Assessing the Role of Renewable Energy toward Sustainable Development in Small Island States

A Case Study of the Island of Bermuda

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I, David Earlston Chapman, hereby declare that this thesis and the work presented in it is entirely my own. Where I have consulted the work of others, this is always clearly stated.

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Abstract

For vulnerable Small Islands States, research into how these locales can meet their energy needs sustainably is extremely critical as we progress into the 21st century. These small islands locales are considered vulnerable in regards to their environmental, economic and social development due to factors related to size, location, isolation and limited natural resources. Dependence on non-renewable fossil fuel sources only exacerbates these vulnerabilities and directly affects progress towards sustainable development. Expounding benefits and potentials of alternative energy strategies such as renewable energy are only first steps towards its effective and holistic integration. Critically, evidence-based research is needed to better understand how these strategies can best be incorporated, both socially and technically, into such societies as an underpinning to local sustainable development policies.

This thesis uses the Small Island State of Bermuda as a research case study. Through examining the role of renewable energy in Bermuda in efforts being made towards sustainable development, the study affirms that consideration of context and place are extremely critical in avoiding misaligned policy and technological integration of alternative energy technologies. While the study confirms the vulnerability of Bermuda as a Small Island State in regards to energy issues such as fuel diversity and import dependence, the unique 'urban and developed' profile of the island creates both barriers and opportunities for renewable energy that may not be present in less developed and developing Small Island States. Hence, the application of 'one size fits all' models of sustainable development that seek to promote generalised adoption of renewable energy technologies across the diverse range of Small Island States is shown to be unrealistic and potentially harmful and assessments into the appropriate application of such technologies must involve approaches representative of the three core facets of holistic sustainable development – economic, environmental and social.

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Abbreviations

BDA-DOE	Bermuda Government Department of Energy
BDA-EGP	Bermuda Energy Green Paper
BDA-EWP	Bermuda Energy White Paper
BELCO	Bermuda Electric Light Company Limited
BPOA	Barbados Plan of Action
BWS	Bermuda Weather Service
CARICOM	Caribbean Community and Common Market
EfW	Waste to Energy
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IPCC	Inter-governmental Panel Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
MSW	Municipal Solid Waste
NGO	National Government Organisation
OECD	Organisation for Economic Co-operation and Development
OTCC	Overseas Territories Consultative Council
PV	Photovoltaic
SIDS	Small Island Developing States
WAsP	Wind Atlas Analysis and Application Program
WCED	World Commission on Environment and Development

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1 Introduction

"*In surrendering our children to westernized 'success', we dismiss the cost to our community and their spirit* (Baruti 2006:11)."

Baruti's quote cited above seems to provide *both* an admonishment and a cautionary warning to the adoption of westernized models of success in cases where more harm than good may be done. Surrender implies either domination, imposition, or at best, a misinformed pursuit, and in this case one that comes with costly consequences. In terms of this research study, Baruti's premonition, whether taken *either* as an admonishment or as a warning, can serve to act as a good starting point and a relevant contextual backdrop to the central theme of this research study, that being 'sustainable development'. Although Baruti's critique was directed at the appropriateness of western models of education for non-western orientated communities, his portrait of a community-wide surrendering to models of "westernized 'success'" and its potential for an associated cost to both community and spirit, has an allegorical similarity to this central focus.

The central aim of this thesis is to identify how accurate it is to assert that renewable energy integration should play a role in sustainable development strategies for Small Island States. The research on the Small Island State of Bermuda, which serves as a useful case study due to its unique urban and developed characteristics, which set it apart from the category of other more well researched Small Island Developing States. By way of a considerate literature review, the thesis first seeks to examine sustainable development in a critical way with the view to outline the evolution of the discourse and its inclusion of renewable energy integration as an environmental problem solving strategy for Small Island States. An outline of Bermuda's uniqueness as an 'urban and developed' Small Island State is then presented in order to provide support for the use of Bermuda as a case study. A methodological chapter then follows, describing the structure of how the research was carried out and the original epistemological framework used to organise and frame the research data. This is followed by a results chapter is which gathered quantitative and qualitative data is presented and organised along intertwined themes of energy security and sustainable development. Finally, a conclusion is given whereby the main findings of the research are discussed, specifically in regards to the need to develop new understandings of the distinct differences in the roles of renewable energy integration in ‘urban and developed’ Small Island States when compared to other culturally and geographically similar but economically different Small Island Developing States.

It should be mentioned that the study necessarily adopts a critical approach to sustainable development from its outset as an embrace of cautionary warnings such as Baruti’s and in the acknowledgment of some discomfort towards the globalized[1] nature of the contemporary sustainable development agenda. Rather than this critical approach being adversarial to sustainable development, the study hopes to further inform sustainable development efforts in relation to Small Island States and in some way assist these communities in the avoidance of promulgating potentially misinformed sustainable development strategies. It is hoped that the outcomes of the study further informs the role of renewable energy and renewable energy systems towards sustainable development in Small Island States in general, as well as having value on a wider international context in related sustainable development efforts. Specifically, it is hoped that the outcome of this study will serve to further illuminate how the exploitation of renewable energy and the use of renewable energy systems can authentically benefit the sustainable development efforts of Small Island States as distinct and diverse geo-socio-political entities, as well as their internal fabric of communities and individual social actors, many of whom may lie outside the spheres of formative influence of national sustainable development agendas.

[1] Globalization refers to a process by which concepts develop international influence and acceptance and start operating essentially at trans-national scale. Often these processes are aided or driven through entities that hope to exert influence beyond local boundaries, often at the expense of national or local identity.

1.1 Sustainable Development in its Modern Context

"In the 1990s the talk was structural adjustment; in 2007 it is sustainable development."

Gordon Brown, July 2007, in a speech to the United Nations, New York, USA. [2]

Researching sustainable development is a relevant study topic for contemporary environmental, geographical and social study disciplines. Over time, inter-related issues in environment and development have become increasingly important on the global[3], international and local stage (Elliot 1999; White 2005). For our contemporary era, sustainable development is a prominent global environmental and development discourse and arguably the most dominant of the past three decades (Elliot 1999; Dryzek 2005; Adams 2009). Countless larger nation states have taken action towards the incorporation of a sustainable development agenda in their national policy (Bass et al. 1995; Elliott 1999). As a diverse and widely called upon concept, the discourse of sustainable development also often seems to find a place in an increasingly wide range of social-related discussions, including many concerned with topics less directly related to the historical discourse of environment and development, such as education and health (Krueger et al. 2007). Likewise, many non-state actors such as non-governmental organisations, business entities and other social organisations also make use of sustainable development lexicon in these locales (Elliot 1999).

Many Small Island States like the island of Bermuda have also incorporated a sustainable development agenda in their national planning as well (Loy et al. 2005; SDU-Bermuda 2005; Strachan & Vigilance 2008). For Small Island States, contemporary sustainable development is seen as the "logical answer by which Small Island States could face up to their special challenges[4]" resulting from their inherent traits of "small size, insularity and remoteness (Briguglio 1995:1)." These special challenges are numerous and have been outlined by various

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[2] See a full text copy of Gordon Brown's July 2007 speech at the United Nations in New York at http://news.bbc.co.uk/1/hi/6924570.stm

[3] 'International' is used to refer to interaction among nation states while 'global' refers to interactions taking place beyond the level of formal national representation. Economic actors, non-governmental organisations and less benign influences such as criminal, terrorist or non-national military organisations may influence affairs on global level.

