As a supporter of solar energy it was of course difficult not to be biased but continuous discussions with the CREDP colleague Sven Homscheid, M.Sc. Technical Advisor and specialist for hydro power plants, helped to neutralize the view and get aware of different aspects. The credibility and validity of the results was increased by comments and evaluations of different experts, Sven Homscheid, the CREDP consultant Winfried Klinghammer, an interviewee Dirk Burkhardt, Managing Director and Chairman of Grenada Solar Power Ltd. and Martin Heins, Sales Manager of the Renewable Energy Department in the Mitsubishi International GmbH, whose opinion was very important as an independent expert without any relations to the project but profound knowledge about the solar energy market. Unfortunately the research time was too short to distribute the results among other experts and interviewees to get more responses. Nevertheless, the study can be seen as representative because many similar answers were given and plausibility was proven by cross-checking.

One issue would be the reliability of the gathered economic data. Because of the relatively new and small markets, there did not exist a big variety of data which would allow comparisons. The calculations in chapter 5.4 and 6.4 are mainly based on statements of the private sector and manufacturers and installers generally tend to promote their products and make them look more attractive. Although there is the awareness of this problem, calculations might still be highly positive. Moreover, the questionnaires served well as a guideline but it was recognized that some questions are too complex and should be revised and simplified for further researches, especially for customers who have a very low knowledge about solar technologies.

4 Case Studies

After consultation with the CREDP team, it was decided to focus on three markets – Barbados, Grenada and St. Lucia, marked in Figure 1 under chapter 1.1. They are quite similar in size, population, economy and culture. The three markets therewith seemed to reflect an appropriate sample, at least for the Eastern Caribbean region. Barbados is known for its exemplary development in the field of solar water heaters and Grenada for their pioneer position in photovoltaic implementations. Both markets can be seen as best practice cases for the corresponding technologies and serve as an example how markets developed and what helped them foster. Solar water heaters as well as photovoltaic systems also exist in St. Lucia but penetration is stagnating as opposed to Barbados and Grenada. This means that the research in St. Lucia helped to identify market barriers and hindrances.

Barbados, Grenada and St. Lucia are states in the Lesser Antilles island group. The climate in this region is tropical, oceanic with an average, very constant temperature of 26.8°C. Weather seasons can be classified as wet or dry. The wet season is coinciding with the Atlantic hurricane season, from June to November. Because of their regional and climatic similarities, especially in solar insolation, ranging within a year from five to seven kWh per square meter per day, as illustrated in Figures 6-8, those three islands offer very good conditions to draw a framework for solar water heater and photovoltaic systems. Doing a research about those three markets helped to identify main market mechanisms which can be transferred to other Caribbean islands.

Figure 6: Barbados, Bridgetown - Solar Energy and Surface Meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m ² /day	5.42	6.03	6.58	6.86	6.79	6.43	6.58	6.52	6.06	5.64	5.16	5.13
Clearness, 0 - 1	0.65	0.65	0.65	0.65	0.64	0.61	0.63	0.62	0.60	0.60	0.60	0.63
Temperature, °C	25.73	25.34	25.36	25.75	26.46	26.71	26.58	26.70	26.74	26.65	26.57	26.31
Precipitation, mm	63	39	37	45	57	98	134	154	159	178	177	96
Wet days, d	13.3	8.3	8.4	7.3	9.8	14.5	18.4	16.4	15.5	15.3	16.5	14.5

Source: GAISMA 2010

Figure 7: Grenada, Saint George's - Solar Energy and Surface Meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m ² /day	5.54	6.19	6.79	7.00	6.88	6.35	6.49	6.49	6.23	5.76	5.25	5.21
Clearness, 0 - 1	0.65	0.66	0.67	0.67	0.65	0.61	0.62	0.62	0.61	0.60	0.60	0.63
Temperature, °C	25.84	25.54	25.62	25.98	26.57	26.71	26.52	26.69	26.74	26.67	26.62	26.42
Precipitation, mm	78	57	59	58	76	155	203	195	186	207	182	138
Wet days, d	14.4	9.4	9.7	7.1	13.2	17.2	19.8	18.3	17.5	16.8	19.8	17.6

Source: GAISMA 2010

Figure 8: St. Lucia, Castries - Solar Energy and Surface Meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m ² /day	5.29	5.95	6.53	6.86	6.78	6.47	6.60	6.50	6.05	5.71	5.02	4.98
Clearness, 0 - 1	0.64	0.65	0.65	0.65	0.64	0.61	0.63	0.62	0.60	0.61	0.59	0.62
Temperature, °C	25.63	25.23	25.26	25.64	26.35	26.69	26.64	26.75	26.76	26.65	26.54	26.22
Precipitation, mm	113	86	76	96	124	182	245	216	224	269	255	149
Wet days, d	17.2	12.9	12.9	11.0	15.3	18.8	20.7	20.1	24.5	17.8	19.1	17.8

Source: GAISMA 2010

4.1 Case Study Barbados

Barbados has an area of 430 km² and an estimated population of 284,589 (Central Intelligence Agency (CIA) Barbados 2010). Despite its small size, Barbados has a relatively high per capita income of 18,500 USD estimated in 2009 (CIA Barbados 2010), making it even a high-income economy, according to The World Bank (2010). Because of its soil, topography and climate, sugar, manufactured from sugar cane, has traditionally been the island's most significant export product, but during the 1970s tourism also emerged as a major foreign exchange earner (Sealy 2007).

Barbados has its own limited oil resources which are used to cover some of their energy needs (Loy 2007). Oil reserves aggregate 2.17 million bbl (2009 est.). The oil imports are 10,390 bbl/day and exports 1,750 bbl/day, according to a CIA estimation for 2007 (CIA Barbados 2010). Proved reserves of natural gas are 141.6 million m³ (2009 est.). The production and consumption made up 29.17 million m³, estimated in 2008 (CIA Barbados

2010). Electricity generation with about 50% and transportation with over 30% are the two largest consumers of the imported fuel, whereas the fossil fuel combustion for electricity generation accounts for 74% of all CO₂ emitted by the country, with transport contributing 14% (Energy Policy Committee 2006). In 2006 the energy consumption per capita was 1,451 kg oil equivalent (Sealy 2007).

4.1.1 Energy Market Actors

Electric Utility

The company Barbados Light & Power Company Limited (BL&P) is an investor owned electric utility and is in operations since June 17, 1911. With 63%, the main part of the shares belong to Barbadian investors (the largest is the National Insurance Board with 28%) and the remaining 37% belong to the Canadian International Power Co. Ltd. The electricity supply network serves the entire island, with only a few exceptions. The electricity is supplied by diesel generator plants, and most of the electricity is produced from the least expensive residual fuel oil (BL&P 2010a). Some locally available natural gas is burned in the steam boilers but this accounted for less than 1% in 2008 (BL&P 2009a). BL&P has a license till 2028 and has a monopoly for power production, transmission and distribution (Loy 2007). The Barbados electricity market is not liberalized and open for new entities yet.

Regulatory Agency

In January 2010 The Fair Trading Commission, a regulatory agency, was established to “Safeguard the interests of consumers, to regulate utility services supplied by service providers, to monitor and investigate the conduct of service providers and business enterprises, to promote and maintain effective competition in the economy and for related matters” (Fair Trading Commission Barbados 2009, p.3).

Governmental Institutions

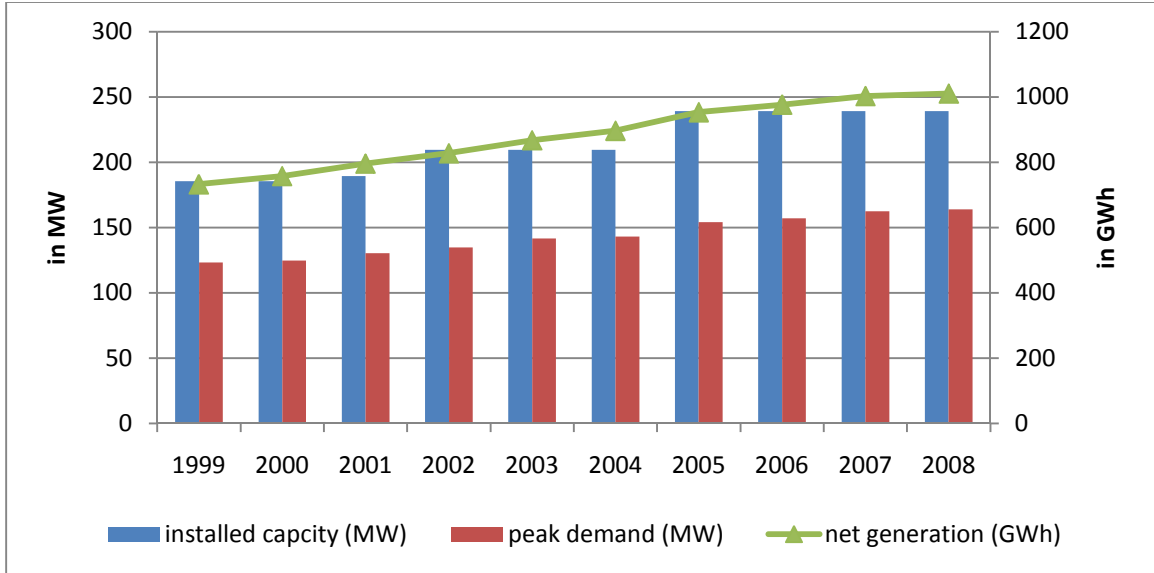
The Ministry of Finance, Economic Affairs and Energy is responsible for decisions regarding natural resources, public utilities, the National Petroleum Corporation and the Barbados National Oil Company (Loy 2007). Besides that, the Ministry is gearing toward “promoting energy conservation practices and the use of renewable energy technologies, where possible, and becoming self-sufficient in oil and gas production; plans to develop

renewable sources of energy are focused on wind energy, solar photovoltaic, solar thermal, fuel cell and biogas/biomass” (UN 2004, p.3).

4.1.2 Electricity Sector

In 2008 BL&P had an installed capacity of 239.1 MW, with a peak demand of 164.0 MW and produced 1010.5 GWh electricity (BL&P 2009b). Peak power demand in 2009 was 165.7 MW and the consumed energy 952 GWh (BL&P 2010b), see also Figure 9. Total costs of the fuel purchased amounted to 297 million BBD/145.5 million USD, representing approximately two-thirds of the costs of electricity (BL&P 2009b). For electricity production, 90% of fuel oil, 2.5% of natural gas and as remainder diesel were used (Energy Policy Committee 2006). In 2005 BL&P replaced older producing plants by adding 2 new generators with a power of 30 MW and an increase of 14% of total installed capacity was achieved. By those more efficient generators, using low-grade-heavy fuel, impacts of increasing oil prices could be reduced (Loy, 2007).

Figure 9: BL&P Electricity Capacity and Generation

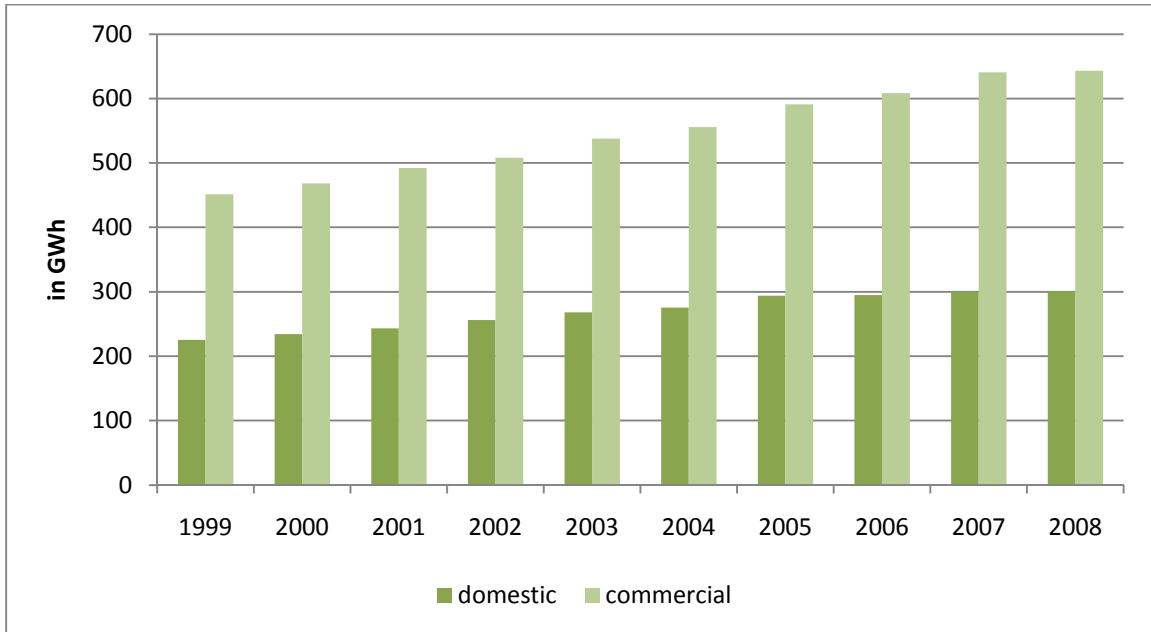


Source: BL&P 2004-2009b

In 2008 the domestic sector consumed 301 GWh and 634 GWh were sold to the commercial sector. As illustrated in Figure 10, there was a big jump in electricity sales of the private and commercial sector of more than 6% from the year 2004 to 2005, clearly

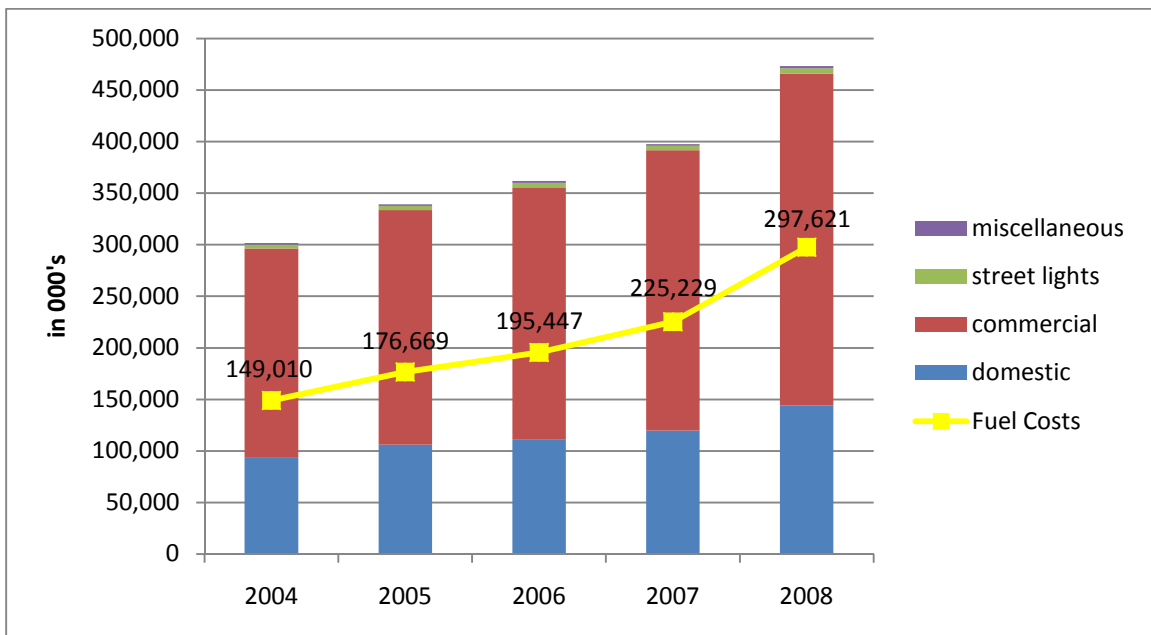
more than the average of 4.1% as of the last 5 years (BL&P 2009b). From 2007 to 2008 consumption only increased by 0.3%. This means customers were able to cut back electricity usage, which was promoted by BL&P.

Figure 10: BL&P Electricity Sales



Source: BL&P 2004-2009b

Figure 11: BL&P Electricity Revenues



Source: BL&P 2004-2009b

Figure 11 shows, that BL&P had revenues of 473.3 million BBD in 2008 which was about 243.3 million USD. After the domestic sector with about 144 million BBD, the commercial sector had the biggest share with 321.7 million BBD. A very small share had street lights with 5.2 million BBD and miscellaneous with 2.2 million BBD. Something very interesting to see is that electricity sales only increased slightly but the revenues from 2007 to 2008 increased more than 20% for the domestic sector and more than 18% for the commercial sector. This indicates that higher costs, which would basically be a higher fuel price, were transferred to the customers. Reason was the oil shock of 2007-2008.

Electricity rates are subject to the approval of the Fair Trading Commission. There are four types of tariffs covering services offered by the company. They are: Domestic Service, General Service, Secondary Voltage Power and Large Power. The Domestic Tariff for example, is calculated as seen below in Figure 12, from a Customer Charge, which are monthly lump sums and covering the fixed costs of providing service installation, meter reading, billing and customer service costs. The monthly Customer Charge is determined based on the customer's average energy consumption in kWh (BL&P 2010a).

Figure 12: BL&P Domestic Tariff

Customer Charge	Rate	VAT	Total inc. VAT
0-150 kWh	\$6	\$0.90	\$6.90/Month
151-500 kWh	\$10	\$1.50	\$11.50/Month
Over 500 kWh	\$14	\$2.10	\$16.10/Month
Energy Charge	Rate	VAT	Total inc. VAT
1 st 150 kWh	\$0.150	\$0.0225	\$0.1725/kWh
Next 350 kWh	\$0.176	\$0.0264	\$0.2024/kWh
Next 1000 kWh	\$0.200	\$0.0300	\$0.2300/kWh
Next 1500 kWh	\$0.224	\$0.0336	\$0.2576/kWh
Fuel Charge			
All kWh at the Fuel Clause Adjustment (cents/kWh) + VAT			

Source: BL&P 2010a

Additionally, a fuel charge for each kWh is applied for the cost of fuel associated with the provision of this service. The Fuel Clause Adjustment is calculated according to the Fuel Clause approved by the Fair Trading Commission and may vary from one month to another (BL&P 2010a).

Because of the oil prices, BL&P increased the fuel charge from 5.6 US-cent/kWh in June 2002 to 10.5 US-cent/kWh in August 2006, and within this 4 years period the average electricity bill increased by over 28%, which had a negative impact on the competitiveness of the manufacturing and tourism sectors (Energy Policy Committee 2006). Two years later in August 2008, for commercial customers the fuel charge was even 24.5 US-cent/kWh and dropped to 5.9 US-cent/kWh in December. Residential customers were cushioned from the full impact of the increase through a government subsidy on fuel oil. It was introduced at end of December 2007 and held the Fuel Clause Adjustment at 11.7 US-cent/kWh. It cost the government about 36 million BBD (about 18 million USD) and was discontinued in November 2008 when the Fuel Clause Adjustment fell below subsidized levels (BL&P 2009b). Giving subsidies for electricity by governments is a very rare and exceptional case because usually governments do not have the necessary financial surplus and operate with a deficit (Auguste pers. comm. 27 April 2010). A CARILEC survey confirms that electricity rates in Barbados are among the lowest in the region (BL&P 2009a), which is due to their own oil reserves. Electricity prices as of March 2010 were 0.58 BBD/0.28 USD (Husbands pers. comm. 24 March 2010)

4.1.3 Renewable Energies

Renewable energies actually have a long history in Barbados. When sugar was introduced in the middle of the seventeenth century, soon several hundred multi-bladed windmills were used to pump water on the sugar plantations, but most of them have been dismantled by now. Sixty years ago, even 50% of Barbados primary energy was generated from renewable energies, when sugar cane waste or bagasse was the main source of process heat for the 22 sugar cane factories (Headley 2000). Today, renewable energies would have a share of 15% of the overall energy mix, basically because of the extend use of solar water heating systems which replace common electrical devices (Loy 2007). But solar water heaters do not generate electricity as other renewable energy technologies and are therefore often neglected and not included in the country's energy mix. That is why the renewable energy share for Barbados is often stated with 0%.

Because of increased economic growth over the last decades and the accompanied increased energy consumption, the Government of Barbados had the plan to develop and implement a national energy policy to mitigate the negative impacts of oil prices and take further advantage of national renewable energy resources. They proposed a Barbados Energy Policy (BEP), based on the principles of the Barbados Sustainable Development Policy. The Energy Policy Committee (2006) suggested some objectives such as the provision of adequate and affordable energy as a prerequisite for a decent quality of life, to maximize the efficiency of energy use, to reduce dependence on fossil fuels with more emphasis on renewable energies, to use an integrated mix of regulation, economic and market-oriented approaches and to increase participation of the private sector in a competitive energy sector. Targets have been set to reach 10% of the national energy usage from renewable sources like wind farms, bio-fuels, ethanol, biodiesel and solar water heaters by 2012 and 20% by 2026. To reach those targets, the government would ensure that adequate financial, technical, legislative and administrative capacity as well as education and research are provided. Furthermore, an establishment of a Renewable Energy Center was announced in that draft (Energy Policy Committee 2006). Unfortunately the government changed right after issuing the draft and a national energy policy for Barbados has still not been published yet.

BL&P is well aware of their dependency on oil and the need to diversify their energy sources. In January 2008, a new Democratic Labour Party administration was elected under the leadership of Prime Minister David Thompson and has stated its support for the increased use of renewable energy. For several years the Company has been seeking to introduce wind energy into the electricity mix and at the end of 2008 was still awaiting a decision on its application to the Town & Country Development Planning Office to construct a 10 MW wind farm at Lamberts, St. Lucy (BL&P 2009b). BL&P is also in discussions with the Cane Industry Restructuring Project for the supply of a 15-20 MW firm capacity from a proposed co-generation plant which would utilize bagasse from the new sugar and ethanol processing facility that the government proposes to commission at Bulkeley, St. George. However, currently there is considerable uncertainty about the project (BL&P 2009a).