[4] http://www.unep.ch/regionalseas/partners/sids.htm

authors over time (W. Beller et al. 1990; Lockhart et al. 1993; United Nations 1994; Bass & Dalal-Clayton 1995; Briguglio 1995; Byrne et al. 2005). The term “special challenges” both refers to the unique developmental challenges of Small Island States as well as many of their inherent vulnerabilities from which these developmental challenges arise.

Table 1 lists many of the specific unique developmental challenges and vulnerabilities of Small Island States as collated from various sources. In many ways, these special development issues and the vulnerabilities of Small Island States may be classified into two main groups, those resulting from isolation and those based on issues of scale (Kerr 2005). However, both isolation and scale are variable and can change with technological advancements, or in cases of issues regarding economic access, success or failure of economic agents (Beller 1990). This is a significant point, as investment towards trendy sustainable development strategies may prove unsustainable and potentially costly if the economic, political or social structure supporting these strategies change, become less important or non-existent.

Table 1: Unique developmental challenges and vulnerabilities of Small Island States (Adapted from various sources).

Geographical

- Small size (Bass & Dalal-Clayton 1995; Briguglio 1995; UNCTAD 2004).
- Geographical isolation (Briguglio 1995; Kerr 2005).

Political

- May be less political stable due to a less developed political systems or inability to effectively counter both outside and internal political influences (Lockhart et al. 1993; BPOA 1994).
- May lack adequate resources to resist malignant influences to both external and internal security (Lockhart et al. 1993).
- Colonial legacies may bring socio-political nuances that impact political stability (Lockhart et al. 1993).

Economic

- Frequently rely on external importation of resources such as energy, food and other commodities (Kristoferson et al. 1985; Chandra 1993; Potter 1993; BPOA 1994; UNCTAD 2004).
- Monopoly and oligopoly may be more common in the economic structures of

Small Island States, specifically as a function of transport constraints, giving rise to the domination of the import and subsequent provision of resources by those who control capital to do so (Hein 1990)

- More sensitive to the effects of global market dynamics, including global energy price and volume fluctuations (Briguglio 1995).
- Economies in Small Island States often lack diversity and are resulting less resilient and more vulnerable to change (Streeten 1993) (Firth 2007).
- Trade globalization on the economies of Small Island States may also be more pronounced, owing to the scarcity and/or diversity of exportable resources (de Albuquerque & McElroy 1999).
- Aid dependency may be high, especially among SIDS (Beller et al. 1990).

Social

- Impacts of excessive population growth, disease and negative social occurrences such as crime may be more pronounced in these locales (Nicholls 1995; de Albuquerque et al. 1999; UNESCO 2003; Shareef et al. 2005; Bunce et al. 2009; Fischer et al. 2009).
- More vulnerable to migration and workforce challenges due to a lack of diversity of human resources (Byrne et al. 2005).

Environmental

- Small size may mean less resiliency to environmental change and impacts on environmental systems, biodiversity and habitat may be more pronounced and significant (BPOA 1994; Byrne et al. 2005).
- Impact of climate change, such as global sea level rise and extreme weather events, will affect many low lying Small Island States or those with major coastal development (Nicholls 1995; Parry et al. 2007).
- Climate change may induce more frequent extreme weather events like hurricanes in proximity of Small Island States (Knutson & Tuleya 2004; Tompkins 2005a).
- Climate change may induce rises in the rates of infectious diseases due to changes in human migration, quality and quantity of potable water supplies and vector expansion (Khasnis & Nettleman 2005).
- Climate change may induce drought, crop failures and famine conditions, particularly challenging for those Small Island States not able to adapt (Parry et al. 2007).
- Lack power to mitigate against the global contributing factors of global climate change (BPOA 1994; Schneider 2001; Byrne et al. 2005).

Essentially, sustainable development for Small Island States was, as still is, seen as an environment and development problem-solving discourse by which these special development challenges and vulnerabilities can be overcome (Beller et al. 1990; BPOA 1994). However, despite receiving special recognition at the international level for their special development issues, and a robust engagement of the topic in the literature, there seems to be a distinct lack of concrete action from the international community in regards to tackling these issues (UNCTAD 2004). Additionally, progress towards sustainable development can be problematic for communities like Small Island States due to their vulnerabilities, making sustainable development research in these locales more relevant.

Much of the sustainable development discourse was shaped through international deliberations numerically dominated by the presence of larger and more powerful nation states, as well as by international NGOs, all with their own specific interests and motivations towards particular goals (Page 2009; Sjöstedt & Corell 2005; Elliott 1999). Table 2 indicates some of the major meetings, events and documents that have had a formative influence on the contemporary sustainable development discourse. The 1980 World Conservation Strategy (IUCN 1980) published by the International Union for the Conservation of Nature and Natural Resources (IUCN) would see the term 'sustainable development' being used formally for the first time. However, unlike the contemporary concept of sustainable development, the scope and context of sustainable development as presented in the IUCN was primarily limited to ecological sustainability rather than a wider social, economic and environmentally linked discourse (Elliot 1999).

Table 2: Selected major meetings, events and documents which may have had a formative impact on the contemporary sustainable development discourse (Adapted from Elliot (1999) and Adams (2009))

Establishment of the International Union for the Protection of Nature (IUPN)	1948
International Technical Conference on the Protection of Nature	1949
Establishment of the International Union for the Conservation of Nature and Natural Resources (IUCN)	1956
African Convention on the Conservation of Nature and Natural Resources,	1968

Organisation of African Unity (OAU)	
Biosphere Conference	1968
United Nations (UN) Conference on Human Environment, Stockholm	1972
World Climate Conference, Geneva	1978
World Conservation Strategy, IUCN	1980
Establishment of the World Commission on Environment and Development (WCED)	1984
World Commission on Environment and Development (WCED), 'Our Common Future' Report (also called The Brundtland Commission Report)	1987
Establishment of the International Panel on Climate Change (IPCC)	1988
UN Conference on Environment and Development, Rio (also called "Earth Summit") – would lead to the establishment of the UN Framework Convention on Climate Change (UNFCCC), the Agenda 21 programme and the United Nations Commission on Sustainable Development	1992
Global Forum	1992
2nd Assessment Report, IPCC	1995
Conference of Parties (COP), UNFCCC – COP 1 (1995) - 15 (2009)	1995
Global Biodiversity Report, United Nations Environment Program (UNEP)	1995
3rd Assessment Report, IPCC	2001
World Summit on Sustainable Development (also called Earth Summit 2002 or Rio +10)	2002
4th Assessment Report – Impacts, Adaptation and Vulnerability, IPCC	2007

The publication in 1987 of The Brundtland Report - Our Common Future (WCED 1987) by the World Commission on Environment Development is considered by many to mark sustainable development's "coming of age" (Kirkby et al. 1995:1) where the "content and structure of the present debate" (ibid.) was established (Kirkby et al. 1995; Elliott 1999; Dryzek 2005; Adams 2009). Its publication would be precipitated by growing consternation within the international community towards on-going international global environmental and economic concerns and would herald in a new era where sustainable development would become mainstream (Adams 2009). The Brundtland Report explicitly attempted to elucidate a "global agenda for change" (WCED 1987:ix), calling for a new era of international cooperation towards "socially and environmentally sustainable economic growth" (WCED 1987: xii). It would characterise a new way of thinking about environment and development problems and would represent an evolution from the pre-Brundtland preoccupation with conservation of ecological resources and 'staying within limits' that typified the 1960's and 1970's, an era iconically represented in texts such as Rachel Carson's Silent Spring (Carson 1962), Ehrlich's The Population Bomb (Ehlrich 1968), Goldsmith's Blueprint for Survival (Goldsmith et al. 1972) and the Club of Rome group's Limits to Growth (Meadows et al. 1972). As stated earlier, within the sustainable development discourse, limits are recognised but thought to be able to be transcended with solutions involving innovative technologies and new ways of organising society.

Although differing in form since the time of the Brundtland Report, much of the international policy documents discussing sustainable development are written with central themes that emanated from this report embedded in them (Elliott 1999; Baker 2006). Despite a diversity of opinions on what sustainable development actually means and how it should be accomplished, writers on the topic generally agree that contemporary sustainable development has some normative concerns and principles. The discourse may be summarised concerning environment and development problem-solving by way of recognising the importance of meeting social, environmental and economic needs of both present and future generations and seeing the responsibility to meet these needs as globally shared, based on the existence of inter-locking relationships between the global and the local (WCED 1987; Redclift & Sage 1994; Dryzek 2005). Table 3 lists a range of issues that contemporary sustainable development is concerned with.

Table 3: A summary of the range of issues that sustainable development is concerned with (Summarised from Elliott (1999:11).

- Pollution (land, freshwater resources, oceans, atmosphere). - Consumption patterns of fossil fuels contributing to climate change and sea-level rise. - Concern about intergenerational flows of natural and man-made capital in a "full world" where natural capital is the limiting factor of production. - Growing inequality between the world's rich and poor, and the need to address poverty and basic needs on a global scale, i.e. food security, displacement, urbanisation, etc. - Concern about powerful trends which could contribute to unsustainable

development, i.e. industrialization, Western-style consumption patterns, explosion of capitalist energy in Asia and South America.
- Issues of governance and mediation in development and the need for long-term planning, i.e. international equity, the need to develop sustainable processes of development through mechanisms of national policies, human resources, management systems and mechanisms for participation.

Sustainable development essentially seeks to set the needs of people as priority with the needs of other living beings sharing the Earth's environments also receiving attention, but with this attention primarily manifested as an expression of a human need for environmental benevolence[5]. Sustainable development essentially takes on the nature of an environment and development problem-solving discourse concerned with '*sustaining development'* (Dryzek 2005). The expansion of limits, as opposed to staying within them, is a key principle within the sustainable development discourse and key developmental challenges are attempted to be solved through new, imaginative and innovative methods of technology and social organisation (Elliott 1999; Dryzek 2005). Sustainable development also crucially acknowledges a shared and common stake across scales of human society towards environment and development challenges as well as their solutions (Baker 2006). In the pursuit of equity, equality and participation, sustainable development attempts to transcend both inter-generational, intra-generational, local, international and global boundaries in terms of needs, allocation of cause when relevant and necessary, subsequent effects and any potential remedial solutions (Elliott 1999; Dryzek 2005; Baker 2006; Adams 2009).

Within contemporary sustainable development, the concepts of environment and development are viewed in specific ways. In contemporary sustainable development, the environment has multiple facets. While preserving the environment is viewed important for a benevolent social role, it is within the context of seeing this role, and others, as a service (so-called 'ecosystem services'), and seeing the physical manifestations of the environment that produce these services as 'natural capital' (Adams 2009). Although sustainable development as an environment and development discourse carries over themes

[5] Author's own interpretation based on a collaborative view of literature cited in the thesis.

of both colonial and post-colonial development ideas (Redclift et al 1994; Adams 2009), the idea of development within the sustainable development discourse has been expanded beyond the conception of "what poor nations should do to become richer" (WCED 1987:ix) to being more seen as an open, although somewhat vague, conceptualisation of "what people do to improve their lives" (ibid.).

1.2 Sustainable development for Small Island States

Despite such issues of concern as outlined above in regards to the evolution, effectiveness and even legitimacy of sustainable development as an environmental problem solving discourse, policy direction urging movement towards a sustainable development paradigm has continued to occur frequently at both international and national levels and has been adopted as a key policy approach by both larger nation states as well as Small Island States like Bermuda. It seems clear from the evolution of sustainable development (outlined in Section 1.1) that small and less powerful geo-political entities such as Small Island States have had less influence on its development as a contemporary global environment and development discourse. In this regard, sustainable development agendas cannot be looked at in isolation from obvious complex political, social and economic connections to those who attempt to define them (Forsyth 2003). As such the scope of internationally defined sustainable development agendas and strategies emanating from them may be limited in their effectiveness to address the needs of Small Island States communities (Bass et al. 1995).

The special development issues of islands would be considered much earlier than the formation of today's contemporary sustainable development discourse, with Brookfield (1993) suggesting a 1965 work by Demas (1965) as "the crystallization of a decade of Caribbean economic thinking about the problems of dependency in small, open economies (Brookfield 1993:23)." Lockhart et al. (1993) documents that interest in the "human issues specific to smaller territories would occur as early as 1962 when the Institute of Commonwealth Studies in the University of London began a seminar series" (Lockhart et al. 1993:1). Benedict

(1967) would subsequently assemble a collection of essays based on this seminar series, which would be viewed by Brookfield (1993) as the first effort to focus on non-economic issues of small countries. Suggestive of the transferability of lessons learned from research involving Small Island States, thinking about the effect on island development as a result of their unique traits seems to have evolved from considering the problems of small geo-political entities[6] in general (ibid), and not just that of islands. In this regard, Brookfield (1993) would also highlight Selwyn's (1975) compilation of a 1972 conference held in Barbados "as the most important collection of writings on the problems of being small and isolated in a developing world (Brookfield 1993:23)". As an aside worth noting here, there also exists a school of thought worth considering that asserts that imageries of islands as 'laboratories of development' are illusionary due to their inextricable ties with external metropolitan societies (Connell 1993; UNCTAD 2004) and that 'islandness' within itself does not inevitably make these systems useful towards the construction of specific social and economic policies, structures or trends (Brookfield 1993). This is an important consideration, as it cautions that not all lessons learned through researching sustainable development in Small Island States may be directly transferable to other similar, but distinctly different geographical entities (i.e. exclaves, enclaves, cities, etc.).

Attention towards sustainable development of Small Island States as specific geo-political entities would begin in earnest with the 1986 Inter-Oceanic Workshop on Sustainable Development and Environmental Management of Small Islands (Beller et al. 1990). These workshops were potentially spawned due to the limitations of the 1980 World Conservation Strategy. Beller et al. (1990:xv) writes that the workshop's "sponsors thought that it was important to convene such a meeting because small islands, just as endangered species of animals, have limited resources upon which to draw for survival." Held under the auspices of several United Nations offices, the workshop again reflects how the sustainable development discourse would often be formulated at the level of environment and development discussions held at the international level rather than from a localised, grassroots approach. The workshop also seems to serve as

[6] For example, continental remote villages, land-locked states and exclaves.

a chronological demarcation marking a movement of the ‘thinking concerning islands’ discourse beyond the special development issues of Small Island States to one which saw the consideration of sustainable development as a method by which Small Island States could alleviate their inherent environment and development constrictions.