4.1.4 Solar Water Heater

Barbados has a high standard of living and is considered among the leading developing countries in the world. Electricity coverage is about 100% and virtually all households have running water. Hot water is therefore not viewed as a luxury but as basic requirement (Langniss & Ince 2004). The implementation of solar water heaters was a big success and in the use of this technology, Barbados is the leader in the Caribbean. In 2009, inhabitants benefited from the 45,000 installed solar water heating systems, which were two out of five households (Epp 2009). According to some expert interviews, there might be even 50,000 SWH installed by now (Husbands pers. comm. 24 March 2010, McClean pers. comm. 29 March 2010). Henry Jordan, Director of Sunpower, (26 March 2010) does not think that this number was reached yet. According to him, penetration is about 40%. Anyhow, Barbados has the third highest per capita use of solar water heaters in the world (Meyer 2008) which is very remarkable for a solar water heater market.

A first solar water design was introduced in Barbados in 1964. This project was conducted with church members, but as many new technologies; it did not quite meet the requirements and expectations in terms of appearance and performance (UNDP 2008). The commercial break-through started during the first oil crisis with a small solar thermal industry in the early 1970s. James Husbands of Solar Dynamics pioneered the industry's development with a small loan of 4,200 USD. Peter Hoyos of Sunpower followed in 1978, who just switched off his electric water heater for 2 months and observed the savings of his electricity bills (Headley 1998). In 1983 a third company called Aqua Sol also entered the market. To meet customers' needs, products were improved to heat water to approximately 135°F/57.2°C, cope with salt air, tolerate the calcium-laden hard water of Barbados, withstand hurricane conditions, overcast conditions and be aesthetically pleasing (UNDP 2008).

The system manufacturers went from door to door informing the people about solar water heating and because of the competition the market established. Technology and cost-effectiveness impressed the government and policies for fiscal incentives were established which are still in place (Epp 2009). There are certain tax concessions for solar thermal applications as import tax releases for manufacturers as well as tax deduction for installations – the costs of the system can be subtracted in full amount of

the income tax. On top of that, a consumption tax of 60% is charged for all electrical water heaters which makes their purchase unattractive (Loy 2007). Starting in 1974, tax incentives soon came under close scrutiny by the Ministry of Finance. But a consultancy report suggested that the benefits of the incentives far outweighed the governmental revenue losses and that the incentives should be kept in place to ensure the success of the sustainable energy program. Nevertheless, incentives were withdrawn in 1993 because the economy was faced with structural adjustment problems. This had a critical effect on the industry, resulting in a decline in purchase of solar water heaters. Three years later, the government of Barbados reintroduced the initiative which relieved the industry (UNDP 2008).

To maintain market growth and to become a self sufficient market, the government committed to use solar water heaters in its housing program with the National Housing Corporation, a division of the Ministry of Housing. Another big effort by the government was to communicate the cost-effectiveness of solar water heaters to the population and educate them (Epp 2009). Solar Dynamics supported this promotion with participation at seminars, workshops, exhibitions and recordings of success stories. The involvement and participation of the government helped Solar Dynamics to its success (UNDP 2008).

To improve consumer's confidence, system efficiency was enhanced, manufacturers established and maintained a policy of installing only properly sized systems suitable for their perspective use and did a voluntary testing of a 66 gallon unit at the Florida Solar Energy Center (Epp 2009). A summary of incentives is listed in Table 3.

Incentives for renewable energies in general are used to reach certain targets, like lower installed costs, reduce risk, help to create a market and to capture social benefits like reducing environmental emissions and oil imports. But of course, there is always the question if the incentives are a prudent justifiable use of taxpayer's money. This question was answered by James Husband in 1994, mentioning that the installed solar water heaters between 1974 and 1992 produced total energy savings of 50 million USD and cost the government 6.6 million USD in revenue (Perlack & Hinds 2008).

Table 3: Solar Water Incentives in Barbados

Incentives	Description
1974 Fiscal Incentive Act of 1974	Elimination of import tariffs on raw materials to manufacture solar water heaters Imposition of consumption tax on electric water heaters
1980-1992 Homeowner Tax Benefit	Income tax deduction (allowed homeowner to claim the cost of the solar water heater on his income taxes up to 3500 BBD)
1993 Cut of Homeowner Tax	Elimination of income tax deduction
1996 Re-Installment of Homeowner Tax (amended)	Home improvement tax deduction (allowing homeowners an annual deduction up to 3500 BBD for mortgage interest, repairs, renovation, energy or water saving devices, solar water heaters, and water storage tanks)
In addition to Incentives	Government purchased a significant number of solar water heaters for housing development projects

Source: Perlack & Hinds 2008, Headley 2001

In 2001, Barbados accounts for more than 60% of the solar water heaters in the Caribbean region and is responsible for about 80% of manufacturing (Ministry of Physical Development Environment 2001). By the end of 2007 the number of solar water heaters produced outside of Barbados was assumed to be 10,000 per year (Energy Policy Committee 2006). Once the market is mature, it is also able to export its technology. Barbados industry made indeed successful steps beyond the island's border. Other main markets besides Barbados are St. Vincent, St. Lucia, Grenada, Antigua and Dominica (Husbands pers. comm. 24 March 2010, Jordan pers. comm. 26 March 2010). Aligning with the different islands solar water heaters are basically sold by distributors with higher purchase rates of 12-15% (UNDP 2008).

Over the years, Barbados has also tried to encourage other Caribbean islands to follow its lead in embracing solar water heating. Institutions such as the Caribbean Hotel Association and the Caribbean Tourism Organization are trying to encourage hotels in the region to use solar water heating and benefit from using this clean technology (Ministry of Physical Development Environment 2001).

4.1.5 Photovoltaic Technology

The first use of photovoltaic systems was for telecommunications to power microwave repeater stations, and navigational aids in remote areas (Headley, 2000). By the end of the 90's, the government had the desire to have the same positive image for photovoltaic as for solar water heater technologies and installed various demonstration projects. By 2001 there were over 30 kWp photovoltaic systems at various sites installed in Barbados, all financed by the government (Ministry of Physical Development Environment 2001).

The systems are:

- 1100 Wp at the University of the West Indies for solar cooling
- 17,300 Wp at Harrison's Cave for running the cave's lighting system
- 3,000 Wp at Combermere School for operating a computer laboratory
- 11,100 Wp at the Skeete's Bay fishing complex on the island's East Coast powering a one-tonne-per-day solar ice maker for the fisher-folk
- a 300 Wp portable photovoltaic system is used to demonstrate the flexibility and versatility of the technology to members of the public

Source: Ministry of Physical Development Environment 2001

Unfortunately the photovoltaic installations stagnated due to missing adequate analyses and their appropriateness for particular applications in the market. Local architects, builders and engineers were not convinced, and high initial costs seemed to be a big burden. Nevertheless, interest kept on growing (Moseley & Headley 1999).

BICO Ltd., an ice cream factory in Barbados, has been independent from the local utility for more than 12 years with its own diesel generator and is considering producing their high electricity demand with renewable energy, mainly with photovoltaic installations. After a fire which destroyed the factory and because of the increasing oil prices, they already started with a 9 kW system of thin-film modules and would have a potential roof area for about 700 kW. Edwin Thirlwell, Executive Chairman, sees BICO as a pioneer and wants to give the people confidence. He mentioned that the ministries are keen about looking at BICO as a big and important company, needing a success story (Thirlwell pers. comm. 25 March 2010).

Also, the utility BL&P has moved towards photovoltaic technologies. In 1995 they became a member of the Solar Electric Power Association (SEPA) and shortly after installed two 2,000 Wp photovoltaic systems, one at its Sewell substation in the year 2000 and in 2005 at the Future Center Trust in St. Thomas (BL&P 2009a). Furthermore, BL&P submitted an application for a review of its electricity rates in May 2009. Last time rates were changed was in 1983 and they needed an update, so Peter Williams, Managing Director of BL&P (pers. comm. 25 March 2010). Among a Time-of-Use and an Interruptible Service Rider they also established a Renewable Energy Rider (RER), proposing a 1.8 Fuel Clause Adjustment or 0.315 BBD/kWh whichever is greater. This means the customer will be reimbursed for the electricity he is generating with his renewable energy system by 1.8 times of the actual utility's fuel clause. In case of a low fuel charge, a price of 0.315 BBD/kWh (about 0.16 USD/kWh) is guaranteed. The RER rate was calculated by BL&P based on avoided fuel costs. The size restriction is 5 kW for residential and 50 kW for commercial customers, with an overall maximum of 1600 kW (Fair Trading Commission 2010).

The proposed rates of BL&P were accepted by the Fair Trading Commission in March 2010 but they advised that the pilot programs should not be undertaken for more than 2 years from the date of tariff implementation which should not be later than the beginning of July 2010 (Fair Trading Commission 2010). BL&P sees the positive aspects of implementing renewable energy in cost deductions, increase security by diversification and environmental protection, which also has positive effects for the tourism industry (Williams pers. comm. 25 March 2010). Furthermore, BL&P is aware of their important position within society. As the only electricity provider, they want to please their customers and Williams (pers. comm. 25 March 2010) states: "When the company is doing well, also the country is doing well."

To coincide with the installation of photovoltaic systems, government offered training workshops to ensure that the capacity is developed to sustain a solar photovoltaic industry. One workshop was held for technicians and another for students of secondary schools to cover the fundamentals of project management, systems design, installation and maintenance. The schools received training in designing and assembling a system and each school received a photovoltaic panel at the end of the workshop for project developments (Ministry of Physical Development Environment 2001).

4.2 Case Study Grenada

Grenada is a three island state and includes Grenada, Carriacou, and Petit Martinique. Because of its small sizes Carriacou, and Petit Martinique will not be considered in this study. Grenada is located in the Eastern Caribbean south of Barbados, only 100 miles north of Venezuela (Grenada Guide 2005). It has an area of 344 km² and 90,739 inhabitants (CIA Grenada 2010). Grenada's estimated GDP per capita in 2008 was 13,200 USD (CIA Grenada 2010), so the World Bank (2010) has classified it as an upper-middle-income economy. The main industries are in food and beverages, textiles, light assembly operations, tourism and construction (CIA Grenada 2010). Grenada lies on the edge of a hurricane belt and was struck by hurricane Ivan in September 2004 causing huge damage estimated to be as high as 2.5 times the GDP. In 2005, hurricane Emily struck but with far less severe effect (Climatelab 2010).

As most of the other Caribbean states, Grenada also heavily depends on fossil fuel imports and spends half of their export earnings on it (Loy 2007). It has no natural resources, although there might be some unexplored gas and oil resources off its coast (Loy & Farrell 2005). Recently Grenada was in talks with Trinidad & Tobago to clarify their borders on the sea (pers. comm. Auguste 27 April 2010).

4.2.1 Energy Market Actors

Electric Utility

The Grenada Electricity Services Ltd. (GRENLEC) is the sole electricity provider for Grenada, Carriacou and Petit Martinique since 1960 with a license until 2073. In the electricity act it is mentioned that generation of electricity for private self-use is allowed only if GRENLEC and the government agree. Since 2001, efforts were made to change this act but so far it only exists as a draft. For their power production, GRENLEC use solely diesel generators. GRENLEC is private owned (Loy 2007, GRENLEC 2010). In 1994, the company was partially sold; the company WRB Enterprise, Inc. from Florida is main share holder with 50% of shares. Other small GRENLEC shares are distributed among employees, local investors and the Government of Grenada (10%) (Loy & Farrell 2005).

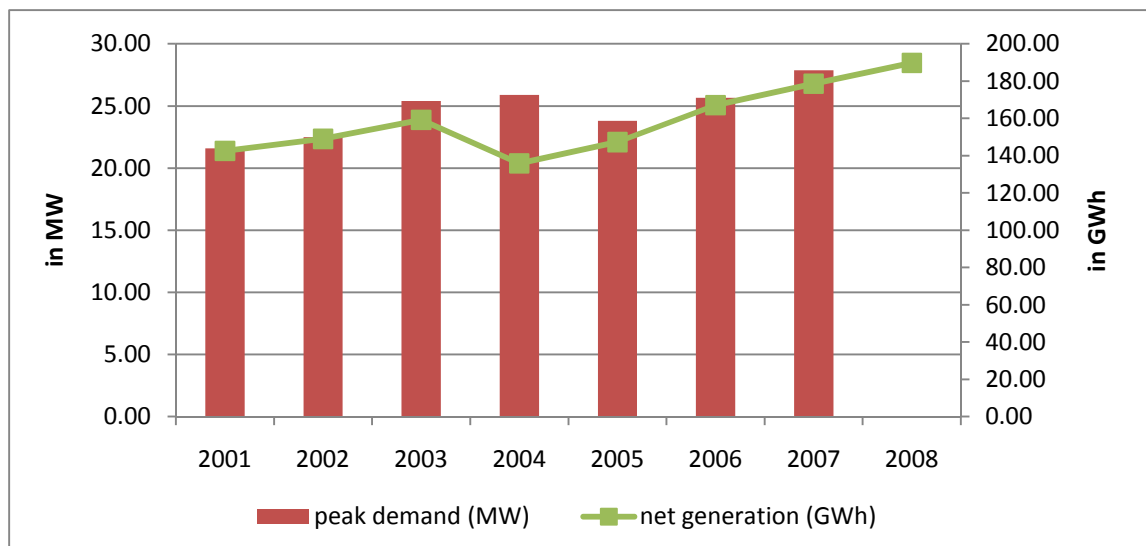
Governmental Institutions

Since late 2003, the Ministry of Agriculture, Land, Forestry, Fisheries, Public Utilities, Energy and the Marketing and National Importing Board (MNIB) are responsible for the energy sector and the formulations of policies. Thus, Grenada is one of a few countries in the OECS with a specialized energy desk within the government (Loy & Farrell 2005). The Ministry of Finance and Planning is in charge for the modeling and implementation of the National Climate Change Policy and Action Plan. A liberalization of the energy sector is allotted in the future (Loy 2007).

4.2.2 Electricity Sector

In the beginning of 2007, installed capacity in Grenada was 45.1 MW (Loy 2007) and net generation achieved almost 190 GWh in 2008 (GRENLEC 2009). GRENLEC projects that a capacity increase of 8 MW will be necessary to satisfy the demand growth and maintain its capacity reserve policy by mid 2011 (GRENLEC 2008a). As can be seen in Figure 13, there was a sizeable break of electricity generation in 2004, of almost 15%. This was due to hurricane “Ivan” and its disastrous damages in September 2004. Reconstruction of the totally destroyed electrical grid took place until April 2005 (Loy 2007). Full net generation recovery after the hurricane was reached again in 2007 and increased further about 6.25% in 2008.

Figure 13: GRENLEC Electricity Generation

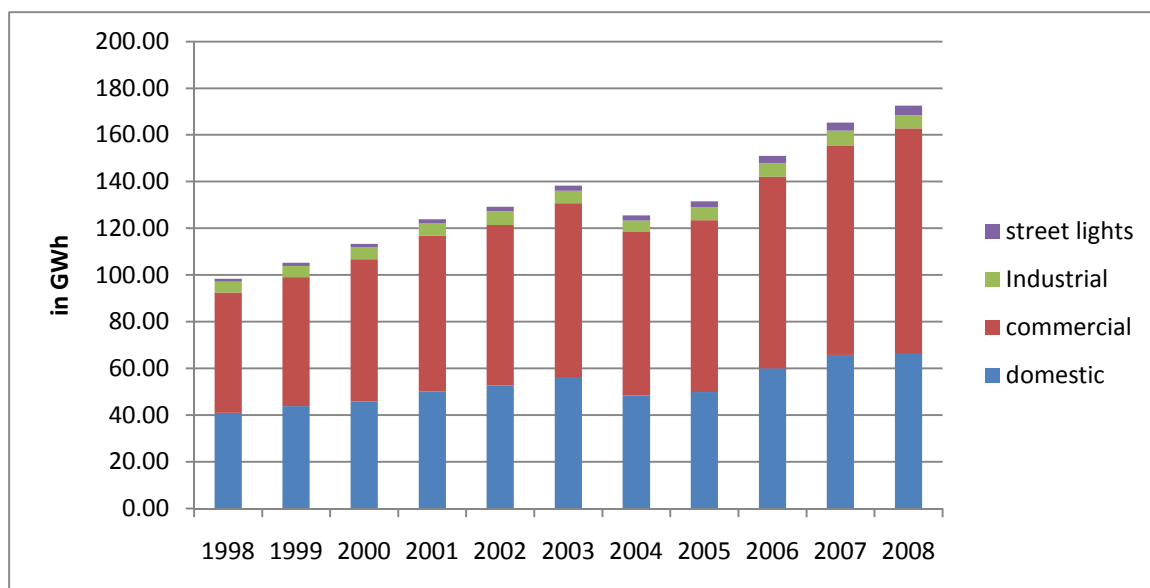


Source: GRENLEC 2003-2009

In 2008 GRENLEC generated 173.3 GWh, which was a growth of 4.41% compared to 2007. The company assumes that customers applied conservation practices because of the high prices, which they strongly advocate and even had an education campaign. Peak demand increased from 27.89 MW in 2007 to 29.39 MW in 2008, an increase of 5.3% (GRENEC 2009).

The biggest part in consumption per GWh is the commercial sector, followed by the domestic, Figure 14. In 2008, GRENLEC sold 96.60 GWh to the commercial and 66.23 GWh to the domestic sector. Total sales including the industrial sector with 5.63 GWh and street lights with 4.04 GWh, were 172.50 GWh (GRENLEC 2003-2009).

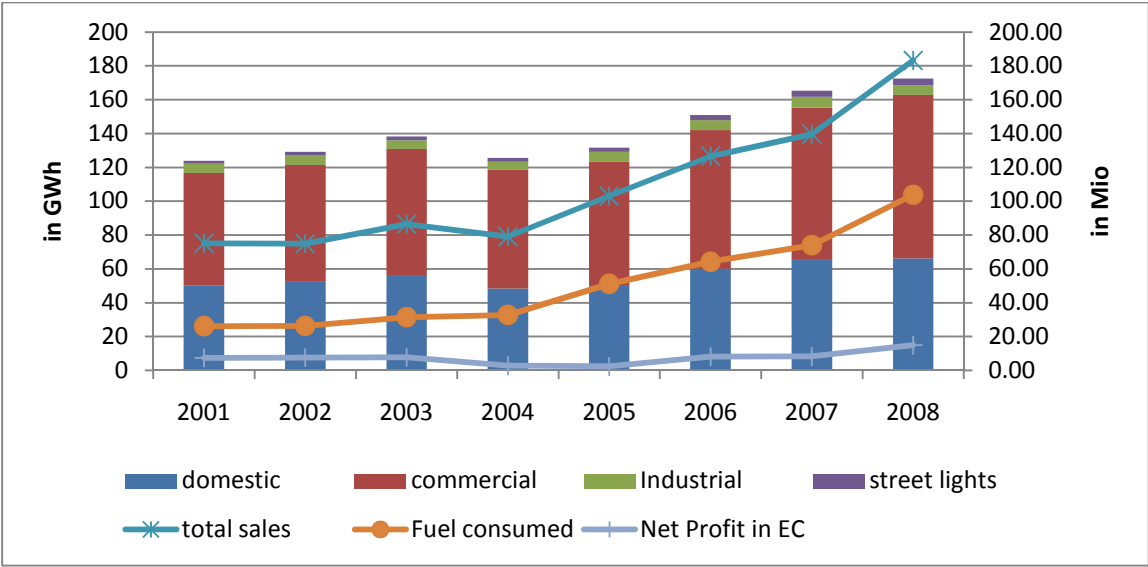
Figure 14: GRENLEC Electricity Sales



Source: GRENLEC 2003-2009

As illustrated in Figure 15, total sales reached 183.20 million ECD (about 67.32 million USD), cost for fuel consumed were 103.81 million ECD and the net profit was 14.86 million ECD in 2008 (GRENLEC 2003-2009). The overall end revenue of 2008 was 188.85 million ECD, which was an increase of 33.6% compared to 2007 (GRENLEC 2009). During the last years, the average consumption per customer was over 4000 kWh (GRENLEC 2003-2009). According to Loy & Farrell (2005), this is considerably higher than in other island states of the Eastern Caribbean.

Figure 15: GRENLEC Revenues

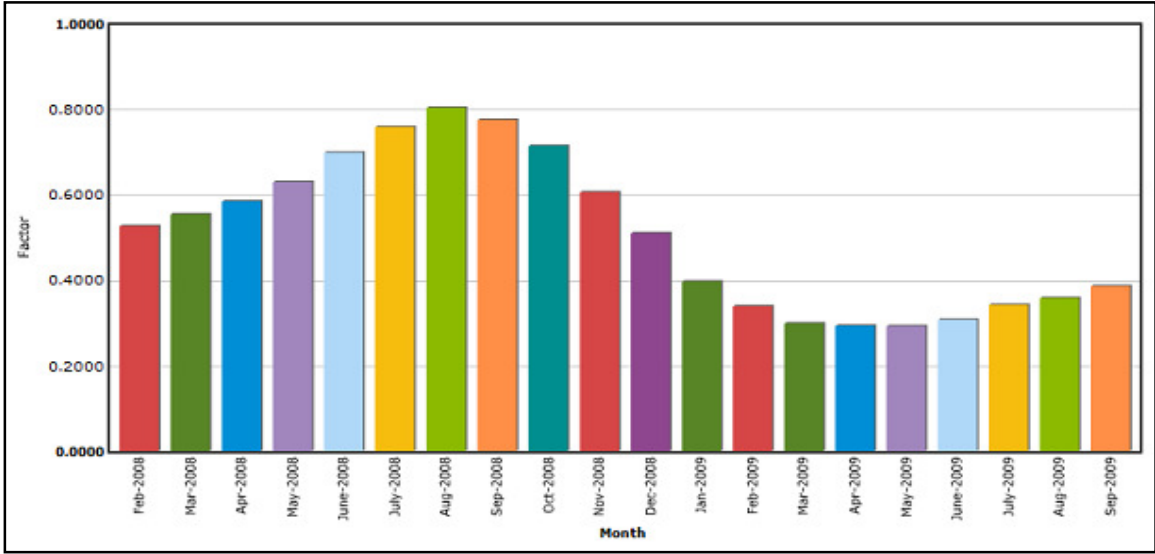


Source: GRENLEC 2003-2009

Electricity prices are similarly calculated as in Barbados. The domestic, commercial, industrial and street light customers are charged based on a fluctuating fuel charge and a fixed non-fuel charge. Additionally, all customers have to pay a government charge of 5% of the non-fuel charge. Domestic customers are also charged an Environmental levy, depending on consumed units (GRENLEC 2010). Domestic average electricity cost is very high. The reason is the high fuel charge, which increased considerably with the global oil price trends. In 2003, fuel charge was about 40% of the basic electricity rates and increased to 42.7% in 2005. The surcharge increased from approximately 97 USD/MWh in 2004 to 139 US/MWh in 2005 (Loy 2007).

Between January and July 2008, when oil prices increased by 60%, Grenada’s fuel charge climbed up to 0.30 USD/kWh (0.80 ECD/kWh) and resulted in an electricity price of 0.44 USD/kWh in August 2008, Figure 16. Customers complained bitterly about those high rates. It declined to a fuel charge of 0.19 USD/kWh (0.50 ECD/kWh) and an electricity rate of 0.33 USD/kWh by the end of 2008 (GRENLEC 2009). According to John Auguste (pers. comm. 27 April 2010), Senior Energy Officer in the Ministry of Finance, Planning, Energy, Foreign Trade & Co-operatives, the average electricity prices in Grenada are above 0.80 ECD, which are 0.27-0.30 USD. At the time of the research, the electricity rate was 0.85 ECD, which was equivalent to 0.31 USD (Burkhardt, D. pers. comm. 27 April 2010)

Figure 16: GRENLEC Fuel Charges 2008-2009



Source: GRENLEC 2010

4.2.3 Renewable Energies

There is no official renewable energy share in Grenada. So far there are some Photovoltaic systems accounting for about 200 kW, which the government sees as an achievement because there were none 5 years ago, as stated by Auguste (pers. comm. 27 April 2010). A private wind plant is not fully commissioned yet and still in the pipeline. Grenada also thought about a mini hydro power plant at the Concord waterfalls but this was turned down by the national water and sewage company stating that this would be their mayor source of water supply (Auguste pers. comm. 27 April 2010).

There is no official governmental renewable energy policy in Grenada but there is an incentive for a release of consumption tax of renewable energy products. In 1974, with the Hotel Incentive Act was set that commercial and industrial entities can apply with government and take advantage of fiscal and economical concessions. Individuals can also apply to the Ministry of Finance and receive duty free concessions, which means that applicable duties will be deducted or zero rated (Auguste pers. comm. 27 April 2010). Already in 2001 a Sustainable Energy Action Plan (SEP) was developed by the Global Sustainable Energy Island Initiative (GSEII), proposing a strategy of the advancement of renewable energies but so far this plan was not adopted by the

government yet. After the hurricane in 2004, a National Climate Change Policy and Action Plan was discussed and adopted by the government in 2007. This plan is asking for liberalization of the energy sector and comprehensive arrangements in favor of renewable energies (Loy 2007).

To facilitate the use of renewable energies, GRENLEC has passed an Interconnection Policy which provides clear guidelines for the interconnection of renewable energies to the company's grid. The policy provides net metering (electricity inflow and outflow are rated the same) for renewable energy sources of 10 kW or less. GRENLEC also continued negotiations to finalize the lease of sites in which to install two wind farms. Wind loggers are already installed and have begun measuring (GRENLEC 2009). The government is pursuing funding from GEF and the European Union Energy Facility for renewable energy and efficiency projects including the GRENLEC installation of wind turbines with battery storage in Carriacou to provide all its electricity generation requirements by 2013 (Burke 2010). GRENLEC is also thinking about using geothermal energy because this could support the base-load and therewith has good prospects (Auguste pers. comm. 27 April 2010).

The Grenadian government states in their Budget Statement of 2010 that a "Prioritization of energy conservation, the use of renewable energy and the environmentally sound exploitation of any offshore hydrocarbon reserves are the core elements of the national energy policy" (Burke 2010, p. 74). Of course Grenada is trying to explore possible oil resources. Nevertheless, the government also intends to develop a legislation to prescribe binding targets for the use of renewable energy for electricity generation and transport as well as a methodology for determining the GRENLEC tariffs for independent micro power producers, for example households with roof-top grid-connected photovoltaic systems. To foster this, a National Sustainable Energy Development Committee with private and public representatives was announced to be established. The goal is "to develop the legislative, regulatory and contractual framework essential to provide confidence to the private sector to make the necessary costly investments in geothermal and other forms of renewable energy; and to provide transparency and protect national interests" (Burke 2010, p.76). The government is informing in its budget statement that the conversion to renewable energies will be costly and that it may not result in an immediate decrease in electricity bills but that consumers will benefit from a stabilization of prices with the potential for savings (Burke 2010).

4.2.4 Solar Water Heater

Solar thermal collectors are common in the tourism sector and most private homes are nowadays equipped with plumbing for solar water heaters. Most of the collectors are imported from Barbados and Dominica (Loy & Farrell 2005). According to the Global Sustainable Energy Islands Initiative (GSEII 2009a), there should be more solar water heaters in use.

The United Nations Industrial Development Organization (UNIDO), the Organization of American States (OAS), and the Energy and Security Group (ESG) - working in partnership with the Grenada Public Service Co-operative Credit Union (GPSCU) - were jointly implementing the Caribbean Solar Finance Programme (CSFP). This program was designed to increase access to solar water heaters for households in the Eastern Caribbean by increasing the capacity for financing by the credit unions that service the credit needs of the target population, while at the same time helping to build awareness among the membership of the credit unions as to the benefits of solar water heaters. Program elements were a training course for lending of a solar water heater for officers in credit unions, a wholesale consumer credit facility offering a low-cost, long-term loan facility to credit leagues for on-lending to members of constituent credit unions to support the purchase of solar water heaters, and a consumer awareness campaign designed to raise awareness of the benefits of solar water heaters among the credit union members (GSEII 2009b).

The CSFP project in Granada followed a project in St. Lucia and tried to learn from some shortcomings. The key activities of the program in Grenada have been executed during the last 9 months and now it has to be seen how it will perform, according to Marco Matteini (pers. comm. 31 May 2010), Industrial Development Officer of UNIDO.

When asked, the Grenadian government did not have any figures that showed how many solar water heaters are in use and replied that it is difficult to rate. But the Statistics Bureau provided the following import figures as listed in Table 4. There are no manufacturers for solar water heaters, so all technology must be either imported or assembled in Grenada. According to the figures in the table, there were more than 4500 solar water heaters imported by the end of 2008 but it cannot be said if there were more assembled.

Table 4: Solar Water Heater Imports in Grenada

	Solar Water Heaters (for domestic use)	Other Solar Water Heaters
2000	182	25
2001	202	6
2002	118	4
2003	373	10
2004	736	30
2005	500	153
2006	509	95
2007	644	11
2008	799	122
Total	4063	456

Source: Ministry of Finance, Planning, Economy, Energy, & Co-operatives 2010

4.2.5 Photovoltaic Technology

Since 2006 a private company, named Grenada Solar Power Limited (GrenSol), is acting as distributor, system designer and installer for photovoltaic systems (Burkhardt, K. pers. comm. 28 April 2008). Dr. Dirk Burkhardt, Professor of Neuroscience, a German living in Granada had the vision of a sustainable home and wanted to have a photovoltaic system for his roof. His German friend, Matthias Kothe, a mechanical engineer, then came up with the idea to found a company for photovoltaic installations. “Because of the almost ideal solar insolation and the high electricity prices” (Burkhardt, D. pers. comm. 27 April 2010), Kothe, Burkhardt and his sons followed this idea and established GrenSol. By August 2006, 3 pilot systems (7 kWp) were installed and monitored by GRENLEC. After many efforts and insistence from the private sector, GRENLEC issued a general feed-in permission in form of 1:1 net-metering for up to 10 kWp renewable energy systems (Figure 17), in February of 2007. One year later, 18 photovoltaic systems of 50 kWp were already installed. So far, GrenSol has installed systems accumulating about 200 kW, almost reaching the cap GRENLEC set for 1% of yearly electricity production which is about 300 kW.

Figure 17: GRENLEC – Interconnection Policy

Net metering

For systems less than 10KW the policy provides for net metering at retail electricity rates. This is done to encourage the use of such a system at this time and is subject to review as penetration increases.

For systems over 10KW; two meters, or one meter with the capability to measure import and export power will be installed and Power purchased from the DG system will be at a rate negotiated between Grenlec and the operator.

Source: GRENLEC 2008b

GrenSol established its business by offering quality products and very reliable service. They can even ask for a 70% advanced payment and because Dr. Dirk Burkhardt is well known throughout the island, promotion spreads fast via word of mouth. Furthermore, GrenSol is conducting educational training in schools and puts much effort into convincing the people of the products' benefits through public events and other advertisement channels (Burkhardt, D. pers. comm. 27 April 2010). The GrenSol team is primarily working for the ideal and to support photovoltaic technology in Grenada. Their mission is to bring "inexhaustible, clean, environmental benign and, last but not least, cost-effective solar energy, which advances Grenada to the forefront in developing a sustainable economy" (GrenSol 2010). According to Dirk Burkhardt (pers. comm. 27 April 2010), another benefit for market establishment is the low price. The company is buying for wholesaler prices, directly from manufacturers, and has a very low profit margin.

In March 2008, GrenSol founded with a partner another photovoltaic company in St. Lucia, named SolLucia. Unfortunately, business did not develop as expected and the cooperation was absolved in 2010. According to Kevin Burkhardt (pers. comm. 28 April 2010), it would have helped if someone from Grenada would have been there to help the market development but so far they do not have the capacities.

4.3 Case Study St. Lucia

St. Lucia has an area of 616 km² with an estimated population of 160,267 in July 2009. The GDP per capita is 10,900 USD (2009 est.). Its main industries are clothing, assembly of electronic components, beverages, corrugated cardboard boxes, tourism, lime processing and coconut processing (CIA St. Lucia 2010).

St. Lucia has no natural gas or oil reserves, and to cover its energy needs St. Lucia imported 120.700 barrel oil in 2005 (Loy 2007). The imported diesel oil used for electricity production is the second major energy consumer behind the transport sector (Loy & Farrell 2005). In 2008, the estimated oil consumption was 3,000 bbl/day (CIA St. Lucia 2010). In 2008, 17.9 million imp. gallons (about 0.5 million bbl) were consumed by GRENELEC to produce electricity which increased to 18.3 million imp. gallons in 2009, an increase of 2.2% (LUCELEC AR 2010)

4.3.1 Energy Market Actors

Electric Utility

St. Lucia Electricity Services Ltd. (LUCELEC) is the sole commercial generator, transmitter, distributor and seller of electricity since 1964 (LUCELEC 2010). LUCELEC has an exclusive statutory license till 2045. In 1994, the company went public and the electricity act of 1964 was replaced by the Electricity Supply Act, which allows electricity generation from independent power producers but only with agreement and sub-license of LUCELEC and certain conditions (Loy 2007). The shareholders of LUCELEC are the Commonwealth Development Corporation (24.87%), the Caribbean Basin Power Fund St. Lucia Ltd. (20.00%), the Castries Town Council (16.33%), the National Insurance Scheme (12.51%), the Government of St. Lucia (12.44%) and other private and institutional shareholders (Loy & Farrell 2005).

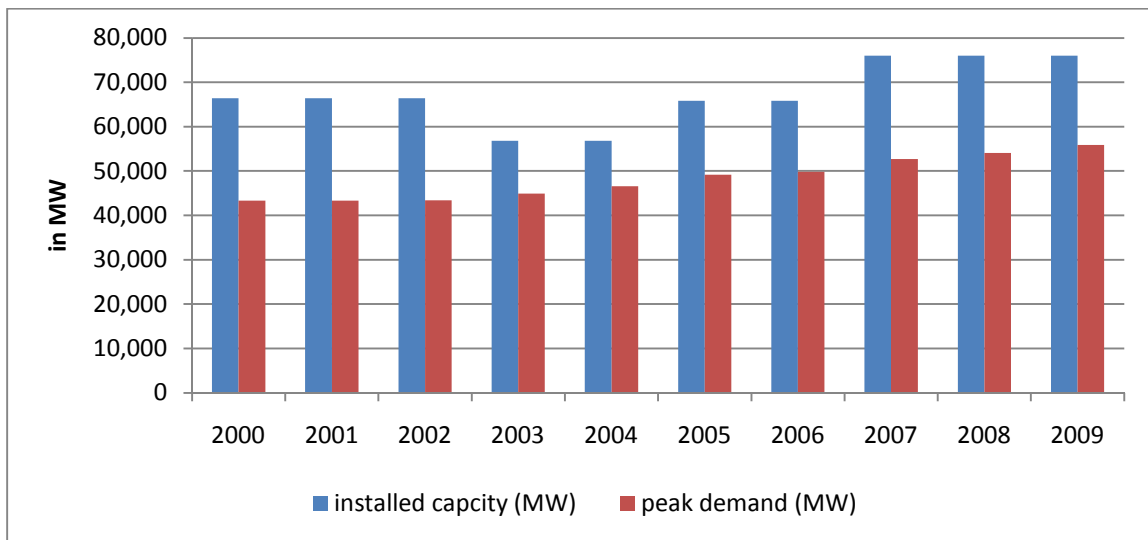
Government Institutions

The responsible Ministry for the utility is the Ministry of Communications, Works, Transport and Public Utilities. The Ministry of Economic Affairs, Economic Planning, National Development and Public Service was newly established in 2006 and is responsible for the development of the energy politics and planning (Loy 2007).

4.3.2 Electricity Sector

As seen in Figure 18, in 2005 the total installed capacity was 65.8 MW with a peak of 49.2 MW, which was 5.6% higher than in 2004. In 2007 a new generator was installed (Loy 2007), increasing installed capacity of 10.2 MW up to 76 MW in total. Demand increased about 3.3% from 2008 to 2009. In 2009, 362.99 million electricity units were generated, which was an increase of 3% as compared with 352.34 million in 2008. The system peak demand increased to 55.9 MW from 54.1 MW in 2008 (LUCELEC Annual Report (AR) 2010).

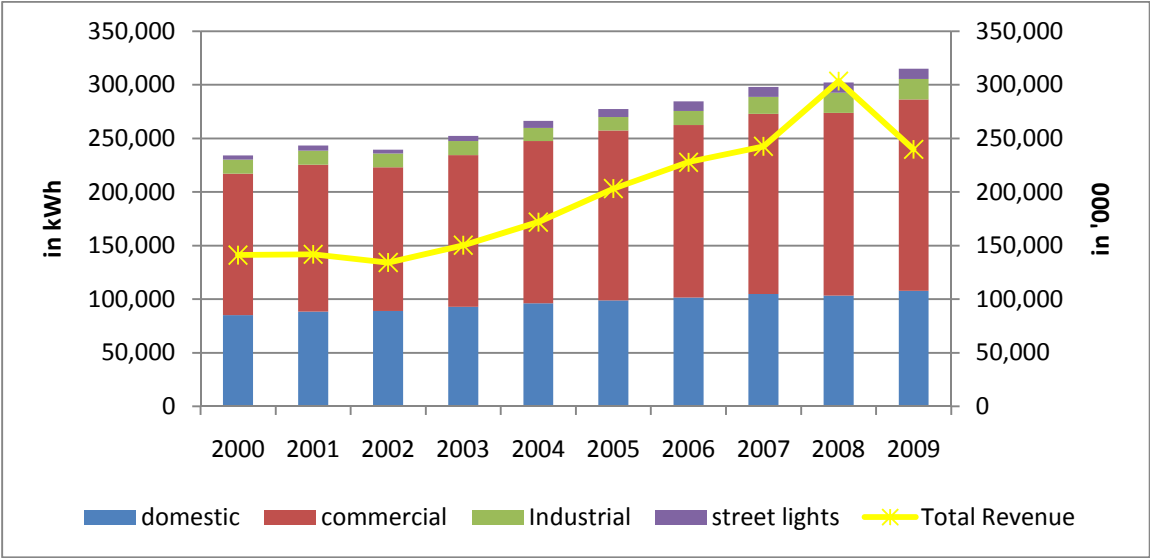
Figure 18: LUCELEC Capacity and Peak Demand 2000-2009



Source: LUCELEC AR 2010

In 2001 after 9/11, there was a big set-back in electricity consumption because of the severe decrease of tourism (Loy & Farrell 2005). The electricity sales decreased about 2% but recovered in 2003. One year later, sales of the commercial sector even increased to 7.13%. Total Sales were 315 GW in 2009, 4.4% more than in 2008 with 301 GW. The peak in 2008, as seen in Figure 19, is due to the high oil prices. Total revenue in 2008 was 303 million ECD (111 million USD) and 239 million ECD (90.9 million USD) in 2009; a decrease of more than 20%, whereas net profit in 2008 was 24 million ECD (8.8 million USD) and 27.6 million ECD (10.5 million USD) in 2009. The annual average consumption between the years 2000 and 2009 was 2,064 kWh in the domestic sector, 27,593 kWh in the commercial sector and 141,218 kWh in the industrial sector (LUCELEC AR 2010).

Figure 19: LUCELEC Sales 200-2009



Source: LUCELEC AR 2010

As in Barbados and in Grenada, electricity prices in St. Lucia are split into two parts – the base price and the fuel surcharge (LUCELEC 2010). Average electricity prices in 2007 were 0.26 USD/kWh (Loy 2007). Actual rates at time of research were 0.85 ECD/kWh, which are about 31 USD/kWh, very similar to the electricity prices in Grenada.

4.3.3 Renewable Energies

As many other Caribbean islands, St. Lucia has a high potential in wind, geothermal and solar energy but only some small applications exist. There are plans of using wind energy to reduce fossil fuel usage and stabilize electricity costs for customers (Loy 2007). Since 2003, LUCELEC embarked on a project to develop a wind farm, but access to the land has been a major challenge. It is seen as a core activity in 2010 (LUCELEC AR 2010). In 2001 the government of St. Lucia established and approved a Sustainable Energy Action Plan (SEP). Targets for renewable energies in electricity generation were set at 5 MW (7%) until 2005 and 17 MW (20%) of installed electrical capacity until 2010. LUCELEC wanted to achieve the targets with a wind park of 12.6 MW. CREDP even advised the government to buy the whole region because it offers excellent conditions with a wind speed of 7 m/s and could be extended to a 40 MW wind park (Loy 2007).

In 1999, the government eliminated all import duties and consumption taxes on renewable energy and equipment and material and 3 years later, in 2001, they even decided to make the purchase of solar water heaters tax-deductible. Nevertheless, it was recognized that this effort was not enough to achieve more energy efficiency and to reduce the reliance on the current energy sources (Ministry of Physical Development and the Environment 2010). So in May 2003, the government made a draft of an Energy Sector Policy and Strategy which identifies and develops short to medium-term energy policy options for renewable energy and energy efficiency (Loy & Farrell 2005). This draft was finalized in January 2010 and it is before the Cabinet of Ministers and waiting to be approved (D'Auvergne 10 May 2010). One key objective of the national energy policy is to create a proper regulatory and instrumental environment for the introduction of indigenous renewable energy to the national energy mix and to achieve greater energy security and independence as well as to support the Sustainable Energy Plan with a proper framework. The paper proposed new electricity targets out of renewable energies as: 5% by 2013, 15% by 2015 and 30% by 2020 (Ministry of Physical Development and the Environment 2010).

Increasing oil prices are reflected in the fuel cost adjustment factor (fuel surcharge) charged to the customers. The high oil prices in 2008 caused an increase of approximately 12-15% in the average customer electricity bill. LUCELEC wants to minimize this impact and sees some sustainable options that "... include intensifying customer education in areas of efficient energy use to encourage customers to implement energy conservation measures, expediting action on all initiatives for generation expansion using alternative technologies and renewable or sustainable sources, reviewing and expanding tax and other concessions for renewable energy and energy efficient products, and the development and implementation of a broad energy policy which sets out targets for energy conservation, demand reduction, reduction of emissions, percentage of power derived from renewable and/or sustainable sources, etc., through which some of these initiatives may be implemented" (CARILEC 2008, p.1,2). LUCELEC is also aware that various actions at different levels are required, from LUCELEC itself, the customers, as well as the government.

4.3.4 Solar Water Heater

Solar energy was spurred by technological improvements, the commercial availability and the waiving of import duties and consumption taxes on renewable energy equipment and materials since May 1999. In 2001, the government gave the impetus for solar water heaters as income tax allowance (Loy & Farrell 2005). According to Crispin D'Auvergne, Chief Sustainable Development and Environment Officer (pers. comm. 10 May 2010) of the Ministry of Physical Development, Environment and Housing, Sustainable Development and Environment Section, Department of Sustainable Development, Science and Technology/Ministry of Finance and Planning, this income tax allowance was only in place for 3-4 years.

In 1993, Solar Dynamics gained a foothold in the St. Lucian market through Solar Dynamics (St. Lucia), a joint venture with Minvielle and Chastenet Ltd., which originally sold units for Solar Dynamics in St. Lucia. Trading arrangements between these regional sub-groupings has allowed Solar Dynamics Ltd. to gain easier market access. The company believes in consistent product quality wherever it is sold. To successfully implement the business in St. Lucia, personnel from Barbados were transferred in key areas of management, sales, and installation. Today the company is run by nationals who have been successfully taught the Solar Dynamics distinctive brand quality and their way of doing business (UNDP 2008). By 2007, Solar Dynamics had a market share of 70%, but then the company Ecosun entered the market and Solar Dynamics lost about 30% of their market share (Wilkinson pers. comm. 21 May 2010). According to D'Auvergne (pers. comm. 10 May 2010), there are about 7000-8000 solar water heaters installed in St. Lucia. Some companies, like Solar Dynamics are manufacturing, others assembling in St. Lucia, so even if there would be import figures available, an accurate number is difficult to obtain.