The sustainable development themes as presented in the 1987 Brundtland Report would also come to characterise post-Brundtland sustainable development themes and would serve as the backdrop of the various international forums the Brundtland Report would give birth to, such as the 1988 International Panel on Climate Change (IPCC) and the 1992 United Nations Conference on Environment and Development held in Rio de Janeiro (also called the ‘Earth Summit’) (Elliott 1999; Baker 2006; Adams 2009). These international deliberations of the post-Brundtland era would also mark a modern drive of seeing sustainable development as something needed by Small Island States. “Agenda 21, which was adopted by this conference, contained a special section (chapter 17, section G) devoted to the sustainable development of small island developing states (UNCTAD 2004:8)”. Specifically, the post-Earth Summit and newly formed 1992 United Nations Commission on Sustainable Development would give rise to the 1994 first Global Conference on the Sustainable Development of Small Island States held in Bridgetown, Barbados. At this conference, distinct recognition would be given to the special development issues associated with Small Island Developing States (SIDS) and the United Nations Programme of Action on the Sustainable Development of Small Island Developing States, popularly referred to as the Barbados Program of Action (BPOA) (UN 1994), would be formulated. The Small Island Developing States (SIDS) Network would be created as a subsequent unit within the United Nations Division for Sustainable Development to facilitate follow-up to the conference and the implementation of the BPOA. For the international community, at the national and supra-national level at least, sustainable development would subsequently become a mainstream environment and development concern for Small Island States in general and SIDS in particular.

In the context of Small Island States, it is again important to remember as mentioned earlier that some writers on the topic suggest that the discourse of sustainable development may represent a continuation of imperial and colonial hegemonic environment and development interests carried over from before its birth as a formal international concept (Baker 2006; Adams 2009). Of specific relevance in the context of Small Island States, the discourse of sustainable development is thought by some to be an extension of not only the 'ecological limits' and conservation discourses of the 1960's and 1970s, but also a remnant of pre-1960's colonial and Third World development discourses (Baker 2006; Krueger et al. 2007; Adams 2009). Rather than ushering in a 'new era' of international cooperation towards social and environmental sustainable economic growth, the post-Brundtland thrusts towards sustainable development in many ways may be a continuation of an economic and development paradigm emanating from a motivation to extend a global North political-economic hegemony reaching back to the early stages of capitalism (Krueger et al. 2007). Manifesting itself over successive evolutions, the essential developmental theme within these hegemonic interests may be seen as exertion of development models that suit the particular needs of the global North, with those communities of the global South being essentially minions in these efforts. In this regard, Lemon (1993) emphasizes that, in regards to political and security issues, much of the perceived vulnerabilities of small states arise from the realities of past conditions rather than the present, reflecting the importance of understanding the role of the political in the development process.

As a result, while it is the modern sustainable development discourse that is most influential to the contemporary environment and development concerns of Small Island States, care must be taken that these historically marginalised communities are aware of the socio-political environmental trajectories from which the sustainable development discourse arrived, especially considering the colonial past of many of these locales. Consideration of implications resulting from socio-political environmental trajectories such as these mentioned above becomes important in discussions regarding discourses concerning sustainability (Krueger et al. 2007). For example, for Small Island States with a colonial heritage, Frendo (1993) mooted that subjugation could possibly serve as motivation towards Small Island States seeking to become part of larger political entities (and possibly their political ideologies) as a method to being less vulnerable from an inherent geo-political and environmental isolation. Formation of and inclusion in international organisations such as the Alliance of Small Island States (AOSIS) and the Caribbean Community and Common Market (CARICOM), which Bermuda is a member of, may be seen in the context of an attempt to establish a sense of independence from any hegemony present within the international community, despite the relatively limited financial and human resources of the Small Island States within these supra-national organisations (UNCTAD 2004). Most Small Island Developing States (SIDS) do not have the organizational, technical nor financial capacity to participate in the level of energy reform needed to progress with such sustainable energy strategies such as integration of renewable energy technology (Roper 2005). Stuart (2006) asserts that the social and political links that Small Island States often have with other larger nation states are also important in the facilitation of such sustainable energy strategies and, as such, lack of support from these external entities or lack of internal support towards engaging with them may be an obstacle towards energy reform. In support of such a view, it is noted that Bermuda's movement towards a sustainable development agenda also resulted more from international top-down and lateral pressure, as its initial inception as a national objective was expressly influenced by the 2002 World Summit on Sustainable Development and the associated Johannesburg Declaration on Sustainable Development (Bermuda Government 2006), rather than from a grassroots' movement upwards. If this is the case, this opens up inherent possibilities that downwards or laterally adopted sustainable development concepts, such as those promoting exploitation of renewable energy and renewable energy systems, may not effectively nor authentically represent the diversity of needs existing in Small Island States communities like Bermuda.

Also significant to understanding the role of sustainable development to Small Island States like Bermuda is recognising that the definition of what sustainable development actually is, should be and/or how it is to be achieved is rather unclear. Sustainable development can mean many different things to different people and how to define sustainable development is rather difficult as its meaning can differ depending on who is defining it and what their intentions may be (Redclift et al. 1994; Adams 2009). Consideration of spatial and temporal dynamics are also significant in determining "what is sustainable and to who" (Forsyth 2003). Problematic is how often flagrant contradictions can exist between what is sustainable development, who it is important to and why (Swyngedouw in Krueger & Gibbs 2007). Indeed, these types of contradictions became highlighted in this research, specifically in regards to the role of renewable energy technology in efforts towards sustainable development in Bermuda and how although its integration may aid some, it actually may be less appropriate to meeting the social, environmental and economic needs of many others (See Section 3 – Results and Discussion). For example, the ease at which global promotion of the sustainable development discourse has been often capitalized on by 'green capitalist' movements (Prudham 2009), often with the only winners being big business whose profits have little impact on those at the local scale, also serves to lessen the enthusiasm for its adoption by Small Island States like Bermuda. Again, issues related to this concern have been uncovered in this research, specifically in the testimonies of large local businesses and how moves towards 'green' corporate policies were mostly made for commercial marketing purposes rather than in hopes of affecting real change towards sustainable development goals (See Section3.6.3). A fundamental challenge that may arise due to this lack of clarity is determining what sustainable development actually means in a specific, localised context, how it can be furthered, who should benefit from sustainable development associated processes and why (Bass et al. 1995). It is precisely this type of ambiguity as a defined concept that has the potential for efforts towards sustainable development to incur more costs than benefits on Small Island States communities who adopt misinformed sustainable development strategies.

The popularity of a sustainable development approach in the national policies of Small Island States, but with an inherent potential for problems, makes further research towards more authentic sustainable development strategies for these communities vital (Bass et al. 1995). Fundamentally, this research should take an opposite course from that which past less relevant influences on the sustainable development discourse have previously stressed and attempt to achieve research that is conducted from a grassroots level looking not to embody a globalized ideal of sustainable development, but rather one that is more authentic and indigenous (Bass et al. 1995). For specific sustainable development strategies, such as those that call for the exploitation of renewable energy and the use of renewable energy systems, this research should look to provide clarity as to whether such strategies will incur costs or benefits based on these authentic and indigenous ideals.