In January 2005, GSEII announced a financing program for solar water heaters (Loy & Farrell 2005). Unfortunately, this project did not achieved the promised result in terms of providing finance through credit unions as a key means to grow the solar water heater number in St Lucia. Reasons for the unsatisfying performance were the insufficiently accurate modeling and analysis of the solar water heater market, as well as limited resources available for the preparatory phase constrained the depth of the analysis (Matteini pers. comm. 31 May 2010).

4.3.5 Photovoltaic Technology

As a reliable back-up power source as the ones found in 70 existing hurricane shelters, in 1999 a school hall in a remote village on west coast was equipped with 400 Wp by the Sustainable Development Science and Technology Office and with the financial support of the UN Trust Fund on New and Renewable Sources of Energy. Three other storm shelters received photovoltaic systems in the past with Italian assistance. Under the current act, grid-connected photovoltaic electricity generation is only allowed for self-supply and as long no excess electricity is fed into the public grid. There is no obligation for the utility and in case of grid-connection of renewable energies, a sub-license by LUCELEC is needed and a specific purchase agreement has to be negotiated (Loy & Farrell 2005).

In the beginning of 2009, LUCELEC and Solar St. Lucia Limited signed off formally on an agreement about a pilot project in grid-tied small PV systems installed on residential premises. System sizes range between 1-10 kW and are limited to 10 locations around the islands. The main aim of this pilot project is to gain knowledge about photovoltaic systems on the grid, including safety, power quality, protection, interconnection and metering (CARILEC 2009). So far only 3 small pilot projects were installed at the National Trust, the Castries Market and a school in Vieux Fort (LUCELEC AR 2010). Another installation is on a private property, the St. Benedict Convent. It is also renting accommodations, thinking about getting a photovoltaic system to reduce their costs.

The awaited National Energy Policy also foresees regulating and simplifying the installation of small photovoltaic systems for self supply up to 10 kW by suggesting an approval, but no license obligations. For commercial entities, co-generation plants with a maximum capacity of 500 kW will be allowed after approval by LUCELEC, but the maximum capacity shall not exceed 30% of the capacity needed to supply the average electricity consumption based on the past three years of that single entity. Furthermore, net-metering rules will be determined and published by an independent regulatory commission to determine a specific rate to be paid by LUCELEC in cases where system electricity production exceeds customer's consumption. To monitor and evaluate the economic and technical effects, the initial phase will run for 4 years and the installed capacity for self-supply from co-generation will be capped at 3 MW electrical capacity (Ministry of Physical Development and the Environment 2010).

4.4 Summary of the Three Case Studies

The table below is summarizing the findings about the case studies. Barbados is the most developed out of the three countries, with the highest GDP. Although it is the second biggest island, it has most of the population and hence very high electricity productions, which also is an indicator for development. The gathered figures and facts will be basis for the following analyses and discussions.

Table 5: Summary about the Three Case Studies

	Barbados	Grenada	St. Lucia
Inhabitants (est.)	284,589	90,739	160,267
Area (km ²)	430	344	616
GDP (est.)	18,500 (2009)	13,200 (2008)	10,900 (2009)
Regulatory Agency	Fair Traiding Comission	no	no
Utility	Barbados Light & Power Company Limited (BL&P)	Grenada Electric Services Ltd (GRENLEC)	St. Lucia Electricity Services Ltd. (LUCELEC)
Licensed till	2028	2073	2045
Installed Capacity (MW)	239.1	45.1	76
Peak Demand (MW)	164.0	29.39	54.1
Electricity Sold (GWh)	952	173.3	315
Electricity Prices (US\$/kWh)	0.28	0.31	0.31
Official Renewable Energy Share	0% (15% with SWH)	0%	0%
Solar Water Heaters	50.000	> 4500	7000-8000
Photovoltaic Technologies	some	200 kW	some
Governmental Policy	Barbados Energy Policy (BEP) – still a draft	no	National Energy Policy (NEP) – before cabinet
Utility Rider	Renewable Energy Rider (1.8 fuel Clause Adjustment or 0.315 BBD/kWh; max 1600 kW; 2 years)	Interconnection Policy (net-metering, max 300 kW)	No (agreed with LUCELEC: max 3 MW; 4 years)
Incentives	Consumption tax release Income tax deduction High consumption tax for EWH	Consumption tax release	Consumption tax release (Income tax concessions are no longer in place)

Refer to chapters 4.1-4.3

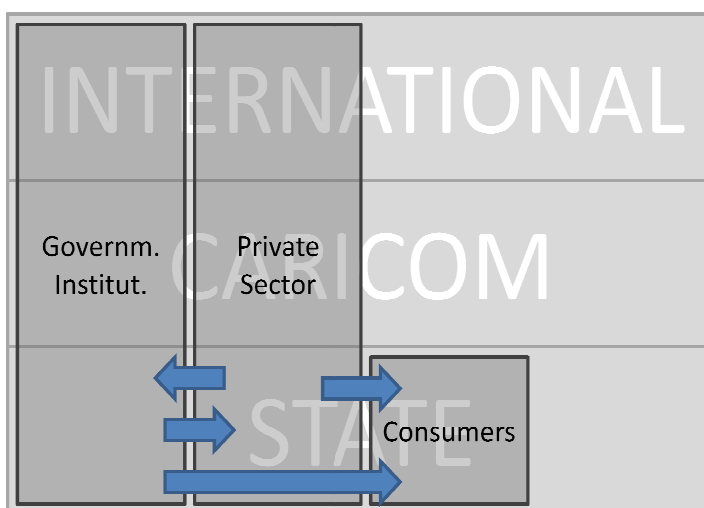
5 Solar Water Heater Framework

Solar water heaters are a viable technology for developing countries because they can be manufactured and maintained locally. For the customers, solar water heaters are not difficult to access, just a few panels meet people's needs (Williams pers. comm. 25 March 2010). Furthermore, solar water heaters have a significant role in the tourism industry. Clients principally come from Europe and North America and expect to have similar standards and comfort as in their home country (Langniss & Ince 2004).

5.1 Drivers for a Successful Market Establishment

As seen in the Barbados success story, the very initial attempt in the solar water heater business started in the private sector. The manufacturers introduced the technology to the customers and convinced them of their benefits, their reliability and especially the cost-effectiveness. To support the business, government set policy incentives and made certain commitments to increase the implementation. Both the government and the private sector were educating the customers with different awareness programs as part of a marketing process. Thus, such a market can be governed successfully on an exclusively local to national scale, depending on market size. Figure 20 reflects such a model for a successful market establishment. The arrows are explained in Table 6.

Figure 20: Model for an Establishment of a Solar Water Heater Market



Arrows illustrate efforts by stakeholders, explained in the text/table

The following efforts can be pointed out.

Table 6: Efforts for an Establishment of the Solar Water Heater Market

	Efforts for Solar Water Heater Business
Private Sector to Consumers	<ul style="list-style-type: none"> • strong company commitment • local reliable products/services • create awareness of cost effectiveness • promotion & marketing strategies • improving confidence and satisfaction by key benefits • recruitment of large number of retailers • research and developments
Private Sector to Governm. Institut.	<ul style="list-style-type: none"> • create product awareness • convincing about benefits for society
Governm. Institut. to Private Sector	<ul style="list-style-type: none"> • government commitment • involvement and participation • fiscal incentives/tax concession (on raw materials and purchased solar water heaters) • increased duty on gas and electric water heater
Governm. Institut. to Consumers	<ul style="list-style-type: none"> • communication and propagation • education to increase acceptance

Referring to chapter 4.1 – 4.3

Besides the main drivers as mentioned above for the solar water heater market establishment, a good manufacturer reputation is also very important. With good contacts, the manufacturer certainly has some influence which can be very helpful, especially in small markets. For further market establishment, the competition among the local manufacturers was beneficial also.

According to William Hinds, senior technical officer from the Energy Division of the Ministry of Finance, Economic Affairs and Energy, the Barbados model is not just based on the innovative leadership of local manufacturers in combination with governmental support, but also with the strategic timing, combined effort and the beginning of the solar water heater start during the first energy hikes in 1973 (Epp 2009).

5.2 Barriers Hindering the Market Development

Barbados is a show case but as seen on other islands, it is not enough just to import affordable solar water heaters. It needs properly trained people to install them. “A combination of bad products installed by incompetent technicians will soon kill off any attempts to establish the industry, even if subsidies succeed in making solar water heaters affordable” (Meyer 2008, p.48). By doing so, and by transferring personnel from Barbados, Solar Dynamics was quite successful in St. Lucia.

On the other hand, there are still many homeowners who do not have a solar water heater. According to Perlack and Hinds (2008), most low-income households cannot afford to purchase a solar water heater because they do not qualify for the tax deduction or do not have available financing. Confirmed by the expert interviews, low cost financing would make solar water heaters easily available (Husbands pers. comm. 24 March 2020, Jordan pers. comm. 26 March 2010, Matteini pers. comm. 31 May 2010). The banks are too conservative and there is a lack of easy consumer finance (Jordan pers. comm. 26 March 2010).

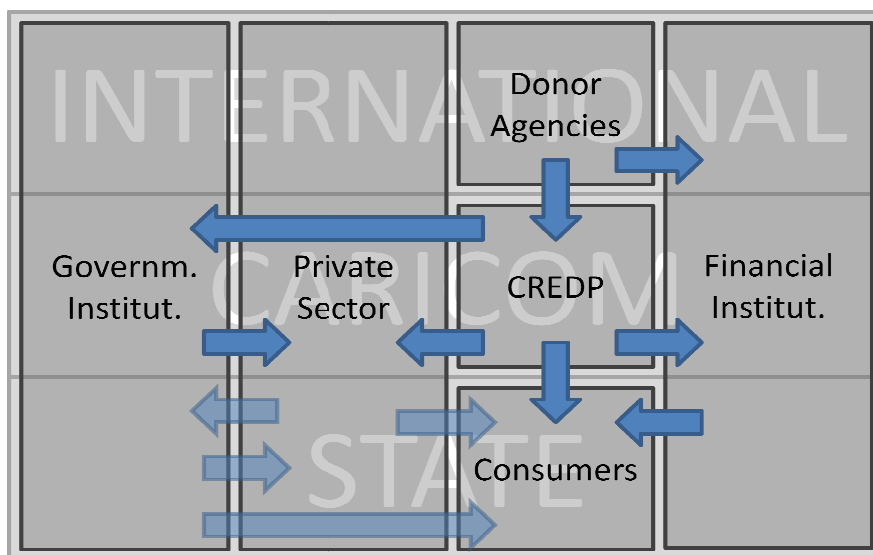
In the Caribbean region, a distribution chain for solar water heater systems is through the retail chain COURTS, via a higher purchase price. This means customers can buy on a three month rate or on negotiated installments for a certain period of time for a higher price. To pay with installments is a big advantage for the people however, deciding to buy on a higher purchase price means also that customers pay in average up to 12-14% more compared to the cash price.

Although companies and banks on the island have offered short-term credit options to finance the purchase of solar water heaters (under chapter 6.4. an overview about financing programs is listed), such credit packages have not been sufficient to deflect the high up-front costs of these systems to the point that monthly repayment rates equal the installed and electric costs for conventional water heaters. Furthermore, such financing has not been made available through institutions trusted by target segments of society, like the credit unions with which they handle all their other banking arrangements (GSEII 2009b). Financial institutions, like credit unions, can give low interest loans to consumers who have a low income and fall below the income tax annual threshold.

5.3 Scenario for a Successful Market Penetration

For a successful market penetration of solar water heaters, it is of course necessary to continue private sector and governmental actions as specified under 5.1 but to proceed from market establishment to further market penetration and to overcome the existing cost barriers it requires inputs from the CARICOM level, as well as from the international level, as illustrated in Figure 21.

Figure 21: Model for a Successful Solar Water Heater Market Penetration



Arrows illustrate efforts by stakeholders, explained in the text

Governments are in the position to help with trading strategies. At the CARICOM level, the member states should support the private sector with the distribution of solar water heaters, illustrated by the arrow from governmental institutions to the private sector on CARICOM level. This can basically be done by education but Jordan even states (pers. comm. 26 March 2010): “If I get more than 2 export orders in the same month the cost of the production & consumption of raw materials coupled with the 30 days credit after the order is shipped can affect the companies short term cash flow, so the government export agency should be able to advance monies the moment we prove the order is shipped and return it within the 30 day payment time frame.”

CREDP/GTZ is financed by the German Federal Ministry for Economic Cooperation and Development (BMZ) and co-financed by the Austrian Development Agency (ADA). Based on CARICOM level, CREDP is supporting governments, for example, with policy

issues and the private sectors in regard to product education. For example, solar thermal energy can be directly used for cooling and dehumidification, which of course finds great interest in the Caribbean region but it is very important to implement good quality products. Once a reputation is destroyed, it is very difficult to fix that and customers easily associate the bad experiences to other solar technologies. To avoid this, CREDP helps to guide the islands and especially the private sector. The program also offers educational seminars for financial institutions as well as education for consumers.

To develop the current financing schemes, it is very important to strengthen the private sector through reducing the economic barriers for customers. This was also recognized by international authorities. As mentioned before, UNIDO, OAS and ESG implemented the Caribbean Solar Finance Programme (CSFP) to increase access to solar water heaters by increasing the capacity for financing by the credit unions (GSEII 2009b). CSFP projects were conducted in St. Lucia, Grenada and Dominica. Although the program did not reach the expectation in St. Lucia, it cannot be said that it was a failure. The solar water heater sales have doubled and CSFP probably usefully contributed via its advertising and marketing element (Pool pers. comm. 29 May 2010). However, the solar water heater market was not sufficiently modeled and analyzed in depth because of limited resources available for the preparatory phase. The CSFP project in Grenada has tried to learn from some of the shortcomings of the St. Lucia CSFP pilot, according to Matteini (pers. comm. 31 May 2010). He believes that awareness of the costs and benefits of solar water heaters was, and still is a key barrier.

According the IEA, policy makers must combine a R&D deployment perspective, a market barrier perspective, and a market transformation perspective:

- Learn from what others have done and developed - a practical product suited not only to the country but also for the surrounding region
- Cut tariffs, give tax breaks, and firmly encourage the use by regulations
- Take a long hard look at what needs to be done to get people not only to buy the products, but to want to buy them
- Be aware that incompetent installers or not fully mature solar products can destroy public confidence

Source: Meyer 2008

5.4 Economical, Environmental and Social Facts

The most significant hindrance preventing governments to adopt sound policies, financial institutions to offer low interest loans, and customers to buy a solar water heater is the lack of awareness. To overcome this barrier, familiarization with the technology as well as education about the economic, environmental and social aspects is necessary. It is important to inform the advantages and limitations to avoid unrealistic expectations and improper operation followed by disappointment and denial.

Heat from the sun is an inexhaustible, reliable, free and abundant fuel. There is no monthly fuel bill and no fluctuating prices with sudden increases. Nevertheless there is a weak point – the dependency from the sun. If there are clouds or shadows, the system output will be diminished. However, related limitations can be mitigated by appropriate system sizing and placing. Using a solar water heater requires some education and occasionally minor consumption adjustments, for example in taking a shower, use preheated water for cooking to save more energy as well as to modify their dish washing and laundry habits. When using cold water, many chemicals are added to clean dishes and laundry. Those can be reduced by cleaning with hot water. Laundry loads just have to be distributed among several days to enjoy hot water.

Using a solar water heater does not produce any gaseous or other emissions during operation and offers an environmentally benign alternative to fossil and nuclear sources of energy. Furthermore, the system operates silently and may offer a more visually pleasing alternative to power conduits strung across the landscape.

The initial capital cost of purchasing a solar water heater is usually higher than an equivalent sized electric heater but the maintenance costs are typically negligible. On small islands, where electricity prices are high, solar water heaters are cost effective in displacing electric water heaters in a very short period. To calculate how much energy is needed to heat water, the following equation can be used.

$$Q = m c \Delta T$$

heat added
mass
specific heat
change in temperature

The specific heat of water is:

1.0 Btu/lb °F or 4.186 kJ/kg °C

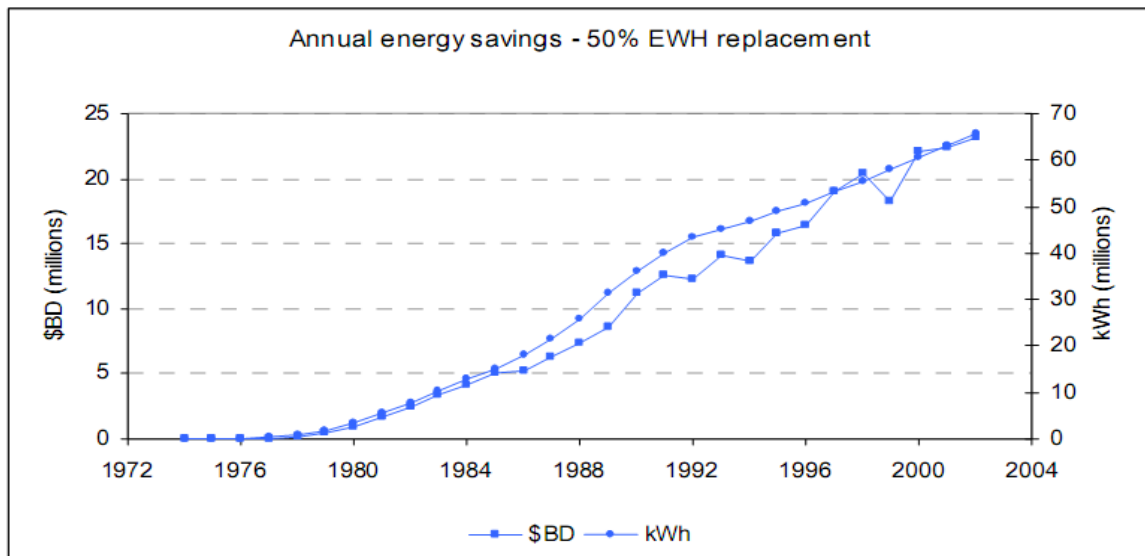
1 gallon of water weights 8.35 lb

1 Liter water weights 1 kg

In the Caribbean region, water has an ambient temperature of about 80°F/26.7°C and needs to be heated up to 125°F/51.7°C, at least. That means to heat 1 gallon/3.8 liter of water for 45°F/25°C it requires energy of 0.11 kWh. Depending on the amount of water, the temperature difference and the efficiency of an equivalent electric water heater (80-95%) to heat up the water, between 3500 and 4000 kWh per year can be saved when using a solar water heater. Besides energy savings for the households, this also means saving effects on the countries' economy. The Caribbean islands pay a big part of their export earnings to import oil and gas. Solar water heater can substitute those costs in the heating segment and save capital of power plants. Furthermore, the sun is a local available resource, which increases energy security and reduces potential hazards associated with transportation and generation of fossil fuels.

Perlack and Hinds (2008) estimated that solar water heater save an estimated 3710 kWh¹ annually which would mean an annual saving of 65 million kWh for Barbados with a value of 23 million BBD (11.4 million USD). This would make a cumulative value of 267 million BBD (about 132 million USD) through the year 2002, Figure 22. This calculation is based on the assumption of a 50% replacement of the electric water heaters.

Figure 22: Annual Solar Water Heater Energy Savings



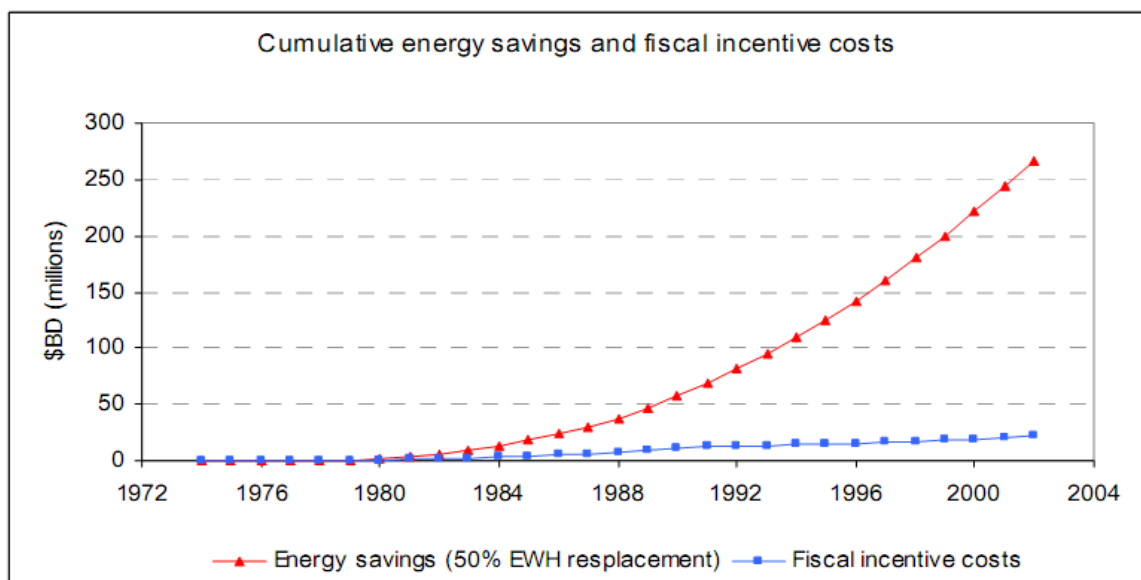
Source: Perlack & Hinds 2008

¹ * based on 35,000 SWH installed in 2002, historical average tank size of 62 gallon, efficiency of 90%, temperature difference of 60 °F assuming SWH replace 50% of electric water heater

35,000 solar water heaters saved about 130 thousand barrels of oil with a value of 6.0 million BBD (about 3 million USD), amounting to about one third of domestic oil production in 2002. The corresponding carbon savings were 15,000 metric tons or 4.3 % of emissions from all Barbadian carbon sources, power and manufacturing (Perlack & Hinds 2008).