1.3 Renewable Energy Systems as a Sustainable Development Strategy in Small Island States

Although, the vulnerabilities of Small Island States due to remoteness are potentially overcome due to increasing advances in technology in the areas of transportation and communications (UNCTAD 2004), there are some development issues that remain challenging. Dependency on the import of fossil fuel based energy supplies is one such issue and the use of renewable energy through renewable energy systems, has been historically looked to as a key sustainable development strategy to alleviate this problem (Takahashi et al. 1990; BPOA 1994; Bass et al. 1995). The provision of energy is a critical component of development and vulnerability in energy security may serve as a barrier towards the sustainable development of Small Island States (Energy Unit - World Bank 2000; Byrne et al. 2005; Spalding-Fecher et al. 2005). Despite the barriers to integration of renewable energy and renewable energy systems on a global scale, there have been significant efforts to utilise renewable energy and integrate renewable energy systems in many Small Island States as a way to overcome vulnerabilities associated with energy supply. Additionally, many Small Island State governments are looking to strengthen key pillars of national energy policy, in particular economic efficiency, environmental performance and security and diversity of supply, and have turned to renewable energy systems in order to help facilitate this process. Fortunately, due to the innate physical characteristics of many Small Island States, many may have access to abundant renewable energy resources and are small enough in size for these renewable energy resources to potentially provide significant amounts of power relative to their needs (Byrne et al. 2005; Weisser 2004c).

‘Renewable energy’ refers generally to energy resources that are self-regenerating or of such quantities that they are not seen as being limited (Boyle 2004). Declarations are also often made as to the vast amount of energy that is available to harness from renewable energy sources (WEC 2000; Archer et al. 2005; Carbon Trust 2005; de Vries et al. 2007). Specific renewable energy sources are those such as solar energy, wind energy, flows of water on land and at sea, geothermal and that derived from biomass (Boyle 2004).

Table 4 list how the use of renewable energy and renewable energy systems is potentially able to address many international environment and development challenges in relation to the global dependency and use of fossil fuels. These potentialities serve as strong motivations for the renewable energy systems integration that is being promoted or is already occurring internationally (See Section 5.1 - Appendix) (WEC 2000; IEA 2007).

Table 4: Key reasons for the modern promotion of renewable energy systems integration (Adapted from various sources including Boyle (2004) and the WEC (2000)).

The majority of the world’s industrial and domestic energy supplies are derived from non-renewable fossil fuel energy sources. Although a subject of debate, the non-renewable nature of these types of energy sources put limits on their extraction. **How renewable energy addresses the challenge?** The self-renewing nature and/or inexhaustibility of renewable energy resources means they do not have these limitations
The extraction, transportation, storage and generation of energy from fossil fuel sources have led to both localised and global environmental degradation. **How renewable energy addresses the challenge?** Although “no energy production or conversion technology is without risk or waste” (WEC 2000:31), energy generation from renewable energy sources tends to contribute much less in terms of environmental pollution when compared to energy generation from fossil fuels, both in terms of their manufacture, greenhouse gas emissions as well as other pollution concerns.
The concentration of these non-renewable fossil fuel energy resources in specific geographic areas has also led to a politicization of their global supply and demand. This politicization, in combination with their finite nature, has led to historical and dramatic market price fluctuations, a major cause for concern internationally due to the

dependency of local and global economies and development efforts on these energy commodities.

How renewable energy addresses the challenge?

Renewable energy resources are widely dispersed, although intermittent in nature and thus their collection is *only* constrained by the ability to collect, store and/or convert relatively diffuse amounts of energy over long periods of time (Boyle 2004). The modern era has seen much progress made toward technological advances in assessment of renewable energy resources and renewable energy systems in ways to generate usable forms of energy once these renewable energy have been harvested.

Economic growth and development is of prime importance to national development. Global economic recession has heightened the importance of stimulating further economic growth.

How renewable energy addresses the challenge?

The integration of renewable energy systems as an alternative to this non-renewable energy source often necessitates the need for the building of new industries, supporting infrastructures and in turn, the growth of new labour markets. These activities can act as stimulus to economic development.

Issues concerning energy in relation to international dialogue on environment and development challenges have been a common focal point of much of international dialogue.

How renewable energy addresses the challenge?

Renewable energy systems integration is often trumpeted as an important strategy in issues involving environmental sustainability, energy reform and sustainable development. As a result, renewable energy systems integration as a strategy is also often cited in the bilateral and multilateral agreements cited above. Even for states that have not entered into such agreements, the integration of renewable energy systems may be seen as a potential environmental, energy reform or sustainable development strategy based on influences (direct and/or indirect) from external discussions or policies.

Historically, the political, economic and environmental issues surrounding global energy supply received particular attention from the time of the dual 1970's fuel crises (Takahashi et al. 1990). Reflecting during this era on how the 'limits to energy supply' challenge could be overcome, Meadows et al. (1972) would give the exploitation of renewable energy only a cursory mention and hypothesised that nuclear energy might play a role as a non-finite energy source, although possibly without any real impact on remediating the 'world problématique[7]' of the time (Meadows et al. 1972:10). At the time, investment in renewable energy systems in the developed world increased substantially but ebbed significantly after the fuel crises became issues of the past (Fisher 2008; Sovacool 2009).

However, the importance of sustainable development to international environmental agendas and the growing importance of climate change as a fossil fuel dependent environmental crisis have caused a major resurgence in interest in renewable energy and renewable energy systems (ibid) and the exploitation of renewable energy resources and the use of renewable energy systems have gained increasing prominence as an energy solution in this regard (IEA 2007). Many international policy documents on sustainable development, such as the 1987 Brundtland Report, 1994 BPOA, 1997 Kyoto Protocol and IPCC Assessment Reports (Parry et al. 2007), national policy strategies (Loy & Farrell 2005; IEA 2007a), as well as countless academic writings have suggested the use of renewable energy and renewable energy systems as key strategies in sustainable development efforts, especially in light of the implications of continued fossil fuel use on global climate change (Parry et al. 2007). Appendix 5.1 lists some key figures portraying information on the historical international uptake of renewable energy over time and its use internationally compared by region and renewable energy type. McVeigh et al. (2000) also provides an excellent and comprehensive review on whether renewable energy systems have met many of the expectations of the international community as an alternative energy source to fossil fuels, with their general finding being that although penetration has not increased at the desirable levels in comparison to fossil fuel use, the cost of renewable energy systems has come down considerably.

The use of renewable energy systems to harness these energy sources has many favourable characteristics that align with the fundamental principles of contemporary sustainable development, in particular, renewable energy's non-finite nature, its global distribution and availability in various forms and the

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[7] The term "world problématique" was used by the Club of Rome group, which was responsible for publishing the Limits to Growth text, to refer to the complex of global problems of their era and the dynamic interactions which exist between them (Warfield & Perino Jr 1999:223).

'clean[8]' and 'green[9]' credentials of renewable energy systems (WEC 2000; Sovacool 2009). As opposed to many still developing and less understood alternative energy technologies such as fuel cells and nuclear fusion (Kristoferson et al. 1985), many renewable energy systems have a long history of use and comprehension (Sorensen 1991). Table 5 lists some key considerations in the potential role to be played by the exploitation of renewable energy and the use of renewable energy systems in meeting the values of the contemporary sustainable development discourse.

Table 5: Key considerations in sustainable development approaches and the potential role played by renewable energy systems (Adapted from various sources).

Key considerations in sustainable development Approaches (Adapted from Reid (1995:ch. 6)	**Potential role played by renewable energy systems (Adapted from Boyle 2004)**
Extending the ecological boundary.	
- Restoring the full production of ecosystems.	- Renewable energy systems may free space otherwise use by non-renewable energy infrastructure, allowing the ecological restoration of this space.
- Increasing the level of sustainable yields without ecological costs.	- Renewable energy systems may allow for energy provision without the extraction of non-renewable energy resources and the associated environmental effects of transportation, storage or generation of non-renewable energy resources.
- Increasing through exploration the size of economically recoverable reserves.	- Renewable energy systems may decrease this need to locate and exploit non-renewable economically recoverable reserves.
Reducing the economy's consumption of natural capital.	- The use of renewable energy may reduce the need to deplete non-renewable energy resources.
Growth	- Integration of renewable energy systems potentially allows for growth without the compromise to the environment as non-renewable energy resources. - Integration of renewable energy systems potentially promotes the development of economic growth through stimulating local and global economies and labour markets.

8 'Clean-tech' may be defined as technology that "avoids environmental damage at source" (Kirkwood & Longley 1995:174).

9 'Green-tech' may be defined as "environmentally conscious" technology, both in terms of the technology manufacturing process and the way it operates (Billatos & Basaly 1997:3).

Renewable energy use is particularly beneficial to Small Island States as a way to address their special developmental challenges and unique inherent vulnerabilities. For Small Island States, renewable energy use may be a method by which dependency on fuel imports is decreased and in this way serve to increase energy security and energy independence (Lippman et al. 1997). Additionally, the use of small scale renewable energy systems offers opportunities for Small Island States residents to gain some independence from energy monopolies that commonly occur in the energy industry in general (Weisser 2004c). It should be noted that the presence of monopolies in energy regimes has often allowed economies of scale to be achieved in the small populations of Small Island States (ibid.) and thus may have been a key factor in keeping energy cost from being even higher than they potentially could be.

Renewable energy systems offer methods by which Small Island States environmental management systems may be integrated, such as in the use of waste for fuel (Headley 1997; Jimenez 2003) to provide co-generation (heat/steam and power). The use of sugar cane bagasse or horticulture waste for power generation via combustion are examples of this (Ramcharran 1988; Headley 1997), with these methods emitting far less environmental pollutants than fossil fuel combustion, such as sulphur dioxide emissions that may lead to acid rain (Headley n.d.). However, it should be noted that such resources may only available from on-island sources for partial times throughout the year and thus may not always be relied on as a year round renewable energy source. For equatorially located Small Island States, the exploitation of renewable energy from solar sources provides more consistent opportunities to substantially displace the need for fossil fuel energy to serve everyday household needs, such as the heating of hot water and the provision of electricity through use of photovoltaics (RECIPES 2006; Headley 1997), potentially allowing considerable reductions in both energy expenditure and greenhouse gas emissions. Domestic solar water heating technology has become extremely efficient and provides effective, yet technologically simple, opportunities for Small Island States to utilise solar energy (Huang et al. 2008).

For less developed nations in particular, including SIDS, renewable energy and the use of renewable energy systems may offer specific opportunities that help to progress core sustainable development objectives such as equity and equality. The distributed nature of renewable energy offers an opportunity to take advantage of energy sources in remote areas and provide for the individualized needs of those community members (Yu et al. 1997; Weisser 2004a; Zahnd et al. 2009). This access to energy can then increase opportunities to both help lessen the marginalisation due to poverty through provision of developmental services such as light, electricity and heat, which in turn may potentially promote further development in business, education and community infrastructure such as water quality and availability, hygiene and food availability (Martinot et al. 2000; Barkat 2006). Access to energy in rural areas through the aid of renewable energy systems has been shown to assist in the increasing of social and economic inter-connections between rural people and their counterparts in national and international urban centres, specifically through increased rural television access, expansion of consumer goods markets that depend on electricity such as radio and televisions and facilitating the use of more ‘rural to urban’ communication devices, such as mobile phones (Jacobson 2007). A transition to renewable energy systems from traditional sources of energy, such as firewood, charcoal or kerosene, often depended on by the poor in developing nation’s societies, may improve soil, water and air quality in these locales (Blyme 2006).

Despite the advantages offered by renewable energy and the use of renewable energy systems, there are numerous challenges that have slowed its uptake as reflected by the reigning dominance of fossil fuels as a global energy source. The intermittency of many forms of renewable energy and the highly distributed and diffuse energy available can be a considerable disadvantage to their use (WEC 2000; Boyle 2004). Due to these factors, when compared with fossil-fuel energy sources, renewable energy harnessing technologies may require substantially more space for relatively small amounts of energy, a conflict when it comes to their use in Small Island States (Institutional Investor 2009; Lambert 2009). More indirect disadvantages to the use of renewable energy systems may also occur. For example, theft of renewable energy systems parts such as solar PV panels has been a serious problem for some solar photovoltaic (PV) electrification projects in developing nations (Ellegard et al. 2004).

Renewable energy use in Small Island States has gained much of its prominence internationally as more importance was attached to it as a mitigation strategy to curb greenhouse gas (GHG) emissions due to fossil fuel combustion (UNFCCC 1997). However the extent to which the use of renewable energy in Small Island States may reduce the global emissions of GHG is minimal as the majority of global fossil fuel consumption occurs as a result of the industrial activities of developed nations (Starke 2007; IEA 2008), with contributions by Small Island States to the global emissions of GHG being, collectively, extremely low in comparison (Lugo 1990). Of additional concern is the reality that despite much international policy momentum towards promoting increased integration of renewable energy technology over the past several decades, its overall penetration into the global share of energy supply has been relatively weak (Hirschl 2009), primarily due to the lasting impact of economic/energy policies that place non-renewable energy industries at a competitive advantage (ibid.). Where gains have been made, most of this has actually been in an increase in the use of traditional biomass energy (ibid., Malhotra 2006), not much used in ‘very small’ Small Island States. More modern techno-centric energy conversion methods such as solar PV and micro-wind turbines are far more useful for these types of Small Island State locales and this study highlights the significance in understanding such local energy use patterns in conjunction with the availability of the physical renewable energy resources available (See Section 3.4).