Many opponents might argue that it is very costly to put incentives to support renewable energies, but as seen in Figure 23, the estimated cumulative energy savings are much higher than the costs of incentives. Nevertheless, it has to be pointed out that the solar water heater industry already started to grow quite fast before the homeowner incentive was introduced. So according to Perlack and Hinds (2008), it is not clear that tax incentives were entirely responsible for the high market penetration more than there are clearly free-riderships for tax deductions taken by homeowners who nevertheless would have installed a solar water heater. Extensive studies would have to be conducted to actually prove this. However, there was an income tax concession implemented in St. Lucia for some years and then repealed and according to D'Auvergne (pers. comm. 10 May 2010), it helped to create interest and would still be useful. He also states that it was not well published and to reintroduce this concession, it should be properly sized and clear and easy for people to understand.

Figure 23: Estimated Cumulative Energy Savings and Tax Cost of Incentives²



Source: Perlack & Hinds 2008

² From 1974 until 2002

As confirmed during the expert interviews, economic benefits are the main drivers for customers to buy a solar water heater system (Preville pers. comm. 05 May 2010, Charles 18 May 2010). The people do not want to pay the high electricity costs but they also hesitate to pay a high initial cost for a solar water heater. That is why, besides the implementation of financing schemes to spread the costs over longer periods, awareness about renewable energy investments and savings has to be created.

Figure 24 illustrates a sample, based on a calculation of Sunpower (Jordan pers. comm. 26 March 2010). In Barbados, the average solar water heater size is 65 gal/ 246 Liter and would cost 1,900 USD, including VAT and installation. An equivalent electric water heater would cost 600 USD (Husbands pers. comm. 24 March 2010). Using an electric water system to heat water for 45°F/25°C would cost 1.83 USD per day and 667.70 USD per year with an electricity rate of 0.23 USD/kWh (as of September 2009, excluding VAT) and a system efficiency of 90%. With an electric water heater lifetime of 10 years, which is very optimistic, the consumer has to pay 1,267.70 USD in the first year and every following year the electricity costs of 667.70 USD. After 10 years, an additional 600 USD needs to be paid for the heater replacement. When using a solar water heater of 1,900 USD it saves the electricity bill right from the first year of operation through the following 15 years. Solar water heater can even last up to 20 years and longer. There might be about 20 days bad weather conditions, when an additional electrical heat up, basically by the included heating element, is required. Those 20 days would cost 36.59 USD electricity per year. Maintenance costs are about 150 USD every 7 years for cleaning and flushing (McClellan pers. comm. 1 April 2010). This means the solar water heater is cost efficient already after one and a half years and achieves total cumulative savings compared to an electric water heater of 9,066.71 USD after 15 years.

Giving tax incentives makes the calculation even more favorable for the customers. Nonetheless, the cases vary from country to country depending on electricity and system prices. For example, with an electricity price of 0.30 USD, close to the prices in St. Lucia or Grenada, the same system would have a break-even point already after 1.3 years (about 16 months) and cumulative savings of 11,947.88 USD. This however, displays a frequent hot water usage, which would reflect the hotel industry but not the low and some of the middle income families. Many people do not use hot water at all because the temperature of 80°F/26.7°C suits them and save the high electricity rates by taking a “cold” shower. Often they have black water tanks on the roof top and the water is also

heated up by the sun. Some people only use hot water only from late October to January when temperatures drop, according to Preville (pers. comm. 5 May 2010), Managing Director/Consultant Engineer of Power Engineering Services in St. Lucia. To heat their water for the shower, often a shower applicant for only 42 USD is used. This would mean that by an average water consumption of 52 gal/196.7 liter per family and an electricity price of 0.30 kW/h, the break-even point for a solar water heater of 1350 USD would be at almost 5 years and the cumulated savings only 2,123.93 USD, considering a replacement of the electric shower heater every 5 years and a solar water heater maintenance of 65 USD every 7 years, Figure 25.

Figure 24: Cumulated Savings of a Solar Water Heater – Case 1

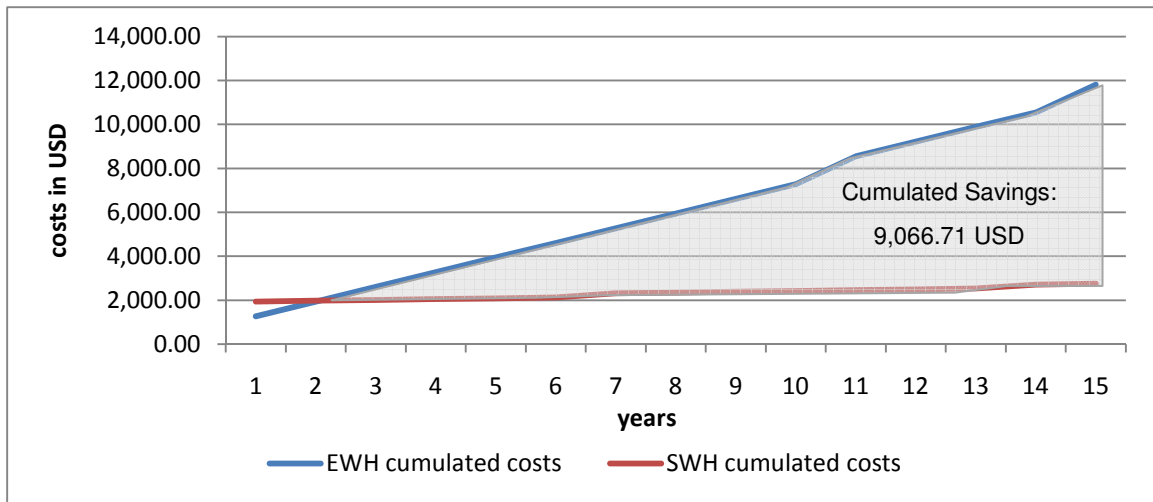
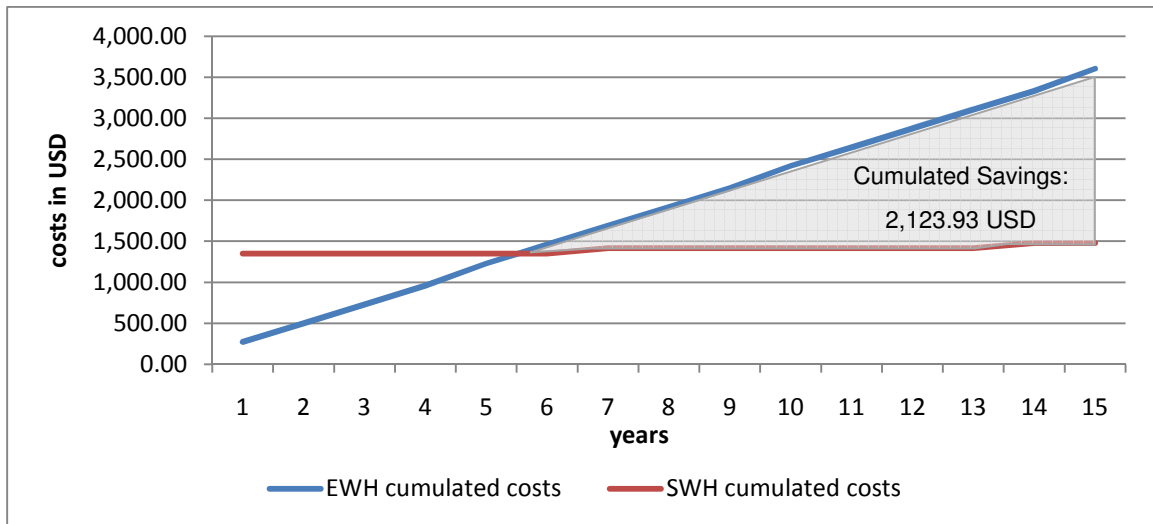


Figure 25: Cumulated Savings of a Solar Water Heater – Case 2



Besides energy oil imports and carbon emission savings, an analysis of UNDP (2008) revealed that the solar water heating industry also

- has saved the country a substantial amount in foreign exchange,
- was contributing to improvements in health, hygiene, living standards and income levels,
- helped to cushion some of the adverse economic effects of the oil crisis,
- expanded the renewable energy share, as well as their acceptance and confidence,
- has provided one of the highest rates of economic return on investments for individuals,
- showed that a uniform Caribbean-oriented company culture is possible and
- affirmed that a great deal is possible when right policies are in place.

Furthermore, expanding the solar water heater market creates jobs and business opportunities.

6 Photovoltaic Framework

Stand-alone systems for remote areas or small systems for water pumps or small lightening installations are still common applications of photovoltaic technologies. The use of those small systems is allowed as long as it does not interrupt the utility services. Some people even take the step and become self-sustaining because they do not want to depend on the utility and pay the high electricity costs. For example, a private person in St. Lucia got 9 panels of 210 Wp and a wind turbine of 2.2 kW and 8 large batteries, so in total he installed about 4 kW and lives off grid now and even produces more than his consumption (Preville pers. comm. 5 May 2010). In case of bigger installations, which would result in a significant revenue loss for the utility and resulting in tariff adjustments for remaining customers, there is generally a limit of 10% of the utility revenue (Hosein pers. comm. 6 May 2010).

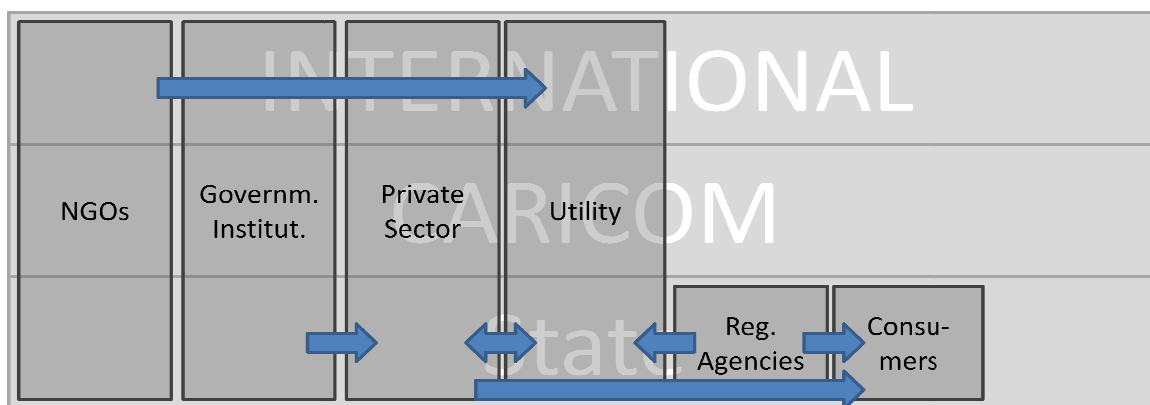
6.1 Drivers for a Successful Market Establishment

The most economically feasible form of photovoltaic installations however, is a grid connected system. Same as in Barbados with solar water heaters, the establishment of the photovoltaic business in Grenada was also driven by the private sector on state level. The core company put much effort to introduce the technology and got an agreement with the local utility company. After a learning process and many negotiations, the utility finally introduced a policy for grid connection of renewable energies, which opened the gate to commercialization. The government supported the private sector with a release from general consumption tax. Companies only pay a handling charge of 5-10% but no import duty. This cost benefit can be passed on to the customers.

It is very important that the utility learns about renewable energy to convince them about their advantages and also how to handle the disadvantages. This can be done by operating pilot systems but also through supports from NGO's and other associations. For example, BL&P became a member of the Solar Electric Power Association (SEPA) - previously called the Utility Photovoltaic Group (UPVG) - which has been a great source for information on the industry (Williams pers. comm. 25 March 2010). The international connections to Germany also helped GrenSol in the market establishment.

There is no regulatory agency in Grenada and the photovoltaic business established anyhow. In Barbados, the Fair Trading Commission is representing the interests of consumers and regulates the utility services. According to Burkhardt (pers. comm. 27 April 2010), such a regulatory body would also help in Grenada. This means a model for a successful market establishment could look like in Figure 26, explained with Table 7.

Figure 26: Model for an Establishment of a Photovoltaic Market



Arrows illustrate efforts by stakeholders, explained in the text/table

Table 7: Efforts for an Establishment of the Photovoltaic Market

	Efforts for Solar Water Heater Business
Private Sector to Consumers	<ul style="list-style-type: none"> • strong company commitment • reliable products/services • create awareness and educate • improving confidence and satisfaction by key benefits
Governm. Institut. to Consumers	<ul style="list-style-type: none"> • communication and propagation • education to increase acceptance
Private Sector to Utility	<ul style="list-style-type: none"> • create product awareness • convincing about benefits
Utility to Private Sector	<ul style="list-style-type: none"> • communication and cooperation • enable grid connection • set appropriate riders/policies
Regulatory Agency to Utility and Consumer	<ul style="list-style-type: none"> • protect and support consumer • regulate utility
NGO to Private Sector	<ul style="list-style-type: none"> • education and assistance for start-up

Referring to chapter 4.1 – 4.3

6.2 Barriers Hindering the Market Development

Photovoltaic applications are still a very expensive technology with very high up-front costs which is a burden for many people. Besides, system costs in the Caribbean are generally higher due to shipping, insurance and eventually taxes during the importation of the technology. Middle income people cannot afford to get a system and costs need to be further decreased, according to Auguste (pers. comm. 27 April 2010). He also mentioned that the panels should be assembled locally to reduce the myth that photovoltaic technology has something to do with magic, similar to what was done with the solar water heaters – creating a local market.

To overcome this bottleneck of high up-front costs, it requires a well established financing scheme, which is not satisfactorily available yet. It is very easy to get a loan for a car but not for a photovoltaic system (Burkhardt, D., Auguste pers. comm. 27 April 2010). Banks are very familiar with vehicle loans because of long experiences but are very hesitant regarding loans for photovoltaic systems. They do not have the confidence and do not know about the risks (Auguste pers. comm. 27 April 2010).

For bigger systems and with the purpose to save electricity costs, cooperation of the utilities is needed to realize grid connection. In most cases, utilities are monopolies and this situation prevents the electricity supply of independent power plants to the national grid. Contracts were made a long time ago and for long periods, which makes it very difficult to introduce new technologies (Ministry of Physical Development Environment 2001). Reduced costs and the ability to connect to the grid would be a massive move towards photovoltaic installations, according to Preville (pers. comm. 5 May 2010).

The dependency on diesel and the fuel adjustments when the prices are going up are not a pleasure for the customers nor for the utility because 99% of the utility staff is national and also affected, according to Hosein (pers. comm. 6 May 2010), Executive Director of CARILEC. This means utilities are also looking for diversification, but to do this with renewable energy is just too cost intensive. According to Hosein, neither the investor owned Caribbean utilities nor the government owned utilities have renewable energy shares. The only islands are the Dutch or French territories, where there are totally different conditions. Cost effective are renewable energies only for rural diversification in remote areas, and in case of grid connection, the costs for renewable

energies must be borne by the governments or the customers, the utilities are already operating on small margins (Hosein pers. comm. 6 May 2010).

The government could set a proper tariff-system supporting renewable energies but this would mean an increase for the already very high customer rates and no government would do that. The Caribbean islands are politically not prepared to set up a tariff system and provide incentives (Hosein pers. comm. 6 May 2010). The government could regulate this by setting binding targets, fixed in a policy. Unfortunately, a legislative period and hence the government planning term is short and for implementing renewable energies it requires stability for a timeframe of decades.

Although photovoltaic systems give an extra surplus to the grid with up-front investments for the utility, a technical barrier of photovoltaic applications is their character of an intermittent supply effect. It only generates electricity during the day and varies with solar irradiation. Besides, its peak does not match with the general electricity consumption peaks, which are generally in the morning and in the evening. This means photovoltaic technologies are not reliable enough to provide a certain base-load nor to be a good peak-shaver. Using photovoltaic systems requires back-up electricity and this is an investment, so utilities put a limiting cap for generating photovoltaic electricity (Hosein pers. comm. 6 May 2010). Small Islands have technical concerns, because if they invest in photovoltaic technologies and not in another type of generating capacity, who would take over the responsibility when losing the system, for example in a tropical storm (Bristol pers. comm. 06 May 2010).

Another hindrance for renewable energies in general is the lack of local experts, relevant expertise, variety of goods, services and supply (Ministry of Physical Development Environment 2001). It is difficult to approach other islands because well trained and reliable people hardly exist (Burkhardt, D. pers. comm. 27 May 2010). Potential customers often are afraid of what would happen with their photovoltaic system in the eventual case of a hurricane. The GrenSol team comments that the systems are fixed tight to the roof and are approved for class three hurricanes. As long as the roof stays on, the system will also stay. Nevertheless, it is not protected from flying objects that might damage the system. That is why the company recommends getting an insurance, which can be done over the regular household insurance (Burkhardt, D. pers. comm. 27 April 2010).

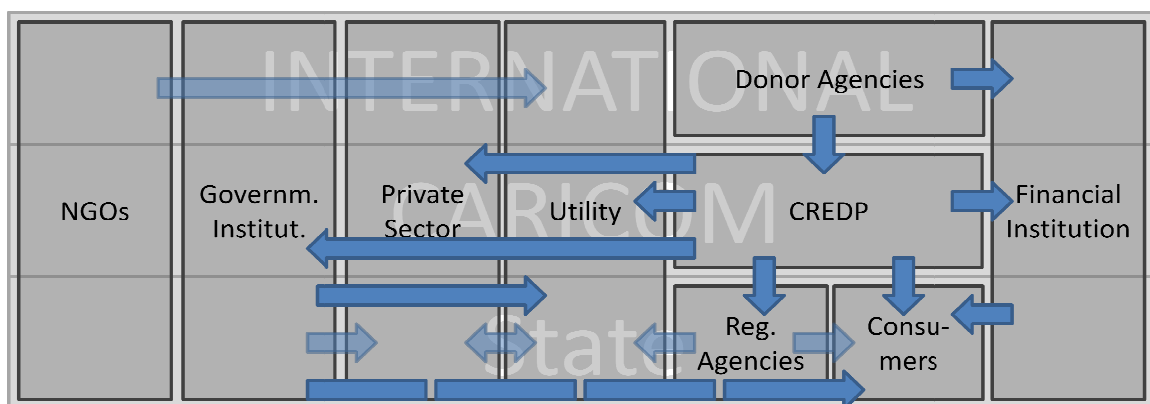
6.3 Scenario for a Successful Market Penetration

To further support the strong growing interest and acceptance for the photovoltaic technology, a suitable financing scheme is necessary. This could be done by offering lower competitive interest rates, monthly payments not higher than the electricity bill and, when building a house, including the photovoltaic system in the house mortgage (Burkhardt, D., Auguste pers. comm. 27 April 2010, Bristol pers. comm. 06 May 2010). Training programs from donor agencies, like the CSFP projects by UNIDO, and CREDP could be very helpful. David Bristol, Consultant Surgeon and owner of a photovoltaic company in St. Lucia, approached the First Caribbean Bank to see if they would be interested in becoming the “green bank” but he could not make big process so far (Bristol pers. comm. 06 May 2010). Support from upper levels is needed.

To convince the financial institutions to offer more attractive loans, their risk perception needs to be reduced. To achieve this, the utilities need to secure grid-connection for longer periods than just the pilot phases. This means there should be at least a contract for the duration of the financing program. Governments can guide this by putting policies into place, providing stability. But also utilities need to consider what process is working best for them, if it is net-metering, net-billing etc. Once setup, it is difficult to withdraw or change into more unfavorable customer conditions (Hosein pers. comm. 6 May 2010). To achieve this, it is advisable to closely collaborate with the private sector and to overcome the uncertainties by pilot projects or similar (Bristol pers. comm. 06 May 2010). Besides providing the crucial stability by setting policies as it already was illustrated with the arrow from the government to the private sector, government can put more incentives like income tax rebates or implement photovoltaic systems in building regulations (e.g. for government institutions, hospitals or rural clinics, hurricane shelters police stations etc.). It is very important that government shows their commitment and supports photovoltaic technologies.

The government, the private sector and the utility, all need to educate customers. To create that awareness, CREDP helps in various aspects, Figure 27. The program supports governments, utilities as well as regulatory agencies with policy set-ups, helps with technical specifications for projects, assists technical colleges with their curriculum expansions and gives training for architects, technicians and students, which means possible future consumers.

Figure 27: Model for a Successful Photovoltaic Market Penetration



Arrows illustrate efforts by stakeholders, explained in the text

Donor Agencies tried to create awareness for photovoltaic systems by placing some demonstration plants. For example, in St. Lucia the European Union financed three photovoltaic systems. Local people see it but unfortunately they do not have a relation to it. Preville (pers. comm. 5 May 2010) states, that it was good to place the demonstration systems but it should have been given more press by the local media to raise awareness and make the people actually think and not just walk by. This activity could be seen as a direct arrow from donor agencies to consumers, which does not make much sense. It should be financed from the international level but need to be done in closer cooperation with institutions actually promoting and working with the system.

To test the photovoltaic panels under the given Caribbean conditions it is also very important to offer consumers most suitable technologies. Panels need to withstand high temperatures and the salty, humid air as well. It is said that thin-film modules have higher efficiency in hot countries but they are more sensitive, also (Heins pers. comm. 10 April 2010). GrenSol is setting up right now a test plant of 15 kWp (2.5 kWp mono-crystalline, 2.5 kWp poly-crystalline and 7.5 kWp thin-film modules) to gain some insights and better serve customers (Burkhardt, D. pers. comm. 27 April 2010).

The Inter-American Development Bank (IDB) has a project called Sustainable Energy and Climate Change Initiative (SECCI). "The purpose of the funds is to finance activities under SECCI, aiming at expanding investment in renewable energy and energy efficiency technologies, increasing access to international carbon finance, and the mainstreaming of adaptation to climate change into the policies and programs across sectors in Latin America and the Caribbean (LAC)." (IDB 2010, p.1). Another project is

CHENACT, an Energy Efficiency project financed, among others by IDB, GTZ, UNEP, BL&P and the government of Barbados, running from December 2009 to October 2010 and available for all Caribbean Hotel and Tourism Association (CHAT) members. The objective is to improve the competitiveness of small and medium sized hotels (<400 rooms) in the Caribbean Region through improved use of energy, with the emphasis on renewable energy and micro-generation (CHAT 2010). Those projects would be very suitable for photovoltaic implementations.

6.4 Economical, Environmental and Social Facts

Same as for solar water heaters, it is also for photovoltaic technologies very important to increase the awareness and to overcome the barriers. The difficulty is that there are more parties involved and that it takes longer to reach the break-even point. But as Dirk Burkhardt (pers. comm. 27 April 2010) says, “Photovoltaic is a no brainer!” Unfortunately, Caribbean people just do not have that planning horizon; they want a payback period of 2-3 years which is just not possible with the system costs yet. This would only be possible with a system price of 3,000 USD/kWp, electricity prices of 0.55 USD/kWh and a 1:1 net-metering, as seen in Table 8. The actual price range installed by GrenSol varies from 4,500 to 5,400 USD/kWp, depending on system size. This means that with an electricity rate of 0.30 USD the pay-back period would be 8.57 years³.

Table 8: Pay-back Periods with Varying Prices (based on 1750 kWh/kWp/a)

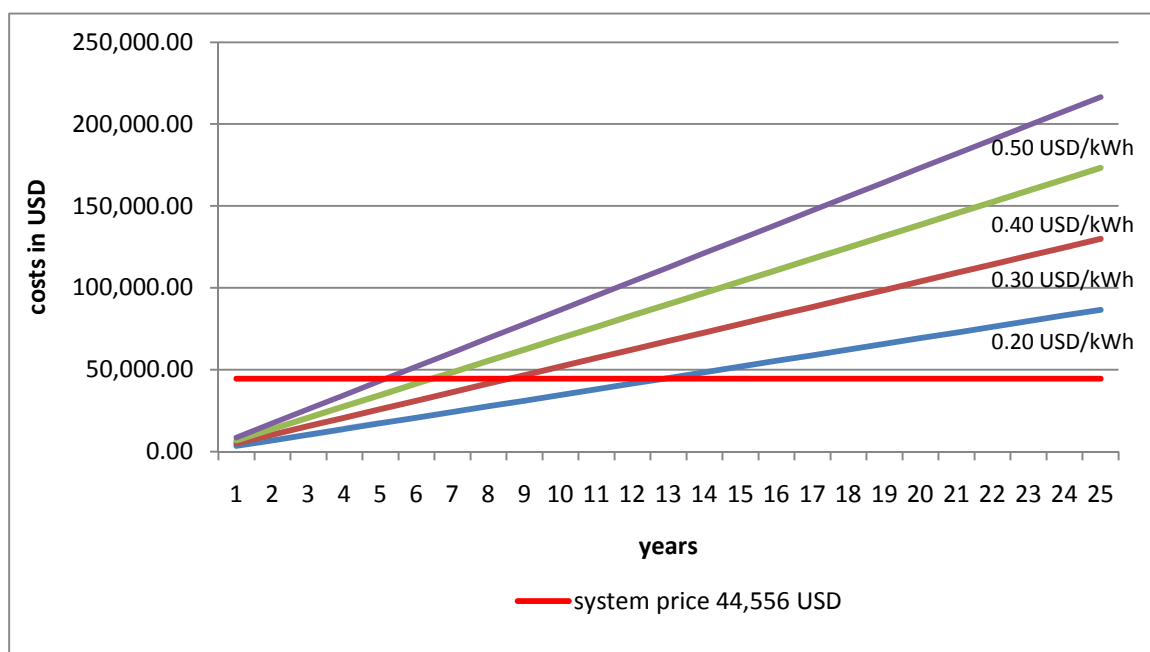
	\$3,000.00	\$3,500.00	\$4,000.00	\$4,500.00	\$5,000.00	\$5,500.00
0.55	3.12	3.64	4.16	4.68	5.19	5.71
0.50	3.43	4.00	4.57	5.14	5.71	6.29
0.45	3.81	4.44	5.08	5.71	6.35	6.98
0.40	4.29	5.00	5.71	6.43	7.14	7.86
0.35	4.90	5.71	6.53	7.35	8.16	8.98
0.30	5.71	6.67	7.62	8.57	9.52	10.48
0.25	6.86	8.00	9.14	10.29	11.43	12.57
0.20	8.57	10.00	11.43	12.86	14.29	15.71

³ Calculated with 1750 kWh/kWp/a and without inflation on electricity, which can be up to 5% per year and decrease the payback period

Based on a photovoltaic installation in St. Lucia, a capacity factor of 20% was calculated. The capacity factor represents the ratio of the average power produced by the power plant over a year to its rated power capacity. According to the calculation tool RET Screen, this results in yearly electricity earning of 1.8 MWh/kWp. GrenSol confirmed the figure of 1750-1800 kWh/kWp/a (Burkhardt, D. 27 April 2010). Germany, for example, has a yearly solar insolation of 900 up to 1160 kWh/kWp (Deutsche Energie-Agentur GmbH 2010). This means that in the Caribbean almost double the output can be generated. The best inclination angle is 12 degrees. Usually the best azimuth is facing south but due to the close distance to the equator and the nearly constant yearly insolation, the direction does not have big negative impacts (Burkhardt, K. pers. comm. 28 April 2010).

Simplified, the pay-back years and the cumulated savings are illustrated in Figure 28. A 9.9 kWp photovoltaic system of GrenSol costs 44,556 USD. In case of net-metering, the system would pay back after 8.57 years with an electricity rate of 0.30 USD/kWh. If the electricity rate is cheaper, like 0.20 USD/kWh it would need 12.86 years and with high electricity prices of 0.50 USD/kWh only 5.14 years. The cumulated savings after 25 years, the general system lifetime, would range from 42,069.00 USD to 172,006.50 USD. With an electricity rate of 0.30 USD/kWh, cumulated savings would be 85,381.50 USD.

Figure 28: Photovoltaic – Cumulated Savings for Various Cases



As seen before, the pay-back period heavily depends on the system prices and electricity prices. The system lifetime is usually guaranteed for 25 years but generally they last longer, which means continued savings. Usually, there are no maintenance costs and the consumer can do a regular check-up by himself. Inverters have a shorter lifetime and need to be replaced earlier which results in some extra costs.

Although a photovoltaic system offers huge energy savings, many Caribbean people are reluctant because of the long pay-back period and of course the very high up-front cost. It is important to have a financing scheme to support customers and hence the private sector. Unfortunately, the banks are inexperienced and afraid of the risks. As seen in Table 9, when asking for the financial schemes of solar water heaters and photovoltaic technology, it is obvious that they might do some financing for solar water heaters, but not for photovoltaic systems, because of the repayment terms of 1-3 years but still with high interest rates of 10% and higher.

Table 9: Financing Schemes for Solar Energy Systems

Financing conditions	First Caribbean Bank	Bank of Saint Lucia
Maximum percentage of the total cost of a solar system as bank loan	90% of the cost	100% for the purchase of a solar system
Minimum equity	10%	minimum of 10% to 20%
Typical repayment terms	36 months	from 1 to 3 years.
Dimension and frequency of installments	monthly installments dependent on cost of system	from 162.00 to 439.58 ECD (60 to 162.81 USD)
Typical interest rates for loans of solar systems	rates negotiable	typically 10% but can be affected upwards
Fees and commissions	1% of loan amount - min 300.00 ECD	from \$150.00 to 300.00 ECD (55.6 to 111.11 USD)
Related insurances available	yes	Loans are insured, solar system is not insured
Customer and system requirements	Job letter, salary slip, bank statements, identification,	proof of income, salary deduction and invoice
Any other requirements	demonstrated ability to service debt	subject to the clients credit history and /or ability to pay

Source: First Caribbean Bank 22 April 2010, Bank of Saint Lucia 23 April 2010

An average family might consume about 300 kWh per month. Financing of a 1.98 kWp system would look in Table 10, in an example from GrenSol. The mortgage is calculated as kWh per month generated by the systems times 0.9 ECD/kWh the electricity price of the utility. This means monthly installments equal the monthly savings of the electricity per month, so the customer does not have to pay extra. In case of an interest rate of 10% the financing year would change to over 17 years, whereas an interest rate of 4% would signify a financing term of less than 10 years. Bristol did make an approach to work with financial institutions asking for a 3-4% interest rate, realizing by a renewable energy fund, but so far unsuccessful. According to him, the best time to finance a photovoltaic system is when buying a new house and put it directly on the mortgage, with mortgage interest rates (pers. comm. Bristol 06 May 2010).

Table 10: Quotation for a 1.98 kW Solar Electricity System in Grenada

System					
Size (kW)	no. of panels	inverters	ECD/kW	Price (ECD)	kWh/month
1.98	9	1x3kW	14,848	29,399	297
Financing					
System price	Downpayment	Mortgage @8%	Years		
29,399 (ECD)	2940 ECD	267 ECD	13.3		
	assumed: 10%	Mortgage equals to initial savings/month			
Economic Assessment					
kWh/mth 2010	kWh/mth 2035	savings/mth 2010	savings/mth 2035	amort. (years)	Savings in 2035
297	237	267 ECD	723 ECD	11.2	92,783 ECD
PV production of new systems	guaranteed min. PV production after 25 yrs.	avoided costs for electricity from Grenlec	includes inflation on electricity price of 5% p.a.	accured savings equal to system price inc. interest	accured savings after amort.
Environmental Impact					
Avoided amount of CO2 (t/yr):		2.6			

Source: GrenSol 06 April 2010

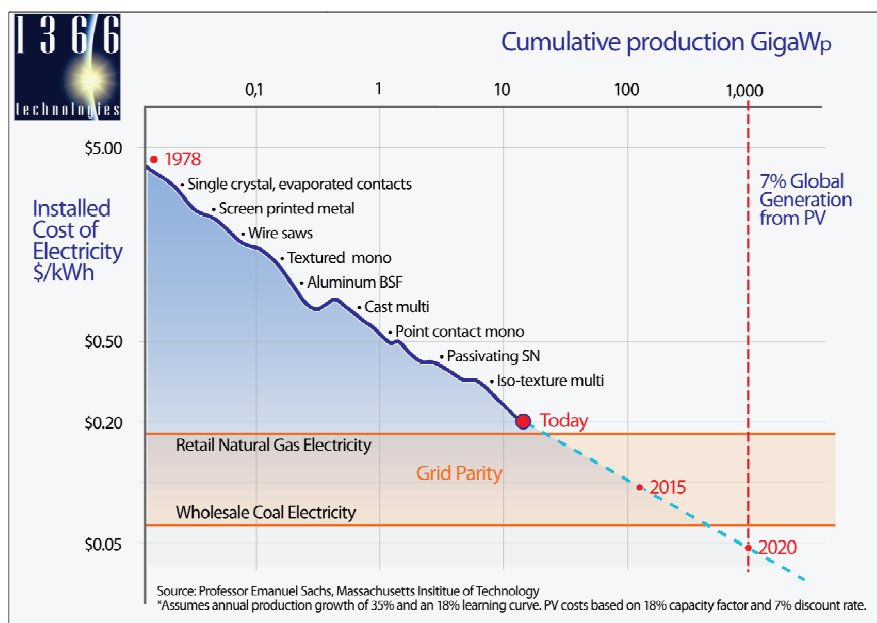
The system would save 2.6 tons of carbon dioxide per year. The energy payback time of a standard photovoltaic cell is around 4 years (Bankier & Gale 2006).

The previous example is a small system and works with net-metering; the tariff for bigger systems has to be negotiated with GRENLEC. For example, for a 16 kWp system on top of an insurance building net-metering was agreed until a surplus is reached. This means that as long as the insurance company consumed the same as they produced, 1:1 net metering applies. As soon as the photovoltaic system is producing more electricity than the building requires, the insurance company is selling electricity to GRENLEC for 0.29 ECD/kWh which equals the avoided cost of fuel (about one third of the electricity bill). If they need more electricity than the photovoltaic system can produce they buy the extra power for the retail price (0.85 ECD/kWh at time of research). By that the insurance company is cutting half of their electricity bill every month. In this special case GRENLEC installed two meters in series one to register electricity bought from GRENLEC and one to register electricity sold to GRENLEC from the photovoltaic system which normally only happens on weekends when the insurance company is closed (Burkhardt, K. pers. comm. 28 April 2010).

The utilities argued that net-metering is not favorable for them because the renewable energy source is just generating electricity but there are still transmission and distribution costs to be covered (Rowe pers. comm. 12 April 2010). So, the compensation should be based on the avoided costs, like in Barbados setting their tariff at 1.8 times the fuel charge and with a minimum of 0.32 BBD/0.16USD. Grid parity, the point at which renewable electricity is equal or cheaper than grid power, will be reached when the electricity cost of renewable energy would reach the same price as the avoided costs (in the case of Barbados fuel charge x 1.8). Costs of photovoltaic systems are constantly decreasing and it is forecasted that it will be reached in 2015, Figure 29 (Wray 2009).

Right now, the solar electricity price in sunny climates is 34.74 US-cents/kWh for a residential (2 kW) system, 24.71 US-cents/kWh for a commercial (50 kW) system and 19.27 US-cents/kWh for an industrial (500 kW) system (Solarbuzz 2010). In case of a fuel charge of 19.3 US-cents/kWh the avoided costs would theoretically reach the 34.74 US-cents/kWh. As seen in Figure 16 under chapter 4.2.2., fuel charges vary heavily, in this example from 0.10 USD to 0.30 USD during the oil crisis. However, the solar electricity price index depends as well on various factors, like the prices of the solar modules, other electrical components, assembly and installation costs, transportation costs and many more.

Figure 29: Electricity Costs and Grid Parity of Photovoltaic Technologies



Source: Wray 2009

Although there are very good sunlight conditions, resulting in higher system outputs, there are still higher transportation costs for the Caribbean region. A standard system in the United States would cost 3.95 USD/Wp (Koerner pers. comm. 27 May 2010), Table 11. Transportation costs to the Caribbean are 135 USD/pallet, plus a 6.5% handling charge to the government and a brokerage fee of 250 ECD/93 USD (Preville pers. comm. 05. May 2010). In case of a bigger order from Houston, Texas, United States to Castries, St. Lucia, a 20 foot container would cost about 3003 USD and a 40 foot container 4553 USD (Fischer pers. comm. 12 May 2010). A 20 foot container would include modules of about 100 kW and a 40 foot container about 50 kW (Heins pers. comm. 27 May 2010).

Table 11: Price for a Standard System in the US

Components	In USD/Wp
Module	2.10
Inverter	0.45
Mounting system	0.40
Electrical material	0.10
Others	0.25
Installer	0.65
Total	3.95

Source: Koerner 2010

The positive aspect of photovoltaic technologies for Caribbean people is mainly the effect of saving energy. “The people do not care much about the environment”, according to Preville (pers. comm. 05 May 2010). Therefore, the marketing of photovoltaic installations should show how much energy and hence money the people can save with photovoltaic systems. Other economic effects, same as for solar water heaters, are energy oil imports and carbon emissions savings. Photovoltaic installations make an important contribution to increase the renewable energy share as well as new job opportunities.

7 Viability in Terms of Sustainable Development

Governments in the Caribbean are aware of the high dependency on fossil fuels as well as the negative effects of climate change on small islands. Thus, they do consider and strive for a use of renewable energy sources. But as mentioned in chapter 2.2, barriers like inadequate policies and strategies, lack of awareness, knowledge and confidence; inadequate capacity and lack of finances are still big hindrances. Large efforts by international organizations or aid agencies were made to setup plans aiming to reach certain renewable energy shares. But as seen in the summary in Table 5 under chapter 4.4, renewable energy shares are still 0% and renewable energy policies exist mainly just as drafts. The reason was that a wrong approach was followed. The case studies showed that not just the government, but mainly the initiative from the private sector is the key factor. The solar water heater and photovoltaic markets were both established because of strong commitment and the high efforts of national to local manufacturers or distributors together with governmental interactions – a successful cooperation.

7.1 The Sustainable Market Implementation on One Island

The main drivers to implement solar energies are economic, the economic optimization for the customer and the emergence of a leading industry (refer to Table 2, chapter 2.1). People want to save high electricity costs and by offering reliable products and services, the private sector is able to satisfy those needs. This would mean the private sector is reflecting the “Leading Industry” under economical drivers in Table 12. The main driver for the government is as well economical – the “Security of Supply”. For the government the “Economical Optimization” in terms of grid coverage is not that significant because in the Caribbean region is already very high with almost 100%, compared to other developing countries. Economical optimization is more important for the consumers to save electricity costs. This driver would also be interesting for the utilities, if photovoltaic technologies would reach grid parity for example.

The economical driver is followed by the environmental aspect, which is more seen as a positive side effect as a “real driver” of solar energies. An important environmental effect of solar energies is to reduce emissions. Both, the private sector and the government,

are aware of this and also use this argumentation for promotion. On international level governmental institutions are involved in discussions about climate changes. Of course solar technologies can help to prevent climate changes and that is why governments strive to implement them. Nevertheless climate change is not on top of the mind, as seen in the St. Lucia budget speech for example (Charles pers. comm. 18 May 2010). Caribbean people are not really conscious about environmental protection. Only a few, especially if they possess a form of solar energy equipment, are aware of the natural protection but it would not be the main driver to get a solar energy installation. Even less aware than the environmental are the social aspects. There exists a big lack of awareness about how many risks and poverty could be diminished.

Table 12: Drivers for Solar Energy Technologies

Economical Drivers	Environmental Drivers	Social Drivers
Economical Optimization Consumer (Utility)	Reducing Emissions Private Sector and Governm. Institut.	Employment <i>Lack of Awareness</i>
Security of Supply Governm. Institut.	Reduc. Climate Change Governm. Institut.	Public Support <i>Lack of Awareness</i>
Leading Industry Private Sector	Protect Natural Life Consumers	Social Econom. Cohesion <i>Lack of Awareness</i>

Refer to chapter 2.1

Remarkable proceedings have been achieved on the solar water heater and photovoltaic market and therefore the *private sector* needs to be supported. Strengthening the private sector, more solar systems will be produced and sold. With increased sales, also awareness and promotion campaigns will enlarge and the private sector will contribute to educate people and hence reduce emissions and protect the environment.

Governmental institutions can make a big contribution by providing fiscal incentives, for example consumption tax releases or income tax concessions. Those incentives are crucial for a solar market establishment. Towards a sustainable market growth, the government should show their commitment by installing solar technologies on public entities, get involved and participate in promotions, as well as help the private sector to educate the customers. Furthermore they should set policies to assure market stability.

Once awareness is created, it is important to enable market accessibility to costumers by means of appropriate financing schemes by *financial institutions*. This can be done for solar water heaters through credit unions and for photovoltaic systems through commercial banks. The UNIDO project CSFP with credit unions is a very good attempt, a trusted and accepted financing source, to offer loans under better conditions for lower income classes. A similar project should be introduced for the financing of photovoltaic installations with commercial banks. It is essential that the banks get familiar with financing photovoltaic systems and reduce their risk perception and reluctance. Low interest rates and adequate financing periods are required.

Regarding photovoltaic technologies, the basic market requirement, even before the financing, is to secure the grid connection by the *utility*. Only with a grid connection, photovoltaic technologies can compete on a commercial level. This is working well in the French territories, like Martinique for example. There exist a certain feed-in tariff similar to France, possible to governmental regulations and the necessary economies of scale. In small independent islands such feed-in-tariffs like in Europe would not work. To realize this, the already very high electricity rates would have to be increased even further just to cover the costs. Hence, other solutions must be found. The utility in Grenada offered a 1:1 net-metering which is very positive for the customers but at the same time means losses for the utility. The best way to calculate the price for renewable energy would be based on avoided cost, like it was done in Barbados. So the utility would pay for the generated electricity but not lose their margins for transmission and distribution. A disadvantage of the Barbadian solution is the linkage to the fuel charge, which is a fluctuating value, illustrated in Figure 16 under chapter 4.2.2. For financing programs, fixed values would offer a better calculation basis.

It is important that the utilities learn from small pilot projects and become confident with the photovoltaic technology. Tariffs and prices should be well considered and calculated so as to not penalize any party involved. Therefore, it is necessary to closely cooperate with the private sector, as it was shown in the Grenada case study. Due to the collaboration of photovoltaic distributors and utility, an interconnection policy for grid connection was developed, even without any forces or regulations from the government. Nevertheless, this might not happen that easily on other islands. Photovoltaic technologies are an intermittent supply source and are not economically viable for the utilities yet. Economies of scale still favour fossil fuels but on the other hand electric

utilities are the largest source of green house gas emissions on the islands. This means that utilities have to be pushed to use photovoltaic systems and other renewable energies. As cited Mallon (2006) in chapter 2.1, the government has the responsibility to establish the market conditions and to use legislation to leverage private sector investments into renewable power projects. Binding, long-term and consistent policies will guarantee stability, which is necessary for investors as well as for financial institutions to reduce the barriers of perceived risks.

According to Loy (2007), the monopolies of the Caribbean utility companies are barriers for renewable energy implementations. This might be true to a certain extent, but it has to be pointed out that they serve the small island grids quite well. This means that the government should consider this aspect when setting up a policy and cooperate with the utility to jointly reach targets. Furthermore, like BL&P in Barbados, utilities should be aware of their important position in society and support their customers and country, which also means these monopolies may become a large opportunity for the promotion of solar energy.

Regulatory agencies or ministries are responsible for implementing and controlling governmental policies, to regulate the utilities and to protect customer interests. They are considered a useful tool to assure a successful realization of a policy introduction. *NGOs* are also very valuable for a market development. As Dubash (2002) pointed out, they rarely participate actively in the design of reforms, but as seen in the Barbados case, they are an important information source when establishing a market.