Market factors, such as the cost of energy, can also encourage or discourage increased uptake of renewable energy systems (Weizsäcker et al. 1998; Sovacool 2009). Evidence suggests that investment in large-scale renewable energy plants have been generally unprofitable (Fisher 2008). Extracting energy from renewable energy sources is more expensive than the comparable cost of the same amounts of fossil fuels due to the distributed nature of renewable energy in the environment, the need for larger harnessing surfaces, longer energy generation times (Weizsäcker et al. 1998; Weisser 2004b; Huang et al. 2008). Praene et al. (2012) research on the island of Reunion suggests that this factor can be a barrier to increased implementation. With the addition of these increases to import costs, this often makes renewable energy systems unattractive when compared to the costs of continuing to use fossil fuel-based energy. The importing of materials to Small Island States usually raises costs considerably as a result of shipping and duty taxes and for renewable energy systems this may add to their overall cost resulting in barriers to affordability. As Small Island States import many of their resources, renewable energy systems components may also be subject to this import dependency. As a result, the vulnerability due to supply dependency on materials would still be a part of renewable energy systems integration. This may be a particular challenge in regards to sourcing parts for scheduled or unexpected repairs that will inevitably occur. Some renewable energy systems may be better in this regard as they do not have many moving parts, such as solar photovoltaic and solar thermal systems.

However, this disadvantage of high cost may be offset as the cost of fossil fuels rises due to increasing scarcity or as a result of associated costs, both economic and social, as well as in regards to changes in opinion whereby environmental impacts from fossil fuel use is seen to outweigh its advantages, especially in locales where energy costs can be prohibitively high such as in many Small Island States. Sovacool (2009) argues that compared to both internalised and externalised cost of fossil fuel use (i.e. that caused by pollution and its damage to health and ecosystem services), the price of energy generation via renewable energy systems is much lower. It should also be noted that access to large, cheap and accessible sources of energy do not always equate to utopias of development, such as may be stated to be the case in some countries in the energy-rich areas of Africa and the Middle East (Toye 1993; Werlin 2005). Encouragingly, the cost of energy generation from renewable energy systems is expected to decrease as technology improves and is made more accessible (Huang et al. 2008; Weisser 2004c).

The existence of complex interlocking relationships between society and current technologies, as well as the interlocking relationships between the current technologies themselves, creates inertia to the development and uptake of new technologies and applications (Kemp 1997). As such, technology and institutional lock-in may act as barriers to the integration of renewable energy systems. Technology lock-in may be seen as the phenomenon by which increasing financial returns from an employed technologies revenue (positive feedback) lead to 'lock-in' of incumbent technologies, preventing the take up of potentially superior alternatives (Arthur 1994). Institutional lock-in is a similar process by which existing institutions serve to lock-in incumbent technologies and/or policies and thus preventing the take up of potentially superior alternatives (Foxton 2002). Institutions may not only be of the organizational type such as businesses but also may "include formal constraints, such as legislation, economic rules and contracts, and informal constraints, such as social conventions and codes of behaviour" (Foxton 2002:2). "Current carbon-based energy systems form a techno-institutional complex which is locked in, by mutually reinforcing technological and institutional factors" (Foxton 2002:4).

In regards to energy, the traditional reliance on fossil fuel sources of energy and their associated generation technologies may work against the move towards cleaner and renewable sources. The integration of renewable energy use through renewable energy systems can be greatly hindered, even when access to large sources of energy is available, when the lock-in factors cause a dependency on fossil fuel energy generation. Roper (2005) suggests that utilities that have depended on fossil fuel technology, as is the case in many Small Island States including Bermuda, often have little to no experience in the integration of renewables. Regulatory and public policy environments are also ill-suited to the integration of renewable energy systems, both globally and on local levels (Sovacool 2009). Combined with behavioural impediments and commercial interests in favour of continued fossil fuel use, renewable energy systems integration often faces considerable barriers to become mainstreamed (ibid.). Interestingly, Sovacool (2009) notes that most homes have energy infrastructure already subscribed in their design and utility for the home owner and thus there are in-built social systems that continue to promote behavioural discomfort with the independence and self-control on energy as facilitated by renewable energy systems integration. Social dynamics such as levels of education seem to have little to do with moving choice towards the use of alternative energy systems (ibid.).

Even if governmental policy seeks to incorporate renewables, the inexperience or unwillingness of the utilities may become a significant barrier to this change (ibid.). Kammen & Shirley (2011) review the experience of various Caribbean islands such as Grenada where energy legislation continues to allow monopolistic concerns which promote barriers toward integration of renewable energy technologies. Kammen & Shirley's (2011) research highlights the role of intra-political conflicts as a barrier towards energy reform, in which a neutral regulatory body would greatly assist. They point to the relative success of Jamaica towards the promotion of renewable energy technology, a growth which in large part they attribute to independent power producers having a historical basis for easy co-existence with the major utility. In Barbados, despite having large and successful solar water heating integration, government intentions do not seem to be matched by actual changes in the legislative policy, which has prevented the integration of other technologies (ibid.). In the Netherland Antilles, utility companies are held under a governmental regulatory body and as such there is no real motivation towards energy reform, meaning that use of wind energy has been able to thrive but largely dominated in the interest of the utility's business interests. Stuart (2006) highlights the importance of institutional support whereby policy creation can take place without conflicting with other concerns such as the lobby interest of power companies, which often have large governmental subsidies, giving them an unfair advantage over renewables.

The challenges of technology and institutional lock-in may present even greater barriers for integration of renewable energy systems in Small Island States due to an inherent higher tendency for utility monopolies and political/economic oligarchies to exist as mentioned previously, specifically in the area of energy supply. Terms such as 'adaptive' and 'resilient' which are associated with sustainable development (Folke et al. 2002), are at odds with the constraints of such lock-in scenarios (Holling 1986). An 'anti-lock in' view aligns well with Sen's (1999) influential views on development discourses by which the primary end and principal means of development should be seen as expansion of freedoms. The impact of lock-in on renewable energy integration in Small Island

States arises as a key finding in this thesis and is considerably expanded upon in the Results Sections 3.2 & 3.5.

The aesthetics and size of renewable energy systems can also substantially discourage the integration of renewable energy systems on Small Island States. Obtrusive renewable energy systems such as wind turbines and solar photovoltaic panels may not win favour in Small Island States (Huang et al. 2008), especially in light of these locales' high dependency on tourism, which often relies on island imagery as an important attraction. Small-scale renewable energy initiatives may be more suitable to Small Island States locations, which potentially rule out more efficient but obtrusive, centralised renewable energy systems initiatives such as large biomass plants (ibid.). Additionally, the sensitivity of island ecosystems to development may prevent the construction of some renewable energy systems such as offshore wind and tidal renewable energy systems, or present opportunities for considerable local objection to such initiatives (Huang et al. 2008). Sovacool (2009) interestingly discusses how renewable energy systems also may suffer public disinterest as it "makes visible patterns of electricity production and use, patterns that have become all but invisible to American consumers in the past century." The salient nature of traditional power networks has also produced incidences of energy illiteracy (ibid.) and these factors may operate as socio-technical barriers to renewable energy systems integration.

The lack of indigenous human resources to operate and service renewable energy systems technologies is also a constraining factor to the uptake of renewable energy systems integration (Weisser 2004c). Many of the more efficient renewable energy systems are still unproven technologies over a long term (Kristoferson et al. 1985) and renewable energy systems have become relevant business and commercial interests with research and development initiatives important in the further development of these technologies (Furnival & Unit 1980). In many cases, Small Island States become selected as test sites for renewable energy systems innovation but often with no serious penetration of technologies on island-wide levels (Takahashi & Woodruff 1990).