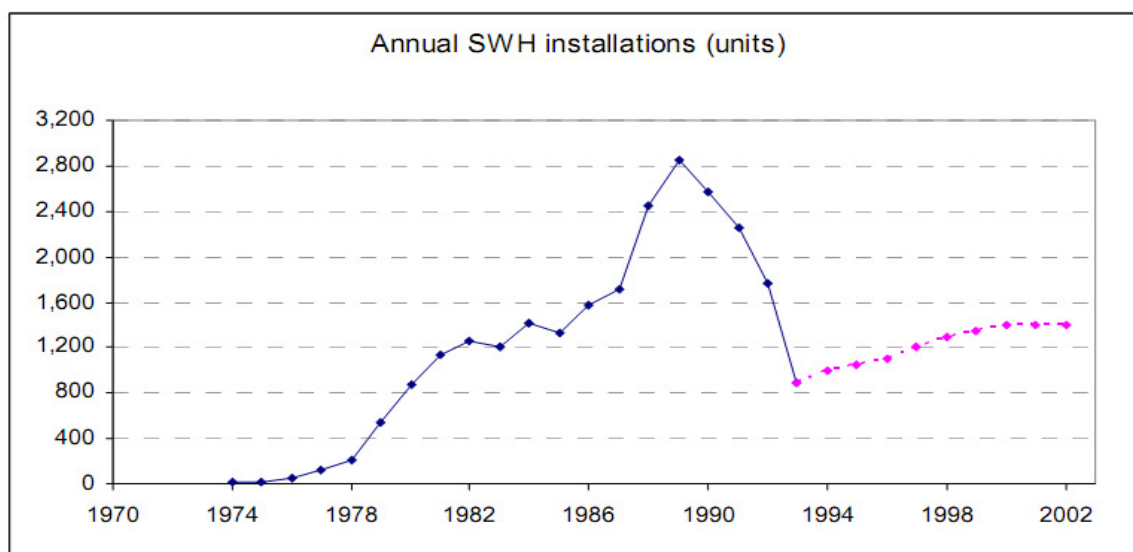
The case studies show that there is a potential market for solar energy systems in the Caribbean region and it is possible to overcome the barriers. As analyzed, once the solar water heater market is established by the private sector and supported by the government, it can be further penetrated when financing for middle and low income classes can be made more attractive. Similar for photovoltaic systems, the government has to endorse the private sector so that the markets can be established and it requires proper financing schemes to assure a prosperous market growth. Very crucial for photovoltaic implementations is the cooperation of the utility, which can be achieved by close collaboration and guiding policies. To further help market growth, international *donor agencies* should put a high focus on improving financing for solar water heaters and photovoltaic systems.

7.2 The Market Transferability to Other Islands

To expand the market to other islands, the mentioned prerequisites have to be in place. Furthermore, the markets have to be defined and quantified, which is quite difficult. For example, coverage of running water is a basic requirement for solar water heater implementations because if the water supply cannot be met, hot water is considered as luxury good. This would mean that solar water heaters preferably address the middle and higher income classes. But even in those income classes, many people reported that they do not need a solar water heater because they are satisfied with the tap water temperature of almost 27°C. That is different in the many hotels of the islands though. Tourists want to experience the same standards as in their home countries and do not want to miss a constant hot water supply.

So the question arises, if there is a relation between income and solar water heater implementations. Out of the three case studies, Barbados is the wealthiest country. With a GDP of 18,500 USD (est. 2009) almost every second household has a solar water heater installed. However, as can be seen in Figure 30, installations declined sharply with the onset of a major economic recession in 1990 to under 1000 units in 1993. With the economic recovery, solar water heater sales increased and stabilized (Perlack & Hinds 2008). That means that there is definitely a correlation between economic welfare and the amount of installed solar water heater systems.

Figure 30: Annual Solar Water Heater Installation in Barbados



Source: Perlack & Hinds 2008

It can be assumed that this correlation also exists for photovoltaic systems. Nevertheless, it cannot be generalized and be said that people with a certain income are potential buyers. As mentioned before, there are different behaviors and habits within and among the Caribbean islands. For example, in Dominica – another island close to the case studies - it is a custom to go to the river for bathing and to chat with the people (Homscheid, pers. comm. 10 May 2010). Solar water heaters will probably have a lower acceptance in this market. Therefore the Caribbean islands must not be seen as homogeneous; every island is different and has to be approached individually to assure adaptation and market growth.

According to Mallon (2006), the renewable energy industry is global and opening up a new market will require the involvement of non-indigenous companies. This can be clearly disproved for the Caribbean solar water heater technology. Local manufactures established and penetrated the market. It seems that Caribbean people are quite suspicious about a new technology. Thus lots of efforts are required to gain their trust and confidence. Same for photovoltaic technologies, although it is a non-indigenous product, only a local company was able to open the market. Only through the high commitment and the close contact to customers, as well as the government, the solar water heater and photovoltaic markets established. As confirmed during the interviews, this exactly is also needed to be successful on other islands - personal staff at site, with the required knowledge, high reputation and reliability (Burkhardt, D. pers. comm. 27 April 2010, Burkhardt, K. pers. comm. 28 April 2010)

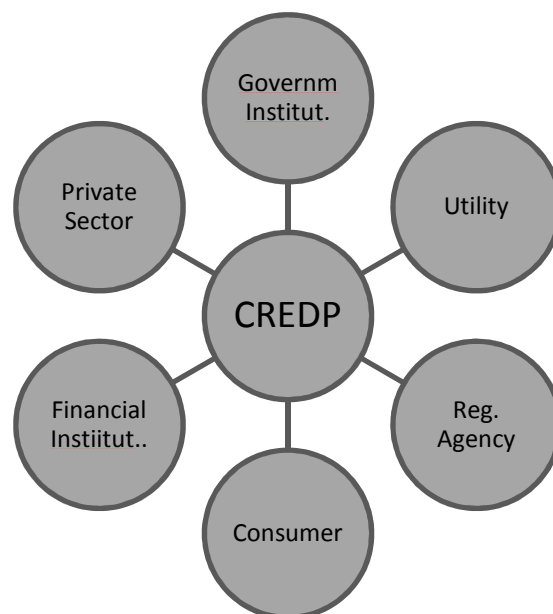
Once the market and the product confidence are established, it is also possible for international companies to enter. This was experienced in the solar water heater market, when Chinese products entered the market a couple of years ago. Due to the cheap prices, they were able to gain significant market shares. However, care has to be taken with new products. Product failure or reliance could not just destroy the manufacturer's reputation but also whole market segments. Because of bad experiences and afraid of reputation losses, GrenSol is exclusively using high quality products. To gain the trust of the Caribbean people is very important (Burkhardt, D. pers. comm. 27 April 2010). Once the market is stable, cheaper products could enter in the markets, as seen at the example of the solar water heaters.

7.3 CREDP as Assistant to Reach Sustainability

Once all mentioned features are all in place, the viability of the solar water heater and the photovoltaic market development in the Caribbean region can be justified as very high. As seen in the previous chapters, solar energy implementations are not only economical but also have many positive environmental and social effects. So far though, the main driver for solar energy implementations is the economic aspect. Environmental aspects play only a minor role, even less social aspects. To change this, they have to be fostered by education. The private sector created the awareness and educated the people about the economic benefits of their products. The same education process has to be undertaken in regards to environmental and social sustainability. This requires an external impulse, which can be given by CREDP, illustrated in Figure 31.

CREDP helps governments, utilities and regulatory agencies when setting up policies, which is the first and basic step to reach stability. They offer trainings for financial institutions and assist the private sector in product decisions. To supplementary support solar energy installations, CREDP is doing various attempts to educate all stakeholders. As mentioned before, the program also assists technical colleges and trains architects, technicians and students.

Figure 31: CREDP Supporting the Solar Energy Market



By creating a higher awareness also for environmental and social aspects, the implementation of solar energy could further increase. The private sector could increase their sales due to higher demand. Furthermore, the private sector and customers alike ask for more and improved financing schemes. Regarding photovoltaic installations, consumers will additionally ask for more “green energy” and along regulatory agencies and governments could push utilities. This is, only to mention some outcomes.

This reflects what was already said under chapter 2.1. The 3A strategy (Qurashi & Hussain 2005) has to be fulfilled to assure a sustainable solar energy market development. “Accessibility” and “Availability” are already given, what needs to be improved now is the “Acceptability” not just as an economical but as well as an environmental and social driver.

- Accessibility (provide clean energy at affordable prices)
- Availability (reliable source and security)
- Acceptability (public attitude, social and cultural circumstances)

Right now, the assistance of CREDP in some parts of the solar energy market is needed. The aim is to reach market function without interconnection by CREDP as well as without any further support by international donor agencies. If this can be accomplished, it can be said that the solar energy market is also viable in terms of social, economic and environmental sustainability.

8 Conclusion and Recommendations

As the case studies showed, there is a potential market for solar energy systems implementations in the Caribbean. The first objective was to gain an overview about the present solar energy situation, which was answered under chapter 4 with a summary under 4.4. Based on this information frameworks for market establishments were developed. They showed that a solar water heater as well as a photovoltaic market could be set-up by a strong committed private sector, supported by governmental incentives.

To offer reliable products and services is the key factor. Caribbean people are very suspicious and do not easily adapt to new products. The awareness has to be created and this requires many efforts by manufacturers or installers. Thus, a high reputation of the vendor is necessary or even obligatory for a successful market establishment. For example the photovoltaic market in Grenada expanded fast because Dirk Burkhardt is well-known among the island because of his medical profession, which symbolizes also a very high reputation in the Caribbean region.

The government should support the private sector by setting incentives. A release of import or consumption taxes was mentioned to be the most effective and essential. Income tax concessions seem to be also very helpful but it was not clear if those deductions could really animate people to buy a solar product or if it is just an attractive side-effect. Besides the fiscal incentives, the government should show their commitment to the product by public installations and promotions helping to create awareness and educate consumers as well as all other stakeholders.

The utilities play an important role regarding the connection of photovoltaic systems to the electrical grid. Without proper settings and regulations it is impossible to establish a commercial photovoltaic market. Because they are in a learning stage now, a close cooperation with the private sector is needed. The government has to set policies to assure stability, which is a basic condition for a prosper market growth.

The second objective was to establish possible scenarios and corresponding attempts to approach the solar market. Hence, barriers hindering the market growth were observed and two frameworks for a successful solar water heater and photovoltaic market penetration were established under chapter 5.3 and 6.3. They showed that the market

penetration could be improved basically by offering better financial schemes. Until now, financial institutions are still very reluctant to offer loans for solar technologies. Long-term credit options and low interest rates are required to guarantee a further market saturation. The chapters were closed by an overview about economical, environmental and social facts about solar water heaters and photovoltaic technologies, because it was noted that a basic understanding is often a lack and big hindrance.

Chapter 7 analyzed the viability in terms of social, economic and environmental sustainability; the third objective. The main drivers for solar energy implementations in the Caribbean are economical drivers. Under chapter 7.1 it was explained what efforts by all stakeholders have to be undertaken to secure a sustainable market development. This is basically the wrapping-up of the two solar frameworks. Chapter 7.2 demonstrated what needs to be done to transfer the scenarios to different islands. Of course, the market mechanisms developed in the research frame have to be implemented in other islands to set the basic structures but the research showed that local company staff and knowledge have to be transferred, too. Once the market is stable, also international companies could enter and enhance competition. Finally, chapter 7.3 summarizes the assistance by CREDP, what help is done supporting the solar energy market and how the social and environmental aspects can be further implemented, which is basically by education and an interconnection of all stakeholders.

Although various different interviews were underdone and the established frameworks can be taken as reliable, it has to be mentioned that the economical data might be highly positive. It was considered as very important to make and illustrate some economical data because the main driver for solar energy implementations is the economical aspect. Nevertheless, most calculations are based on manufacturers or installers statements which are not neutral. Independent calculations about solar energy in the Caribbean hardly exist and it is recommended to generate more precise figures.

Solar water heaters are spread among all of the islands in the case studies. However, it is not possible to clearly quantify them. There are no official figures or statistics. According to Jordan (pers. comm. 26 March 2010), the Government of Barbados conducts once every ten years the National Housing & Economic Survey, and they have dedicated three out of 51 questions to solar systems, so there will be a published report with more accurate numbers by 2011. Such kind of research should be standard on all

islands in order to quantify and help to evaluate the solar water heater market. Import data is not very accurate because many solar water heaters are manufactured or assembled locally. Accurate figures, also in relation with basic household information, could further help to draw conclusions about implement motivations and user habits. This could help the private sector to improve products and services as well as to extent their marketing approach.

Without exact numbers, it cannot be precisely calculated how much energy could be saved or what is the renewable energy share. Solar water heaters save electricity which would be used to heat water. As seen in the case of Barbados, solar water heaters would reach a renewable energy share of 15%. Unfortunately, this technology is often underestimated. Because it is separate from the grid system and not “directly” replacing electricity produced from fossil fuels, it is generally neglected. Governments as well as utilities need to be educated about the magnitude of solar water heaters and their ability as power generating plants. An energy calculation would also be very interesting for solar drying crops, which is quite common in the Caribbean region, or for SODIS and solar desalination systems.

Quantification is easier for photovoltaic systems because they are connected to the electric grid and the utilities can give accurate numbers about systems as well as electricity saved. More importantly, to further support photovoltaic implementations is the availability of system data. To evaluate the different photovoltaic technologies (mono-crystalline, poly-crystalline and thin-film modules) under Caribbean climate conditions, GrenSol is establishing a testing plant. In addition, the various pilot and demonstration plants should also be used to generate data. Therefore, it is helpful to include a web-box to attach to the systems, which provides data via the internet. All this data, together with the basic system information (a check list is attached in the appendix), can provide the capacity factor, as well as recommend the most suitable technology.

Summarizing it can be said, analyzing the case studies, recognizing the big improvements within the last years and expecting further developments, the future looks very promising or better very “bright” for the Caribbean region.

References

- Agency for International Development 2009, Solar energy in developing countries, General Books LLC
- Arnould, E. J. & Thompson, C. J. 2005, Consumer Culture Theory (CCT): Twenty Years of Research, in: Journal of Consumer Research, vol. 31 no. 4, 868-882
- Bankier C. & Gale S. 2006, Energy Payback of Roof Mounted Photovoltaic Cells, Energie Bulletin, <http://energybulletin.net/node/17219>, viewed 26 May 2010
- Bates, B.C., Kundzewicz, Z.W., Wu, S. & Palutikof J.P. 2008, Climate Change and Water, Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat
- The Barbados Light & Power Company Limited (BL&P) 2010a, <http://www.blpc.com.bb/>, viewed 11 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2010b, BL&P Renewable Energy Initiatives – The Energy Facility, and Sustainable and Renewable Energy Workshop, in Barbados on 24 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2009a, Application, Pursuant to Section 16 of the Utilities Regulation Act CAP.282 of the Laws of Barbados, http://www.ftc.gov.bb/library/blip_app/2009-05-08_volume_1_section_2_application_by_barbados_light_and_power_company_limited.pdf, viewed 11 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2009b, Annual Report 2008, http://www.blpc.com.bb/co_rep.cfm, viewed 09 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2008, Annual Report 2007, http://www.blpc.com.bb/co_rep.cfm, viewed 09 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2007, Annual Report 2006, http://www.blpc.com.bb/co_rep.cfm, viewed 10 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2006, Annual Report 2005, http://www.blpc.com.bb/co_rep.cfm, viewed 09 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2005, Annual Report 2004, http://www.blpc.com.bb/co_rep.cfm, viewed 10 March 2010
- The Barbados Light & Power Company Limited (BL&P) 2004, Annual Report 2003, http://www.blpc.com.bb/co_rep.cfm, viewed 10 March 2010

- BBC 2010, BBC Caribbean.com – Caribbean battles drought, published 18 February 2010, http://www.bbc.co.uk/caribbean/news/story/2010/02/100218_drought.shtml, viewed 2 May 2010
- Berekoven, L., Eckert, W., & Ellenrieder, P. 2001, Marktforschung. Methodische Grundlagen und praktische Anwendung, 9th Edition, Gabler
- Buber, R & Holzmueller, H. H. 2007, Qualitative Marktforschung, Konzepte – Methoden – Analysen; Gabler
- Burke, H.V.N. 2010, 2010 Budget Statement, Minister of Finance, Planning, Economy, Energy and Cooperatives, Government of Grenada
- Caribbean Council for Science and Technology (CCST) 1999, Renewable Energy in The Caribbean – Where We Are; Where We Should Be, <http://www.eclac.org/publicaciones/xml/3/10253/carg0565.pdf>, viewed 13 May 2010
- Caribbean Cruises 2010, <http://www.caribbean-cruise.org/wp-content/uploads/2007/12/caribbean-islands-map.png>, viewed 13 May 2010
- Caribbean Hotel and Tourism Association (CHAT) 2010, Caribbean Alliance for Sustainable Tourism, <http://www.caribbeanhotelandtourism.com/CASTchenact.php>, viewed 25 May 2010
- Caribbean Solar Alliance (CSA) 2010, <http://www.caribsolaralliance.com/>, viewed 10 March 2010
- CARICOM 2010, Caribbean Community Secretariat, <http://www.caricom.org>, viewed 1 May 2010
- CARILEC 2010, Caribbean Electric Utility Services Corporation, <http://carilec.com>, viewed 1 May 2010
- CARILEC 2008, Minimising the Impact of Rising Fuel Prices - LUCELEC's Perspective http://www.carilec.com/publications/NewsletterArticles/Aug08_Article6.pdf, viewed 2 May 2010
- CARILEC 2009, Issue No. CN0709 April 2009, <http://www.carilec.com/publications/Apr09.pdf>, viewed 1 February 2010
- CEIS 2010, Caribbean Energy Information System, <http://www.ceis-caribenergy.org>, viewed 1 May 2010

- Central Intelligence Agency (CIA) Barbados 2010, The World Factbook, Central America and the Caribbean: Barbados, <https://www.cia.gov/library/publications/the-world-factbook/geos/bb.html>, viewed 10 March 10,
- Central Intelligence Agency (CIA) Grenada 2010, The World Factbook, Central America and the Caribbean: Grenada, <https://www.cia.gov/library/publications/the-world-factbook/geos/gj.html>, viewed 17 March 10
- Central Intelligence Agency (CIA) St. Lucia 2010, The World Factbook, Central America and the Caribbean: Saint Lucia, <https://www.cia.gov/library/publications/the-world-factbook/geos/st.html>, viewed - 3 May 2010,
- Christou, R. 2005, Drafting Commercial Agreements, Sweet & Maxwell Limited, London
- Climatelab 2010, Grenada, <http://climatelab.org/Grenada>, viewed 19 March 2010
- CREDP 2009, Caribbean Renewable Energy Development Programme - Programme Component CREDP/GTZ – Project Profile
- ECLAC/GTZ 2004, Renewable Energy Sources in Latin America and the Caribbean: Situation and Policy Proposals, United Nation ECLAC, German Agency for Technical cooperation (GTZ)
- Ehrhardt, D. & Oliver, C. 2007, Big Challenges, small states – Regulatory options to overcome infrastructure constraints, Gridlines, Note No. 24, c/o The World Bank
- Energy Information Administration (EIA) 2010, Independent Statistics and Analysis, Barbados energy Profile, http://tonto.eia.doe.gov/country/country_energy_data.cfm?fips=BB, viewed 12 March 2010
- Energy Policy Committee 2006, Draft: The National Energy Policy of Barbados
- Epp, B. 2009, The Barbados Model: A Success Story in 3 acts, http://www.solarthermalworld.org/files/Barbados_successmodell.pdf?download, viewed 20 February 2010,
- Ereaut, G., Imms, M. & Callingham, M. 2002, Qualitative Market Research: Principles and Practice, in Qualitative Marktforschung, Konzepte – Methoden – Analysen, Gabler

-
- Deutsche Energie-Agentur GmbH 2010, thema energie, <http://www.thema-energie.de/energie-erzeugen/erneuerbare-energien/solarwaerme/auslegung-montage/solarstrahlung.html>, viewed 15 June 2010
 - van Dijk, A.L., Beurskens, L.W.M., Boots, M.G., Kaal, M.B.T., de Lange, T.J., van Sambeck, E.J.W. & Uytterlinde, M.A., 2003, Renewable Energy Policies and Market Developments, part of analysis phase of RAMC 2000 project
 - Dubash, N.K. 2002, Power Politics – Equity and Environment in Electricity Reform, World Resources Institute
 - Fair Trading Commission Barbados 2009, Annual Report 2009, http://www.ftc.gov.bb/index.php?option=com_content&task=view&id=136&Itemid=2, viewed 09 March 2010,
 - Fair Trading Commission 2010, Findings Report – The Barbados Light & Power Co. Ltd. Pilot Programmes, Document No. FTC/URD/FINREP2010-01
 - FirstCaribbean 2010, First Caribbean International Bank, <http://www.firstcaribbeanbank.com/index.php?page=about-firstcaribbean>, viewed, 24 June 2010
 - GAISMA 2010, <http://www.gaisma.com/en/location/crane.html>, viewed 13 March 2010
 - Gardner, T.A., Cote, I., Gill, G., Grant, A. & Watkinson, A., 2003, Long-term region-wide declines in the Caribbean corals, Science
 - Global Sustainable Energy Islands Initiative (GSEII) 2009, Grenada - National Energy Policy * Solar Hot Water Systems * Nutmeg Biofuels * Earth Home, <http://www.gseii.org/islands/grenada.html>, viewed 19 March 2010
 - Global Sustainable Energy Islands Initiative (GSEII) 2009b, Caribbean Solar Finance Programme, Lending for Consumer Applications of Solar Hot Water Systems in Grenada, Project paper
 - Grenada Guide 2005, Grenada General Information, <http://www.grenadaguide.com/General.htm>, viewed 16 March 2010
 - Grenada Electricity Service Ltd. (GRENLEC) 2010, <http://www.grenlec.com>, viewed 18 March 2010
 - Grenada Electricity Service Ltd. (GRENLEC) 2003, Annual Report 2002, http://www.grenlec.com/index.php?option=com_content&view=article&id=202&Itemid=101, viewed 18 March 2010

-
- Grenada Electricity Service Ltd. (GRENLEC) 2004, Annual Report 2003, http://www.grenlec.com/index.php?option=com_content&view=article&id=202&Itemid=101, viewed 18 March 2010
 - Grenada Electricity Service Ltd. (GRENLEC) 2005, Annual Report 2004 http://www.grenlec.com/index.php?option=com_content&view=article&id=202&Itemid=101, viewed 18 March 2010,
 - Grenada Electricity Service Ltd. (GRENLEC) 2006, Annual Report 2005, http://www.grenlec.com/index.php?option=com_content&view=article&id=202&Itemid=101, viewed 18 March 2010
 - Grenada Electricity Service Ltd. (GRENLEC) 2007, Annual Report 2006, http://www.grenlec.com/index.php?option=com_content&view=article&id=202&Itemid=101, viewed 18 March 2010
 - Grenada Electricity Service Ltd. (GRENLEC) 2008a, Annual Report 2007, http://www.grenlec.com/index.php?option=com_content&view=article&id=202&Itemid=101, viewed 18 March 2010
 - Grenada Electricity Service Ltd. (GRENLEC) 2009, Annual Report 2008, http://www.grenlec.com/index.php?option=com_content&view=article&id=202&Itemid=101, viewed 18 March 2010
 - Grenada Herald 2010, Prime minister calls for energy security, <http://www.grenadaherald.com/?p=1216>, viewed 09 April 2010
 - Grenada Electricity Service Ltd. (GRENLEC) 2008b, Renewable Energy Interconnection Policy
 - Grenada Solar Power Limited (GrenSol) 2010, http://grensol.com/about_us/our_mission/index.html, viewed 19 May 2010
 - Gorbach, P.M. & Galea, J. 2007, Qualitative Methods - Behavioral Interventions for Prevention and Control of Sexually Transmitted Diseases, Springer US
 - Headley, O. 1998, Solar thermal Applications in the West Indies, Pergamon, Renewable Energy 15, 257-263, Elsevier Science Ltd.
 - Headley, O. 2000, Use of Photovoltaic Systems in the Caribbean, Centre for Resource Management and Environmental Studies (CERMES), Faculty of Science and Technology, University of the West Indies
 - Headley, O. 2001, Barbados Renewable Energy Scenario Current Status and Projections to 2010, Centre for Resource Management and Environmental Studies (CERMES), Faculty of Science and Technology, University of the West Indies

- Heidegger, M. 1927/1995, Sein und Zeit, in Qualitative Marktforschung, Konzepte – Methoden – Analysen, Gabler
- Huacuz, J.M. 2003, Overview of Renewable Energy Sources in Latin America, International Electrical Research Exchange: Central American Forum
- Inter-American Development Bank (IDB) 2010, Climate Change and Renewable Energy, <http://www.iadb.org/topics/climateChange/secci/index.cfm>, viewed 25 May 2010
- Holm, D. 2005, Renewable Energy Future for the Developing World, International Solar Energy Society (ISES)
- Johansson, T.B & Goldemberg, J. 2002, Energy for Sustainable Development – A Policy Agenda, United Nations Development Programme (UNDP)
- Kaltschmitt, M., Streicher, W., Wiese, A. 2007, Renewable Energy – Technology Economics and Environment, Springer
- Kinnear, T.C. & Taylor, J.R., 1996, Marketing Research: An Applied Approach, 5th Edition, McGraw-Hill
- Knassmueller, M. & Vettori, O. 2007, Hermeneutische Verfahren – Verstehen als Forschungsansatz, in Qualitative Marktforschung, Konzepte – Methoden – Analysen; Gabler
- Langniss, O. & Ince, D. 2004, Solar Water Heating, A Viable Industry in Developing Countries, reFOCUS, 1471 0846/04, Elsevier Ltd.
- Larsen, B. & Shah, A. 1992, World Fossil Fuel Subsidies and Global Carbon Emissions, Background Paper for World Development Report 1992, Policy Research Dissemination Centre, <http://info.worldbank.org/etools/docs/library/206933/WorldFossilFuelSubsidiesandGlobalCarbonEmissions.pdf>, viewed 24 June 2010
- Loy, D. 2007, Energiepolitische Rahmenbedingungen fuer Strommaerkte und erneuerbare Energien – 23 Laenderanalysen, Kapitel Karibik, Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH
- Loy, D. & Farrell, C. 2005, The Status of Energy Policy in selected Caribbean Countries. A joint study of CREDP/GTZ and CARILEC, on behalf of deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) GmbH
- LUCELEC 2010, St. Lucia Electricity Services Ltd., <http://www.lucelec.com/discover/history.php>, viewed 05 May 2010

-
- LUCELEC Annual Report (AR) 2010, Annual Report 2009, http://www.lucelec.com/PDFs/LUCELEC_Annual_Report_2009.pdf, viewed 05 May 2010
 - Mallon, K. 2006, Renewable Energy Policy and Politics – A Handbook for Decision-making”, Earthscan
 - Margolis, R. & Zuboy, J. 2006, Nontechnical Barriers to Solar Energy Use: Review of Recent Literature, Technical Report, NREL/TP-520-40116
 - Mayring, P. 2000, Qualitative Inhaltsanalyse. In: Forum Qualitative Sozialforschung, in Qualitative Marktforschung, Konzepte – Methoden – Analysen, Gabler
 - Mayring, P. & Brunner, E. 2007, Qualitative Inhaltsanalyse, in Qualitative Marktforschung, Konzepte – Methoden – Analysen, Gabler
 - Meyer, C.M. 2008, The strange story of solar water heating: Part 3, energize - GENERATION
 - Michel, H. 2008, Die Zukunft der Energien – Die Antwort der Wissenschaft, Report der Max-Planck-Gesellschaft, C.H. Beck
 - Milton, S. & Kaufman, S. 2005, Solar Water Heating as a Climate Protection Strategy: The Role for Carbon Finance, Green Markets International, Inc.
 - Ministry of Finance, Planning, Economy, Energy, & Co-operatives 2010, Barbados, visited 27 April 2010
 - Ministry of Physical Development Environment 2001, Barbados’ First National Communications Report 2001, Under the United Nations Framework Convention on Climate Change (UNFCCC), published by the Ministry of Physical Development Environment
 - Ministry of Physical Development and the Environment 2010, Saint Lucia National Energy Policy January 2010, CREDP internal Document
 - Moseley, M & Headley, O. 1999, Medium scale photovoltaic applications for Barbados, Pergamon, Renewable Energy 17 (1999) 1-17, Elsevier Ltd.
 - Simon, C. P., 2008, Sichere Energien im 21. Jahrhundert, Hoffmann und Campe Verlag GmbH
 - OECS 2010, Organisation of Eastern Caribbean States, <http://www.oecs.org>, viewed 1 May 2010

-
- Qurashi, M.M. & Hussain, T 2005, Renewable Energy Technologies for development Countries – Now and to 2023, Publications of the Islamic Educational, Scientific and Cultural Organization
 - REN21 2008, Renewables 2007 Global Status Report, Paris: REN21 Secretariat and Washington, DC: Worldwatch Institute, Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH
 - Perlack, B. & Hinds, W. 2008, Evaluation of renewable Energy incentives: The Barbados Solar Water Heating Experience
 - Riege, A. 2007, Gueltigkeit und Zuverlaessigkeit von Fallstudien, in Qualitative Marktforschung, Konzepte – Methoden – Analysen, Gabler
 - Roper, T 2006, The Global Sustainable Energy Initiative (GSEII) 2006, Sustainable Energy for SIDS – Time for Action
 - Sealy, H. 2007, The Role of Hydrogen in the Economy of a Small Island Developing State like Barbados, http://www.un.org/esa/sustdev/sdissues/energy/op/hydrogen_seminar/presentations/13_sealy_barbados.pdf, viewed 12 March 2010
 - Solar and Wind Energy Resource Assessment (SWERA), <http://swera.unep.net/index.php?id=7>, viewed 28 January 2010
 - Solarbuzz 2010, Solar Electricity Global Benchmark Price Indices, <http://www.solarbuzz.com/solarindices.htm>, viewed 26 April 2010
 - Solar Electric Power Association (SEPA) 2010, Utility Solar Solutions, <http://www.solarelectricpower.org/>, viewed 01 April 2010
 - UN 2010, UN Office of the High Representative for the Least developed Countries, Landlocked developing Countries and Small Island developing States, <http://www.un.org/special-rep/ohrlls/sid/list.htm>, viewed 2 May 2010
 - UN 2004, Human Settlement Country Profile Barbados, UN Department of Economic and Social Affairs, Division for Sustainable Development, http://www.un.org/esa/agenda21/natlinfo/countr/barbados/human_settlements.pdf, viewed 11 March 2010
 - UNDP 2008, Solar Technology and Sustainable Development: Building on the Solar Dynamics Experience Barbados, UNDP Special Unit for South-South Cooperation, http://ssc.undp.org/uploads/media/Solar_technology.pdf, viewed 15 April 2010

-
- UNDP 2010, United Nations Development Programme – Barbados and the OECS, <http://www.bb.undp.org/index.php?page=enabling-activities>, viewed 06 April 2010
 - Schub von Bossiazky, Gerhard (1992): Psychologische Marketingforschung: qualitative Methoden und ihre Anwendung in der Markt, Produkt und Kommunikationsforschung. München
 - Srnka, K.J. (2007): Hypothesen und Vorwissen in der qualitativen Marktforschung, in Qualitative Marktforschung, Konzepte – Methoden – Analysen, Gabler
 - The World Bank 2010, Data – Country and Lending Groups, <http://data.worldbank.org/about/country-classifications/country-and-lending-groups>, viewed 1 May 2010
 - The World Bank 2010, Data & Statistics, <http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20421402~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html>, viewed 14 March 2010
 - Wray, P. 2009, Ceramic Tech Today - Cutting PV costs, Part 2: Process improvements versus science breakthroughs, The American Ceramic Society, <http://ceramics.org/ceramictechtoday/materials-innovations/cutting-pv-costs-part-2-process-improvements-versus-science-breakthroughs/>, viewed 26 May 2010

Appendices

Interviewees

- Auguste, J., Senior Energy Officer, Ministry of Finance, Planning, Energy, Foreign Trade & Co-operatives, St. George's, Grenada, 27 April 2010
- Bristol, D.C., Director, Consultant Surgeon, Gearing Up Limited (GUL), Vieux Fort, St. Lucia, 06 May 2010
- Burkhardt, D., Managing Director and Chairman & Entzmann, G., Chief Technical Officer, Grenada Solar Power Ltd., St. George's, Grenada, 27 April 2010
- Burkhardt, K.M., Chief Operations Officer, Grenada Solar Power Ltd., St. George's, Grenada, 28 April 2010
- Compton, U., Personal Lending Officer, Loans Department, Bank of Saint Lucia Ltd, Gros Islet, St. Lucia, 23 April 2010
- Charles, M., Managing Director, Paramount Holding Ltd, Castries, St. Lucia, 18 May 2010
- Christine Wilkinson, E3-Consulting, Environment, Energy Efficiency, Emergencies, Health & Safety, Castreis, St. Lucia, 21 May 2010
- D'Auvergne, C., Chief Sustainable Development and Environment Officer, Ministry of Physical Development, Environment and Housing, Sustainable Development and Environment Section, Department of Sustainable Development, Science and Technology/Ministry of Finance and Planning, Castries, St. Lucia, 10 May 2010
- Fischer, A., Logistic Expert, Mitsubishi Corporation LT Europe GmbH, Dusseldorf, Germany
- Heins, M., Manager Renewable Energy Department, Mitsubishi International GmbH, Dusseldorf, Germany
- Homscheid, S., Technical Advisor, Caribbean Renewable Energy Development Programme – CREDP/GTZ, Castries, St. Lucia
- Hosein, N., Executive Director, CARILEC, Castries, St. Lucia, 06 May 2010
- Husbands, J., Managing Director, Solar Dynamics Ltd., St. Michael, Barbados, 24 March 2010

-
- Jacobs, J., Electrical Engineer & Forsyth, D., Planning and Engineering Manager, Grenada Electricity Services Ltd., St. George's, Grenada, 27 April 2010
 - Jordan, H., Director, Sunpower - Hot Water Systems, Christ Church, Barbados, 26 March 2010
 - Koerner, T., VP Product and Business development Solar, Schüco USA L.P. Solar Technologies, Union City, CA, USA
 - Matteini, M., Industrial Development Officer, Industrial Energy Efficiency Unit, Energy and Climate Change Branch, UNIDO, Vienna, 31 May 2010
 - McClean, V., Director, Aqua Sol Components Ltd., Christ Church, Barbados, 28 March 2010
 - Peter, M., First Caribbean Bank, Castries, St. Lucia, 22 April 2010
 - Pool, F., Clean Energy Consultant, New Zealand, 29 May 2010
 - Preville, U., Managing Director/Consultant Engineer, Power Engineering Services, Gros Islet, St. Lucia, 05 May 2010
 - Row, D., Renewable Energy Advisor, CARILEC, Castries, St. Lucia, 12 April 2010
 - Scheutzlich, T., Principal Advisor, Caribbean Renewable Energy Development Programme – CREDP/GTZ, Castries, St. Lucia
 - Thirlwell, F.E., Executive Chairman), BICO Ltd., Bridgetown, Barbados, 25 March 2010
 - W.B. Williams, P.W.B., Managing Director, Barbados Light & Power Company Limited, St. Michael, Barbados, 25 March 2010

Check List for Photovoltaic Systems

GENERAL	
location	
solar insolation (kWh/kWp/a)	
azimuth (orientation of roof)	
inclination/tilt (in°)	
MODUL	
Brand	
Wp	
Efficiency	
Price (in US\$/Wp)	
Lifetime	
INVERTER	
Name	
Price (US\$/Wp)	
Lifetime	
SYSTEM	
Mounting system (in US\$/Wp)	
Cabelling etc. (in (in US\$/Wp)	
Other costs (in US\$/Wp)	
Total costs	
LOGISTIC	
Quantity	
Conditions (DDU)	
Transport (in US\$)	
Insurance (in US\$)	
Import (in US\$)	
Total costs	
INSTALLATION	
Mounting costs (in US\$/Wp)	
Administrative process (in US\$/Wp)	
Projection (in US\$/Wp)	
Profit (in US\$/Wp)	
Total costs	
MAINTENANCE	
Modules	
Cabelling etc.	
Inverter	
Total costs	
OVERALL COSTS	

Questionnaire

Country:

Date:

Solar Energy Analysis

1 International / National Ministry and Agency

1.1 Is there a national renewable energy policy? Yes, since _____

No not approved not established not intended

1.2 What is the actual renewable energy share? _____% of country's energy mix
 with: Photovoltaic _____% total installed _____ units
 (of those are _____% on-grid; _____% off-grid),
 Solar Water Heater _____% total installed _____ units
 Other solar energy technology like _____ %

1.3 What are the renewable energy targets? _____% till the year _____
 with: Photovoltaic _____% total installed _____ units
 (of those are _____% on-grid; _____% off-grid),
 Solar Water Heater _____% total installed _____ units
 Other solar energy technology like _____ %

1.4 Are there any incentives for solar energy?

Financial incentives in form of: _____

Fiscal benefits (e.g. tax concession): _____

Regulations or laws favoring or hindering solar energy implementations (e.g. building codes, import restrictions): _____

Other subsidies / funds: _____

Penalties (e.g. using electricity or gas for solar water heaters): _____

1.5 How would you rate the importance of solar energy implementation for your country's energy mix?

Not important ① ② ③ ④ ⑤ Very important

Because _____

Country:

Date:

Solar Energy Analysis

2 National / Municipal Utility

2.1 Does the utility have a renewable energy rider? Yes since _____

No not approved not established not intended

2.2 What is the renewable energy share? _____% of the energy mix end of 2009 with Photovoltaic _____%, targeting _____% for the year _____.

2.3 How would you rate the importance of solar energy implementation for the utility's energy mix?

Not important ① ② ③ ④ ⑤ Very important

Because _____

2.4 Do you see solar water heating helping to reduce the use of electricity?

No Yes, it saves about _____% of total electricity production

2.5 How much oil did you have to import in 2009 for which price?

_____ barrels, for _____ \$US/barrel

2.6 How much electricity was consumed in 2009 and what were the average prices?

Sector	kWh/year	per US\$/kWh
domestic		
industrial		
commercial		

2.7 When are the daily peak loads? _____ with _____ kWh

2.8 Under which assumption photovoltaic gets interesting for the utility?

Oil price higher than _____ US\$/barrel

Photovoltaic price lower than _____ US\$/Wp

Break-even point lower than _____ years

Efficiency higher than _____ %/panel

Other _____

Country:

Date:

Solar Energy Analysis

2.9 What are the advantages and disadvantages of Photovoltaic for the utility?

2.10 What are/would be the size restrictions for photovoltaic systems?

Sector	Maximum units	Maximum kWp
domestic		
industrial		
commercial		
TOTAL		

Because _____

2.11 What would be the best solution for realizing photovoltaic connection?

- Net-Metering, e.g. _____
- Net-Billing, e.g. _____
- Feed-in-Tariff, e.g. _____
- Power purchase agreement, e.g. _____
- Other _____

2.12 Are there any subsidies or funds to promote the implementation of photovoltaic?

- No Yes, e.g. _____
-
-

2.13 How could the implementation of photovoltaic be supported and be more attractive for the utility?

Country:

Date:

Solar Energy Analysis

3 Manufacturer and Distributor

3.1 Your business is in Solar water heating Photovoltaic as
 Manufacturer Distributor Other _____

3.2 In your country, the actual total number of
 Solar water heaters is _____ units and your market share of it is _____ %
 Photovoltaic systems is _____ units and your market share of it is _____ %

3.3 How did you start up your business?
 market was already established market was created by _____

3.4 Did any policies, incentives, funds, fiscal benefits etc. help to establish or develop your business? No Yes, e.g. _____

3.5 Are there any barriers preventing further market growth?
 No Yes, e.g. _____

3.6 What is the average system size for the private and commercial sector?

	Solar Water Heater		Photovoltaic	
	private	commercial	private	commercial
System size	Liter	Liter	Wp	Wp
System price	US\$	US\$	US\$	US\$
System lifetime	years	years	years	years
Installation costs	US\$	US\$	US\$	US\$
Maintenance costs	US\$	US\$	US\$	US\$
Other costs in US\$	US\$	US\$	US\$	US\$
Electricity savings	kWh/a	kWh/a	kWh/a	kWh/a
Payback period	years	years	years	years

Country:

Date:

Solar Energy Analysis

3.7 What is your company doing to further penetrate the market?

3.8 How do customers generally finance the systems?

Solar Water Heater

Equity/cash Private loan Credit union higher purchase

Commercial Bank Developing Bank Other _____

Photovoltaic

Equity/cash Private loan Credit union higher purchase

Commercial Bank Developing Bank Other _____

3.9 How is the people's awareness and acceptance of solar energy in your country?

Solar Water Heater Not high at all ① ② ③ ④ ⑤ Very high

Photovoltaic Not high at all ① ② ③ ④ ⑤ Very high

3.10 Under which assumption the solar energy demand will grow?

	Solar Water Heater	Photovoltaic
Oil price higher than	US\$/barrel	US\$/barrel
System Price lower than	US\$/system	US\$/Wp
Payback period lower than	years	years
Efficiency higher than	%/panel	%/Panel
Other		

3.11 Do any Non-Governmental Organizations support your business?

No Yes, e.g. _____

3.12 What kind of support would help to further develop your business?

Country:

Date:

Solar Energy Analysis

4 Financial Institutions

- 4.1 Up to what percentage of the total cost of a solar water heater or photovoltaic system could be lent from a bank?
- 4.2 How much equity is needed?
- 4.3 What are the typical repayment terms/times?
- 4.4 How high can the installments be and what is their frequency?
- 4.5 What are typical interest rates for loans of solar systems?
- 4.6 What fees and commissions have to be paid?
- 4.7 Do you also offer insurances?
- 4.8 What requirements need the customer and the system to fulfill?
- 4.9 Are there any other requirements that a potential lender has to fulfill?

Country:

Date:

Solar Energy Analysis

5 Private / Commercial Customers

5.1 Please indicate sector and the number of persons in the household/commercial establishment?

- private with _____ persons in household or
 commercial with _____ people minimum and _____ people maximum

5.2 How much hot water do you use? _____ liter/person/day for _____ US\$/liter with

- shower _____% kitchen _____% laundry _____% other _____%
 I do not use hot water

5.3 How much electricity do you use? _____ kWh/month for _____ US\$/kWh most

- used for lightening _____% air-condition _____% do not know

5.4 Do you have electric water heater solar water heater photovoltaic system?

Please give some more details

	Electric water heater	Solar water heater	Photovoltaic system
System size	Liter	Liter	Wp
System price	US\$	US\$	US\$
System lifetime	years	years	years
Installation costs	US\$	US\$	US\$
Maintenance costs	US\$	US\$	US\$
Other costs as _____	US\$	US\$	US\$
Electricity savings	kWh/a	kWh/a	kWh/a
Payback period	years	years	years

5.5 If you have a solar water heater or photovoltaic system, how did you finance it?

- Equity/cash Private loan Credit union higher purchase
 Commercial Bank Developing Bank Other _____

Country:

Date:

Solar Energy Analysis

5.6 How do you evaluate solar energy? (① = low importance, ⑤ = high importance)

	Solar Water Heater	Photovoltaic
<input type="checkbox"/> helping to protect the environment	① ② ③ ④ ⑤	① ② ③ ④ ⑤
<input type="checkbox"/> helping to reduce electricity usage	① ② ③ ④ ⑤	① ② ③ ④ ⑤
<input type="checkbox"/> helping to save you money	① ② ③ ④ ⑤	① ② ③ ④ ⑤
<input type="checkbox"/> helping to improve living standard	① ② ③ ④ ⑤	① ② ③ ④ ⑤
<input type="checkbox"/> helping to improve image	① ② ③ ④ ⑤	① ② ③ ④ ⑤

Other advantages are: _____

Other disadvantages are: _____

5.7 Under which of the following conditions solar energy would be more attractive for you?

	Solar Water Heater	Photovoltaic
System Price lower than	US\$	US\$/Wp
Payback period lower than	years	years
Efficiency higher than	%/panel	%/panel
Electricity prices higher than	US\$/kWh	US\$/kWh
Financing schemes would offer		
Incentives (tax deduction etc.) would offer		
Other		

5.8 Are there any Government incentives or any other funding incentives to use solar energy?

No
 I do not know
 Yes, e.g. _____