There is also a lack of understanding as to the potentials available in regards to renewable energy supplies in Small Island States (Weisser 2004b). Renewable energy assessments and feasibility studies are needed to assess these potentials so that the resource base can be understood more fully (Weisser 2004a; Takahashi et al. 1990). There also may be a general misunderstanding of the role that renewable energy systems can play in communities at the grassroots level. While international discourses seem to portray renewable energy systems as methods by which citizens can be empowered to meet their energy needs in a sustainable way, some studies have shown that people are less interested in renewable energy systems technology themselves and more so in what they can do with the provision of power (Ellegard et al. 2004).

1.4 Bermuda as a Case Study in Small Island State Sustainable Development

"Aim is to reduce greenhouse gas 30 percent by 2020" September 01, 2011
"More Islanders are turning to the sun for energy" January 11, 2012
"Residents hit as electricity bills rise" June 13, 2012
Article titles from the Royal Gazette newspaper, Bermuda.

As a Small Island State, the island nation of Bermuda faces many of the special developmental challenges and vulnerabilities characteristic of these unique locales that have already been described (Section 1.1). In terms of remoteness, Bermuda is particularly isolated as an island archipelago, being situated in the middle of the North Atlantic and located some 940 km east of its nearest continental land point of Cape Hatteras, North Carolina (World Encyclopedia 2008). Bermuda is also very small in size relative to other Small Island States and with a land area of only 53 km^2, this small size adds to the impact of its isolation. Bermuda also has a very small population of approximately 71,328 people (c. 2010[10]). Environmentally speaking, although a small land mass, Bermuda has many unique habitats as well as endemic and native flora and fauna, many of which are extremely rare , with some threatened with extinction (Department of Statistics 2009b).

However, the island's socio-political and economic context makes it unique in

[10] Bermuda Census 2010 (http://www.govsubportal.com/census/2010-census)

regards to any efforts towards sustainable development. The island is considered to be politically stable, but its internal political atmosphere can be quite charged due to issues arising from disparaging views in local politics (Palmowski 2008). For example, its on-going colonial status has served to engender some local feelings of resentment towards the island's coloniser, Great Britain, as well as contributing to the basis for localised socio-political conflict between supporters of continued colonisation and those against (Stalker 2007). A 1995 referendum on independence saw a majority rejection; however the pursuit of independence remains a point of debate today. The island also has a history of racial segregation and the island's population demographic resultantly reflects an ethnic make-up dominated by Caribbean and African-descended blacks (~61%) and primarily British-descended whites (~39%) (Department of Statistics 2009c). Racial tension has been a specific issue challenging historical political consensus (Palmowski 2008; Swan 2009) as well as serving as a basis for defining social practices in many ways. The island's colonial past and legacy of racial segregation have contributed to a historical oligarchic nature to both local politics and the local business climate (Swan 2009). Historically, this has resulted in a stratification of economic opportunity along racial class lines, which continues to affect local socio-economic trends today.

The island's economy also lacks diversity, being primarily concentrated in two main industries, tourism and international business, both having a heavy dependence on the state of the world economy and both being threatened in recent years, particularly as a result of global recession (Stalker 2007; Caribbean Monitor 2010). Recent significant increases in local gun crime have been reported in the local news media and may pose an additional threat to both industries. The local government relies heavily on international financial credit ratings agencies (McDonald 2009) to fortify its status as a sound financial jurisdiction, as well as the ratification of international agreements with multilateral partners such as the Organisation for Economic Co-operation and Development (OECD) to bolster its credibility in the face of mounting criticism and pressure towards its reputation as a tax-friendly financial jurisdiction providing domicile for offshore wealth relocation (Snowdon 2009). The recent global recession has also affected local island micro-economic industries, such as construction (Caribbean Monitor 2010), which has seen a decline in some cases or an increase in foreign labour as a strategy to reduce labour cost. The increased importation of foreign labour has served as an issue of discontent among local workers (Strangeways 2010). Possibly as a strategy to lessen the political weaknesses due to both its isolation and colonial status, Bermuda has also aligned itself with other Small Island States that share many of its socio-political and economic characteristics, such as Jamaica and the Bahamas through international geo-political entities like the Caribbean Community and Common Market (CARICOM) and the Overseas Territories Consultative Council (OTCC).

Adding further to the significance of issues concerning the island's main economic sectors, residents face continued rises in living costs, particularly in fundamental needs such as housing, food supply and energy (Department of Statistics 2009a). The island's small size, resulting in an extremely high population density of 4,984[11] persons per square kilometre and a lack of area for new housing, combined with the high cost of living and rising inflation, makes meeting such needs even more challenging (Department of Statistics 2009b & 2009c). The island is largely dependent on meeting most of its material needs through importation and over $1 billion was spent on imports since 2006 compared to less than $30,000 worth of goods being exported (Department of Statistics 2009a). While there are some crops grown on the island, only 20% of land is now considered arable (CIA n.d.) and the import of food supplies is an essential part of the island's economy. Water supply is also severely limited on the island and as the island depends largely on aquifers as well as domestic roof-top catchment to supply its needs, the on-going conservation of water is vital for islanders.

1.4.1 The Bermuda Energy Sector

The management of energy production capacity is crucial for Small Island States like Bermuda from both a utility point of view and a regulatory perspective. As Table 1 outlines, a key vulnerability of small islands are that they mostly rely on external importation of energy resources and as a result are more sensitive to

[11] Bermuda Census 2010 (http://www.govsubportal.com/census/2010-census)

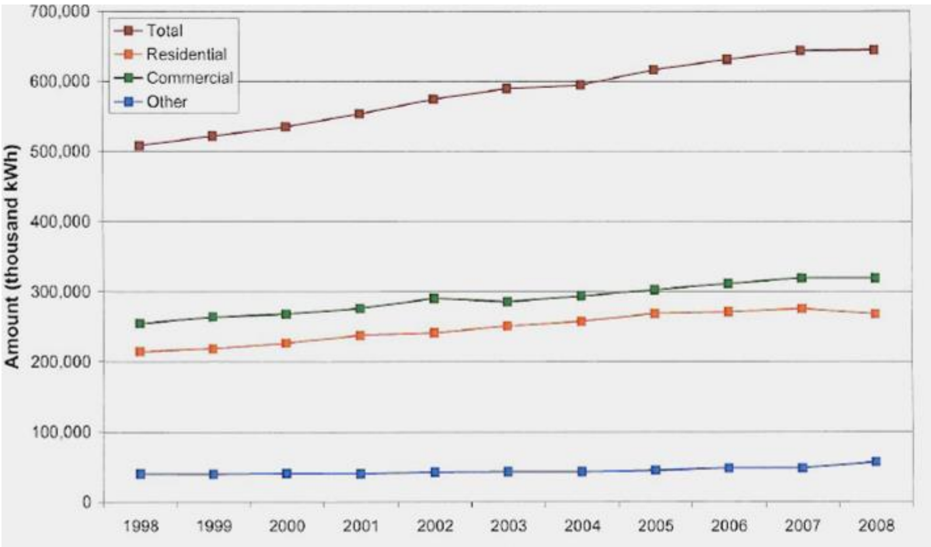
global changes in price or volume. In character with this vulnerability, energy supply in Bermuda is mostly maintained through fuel importation (specifically liquid petroleum gas, propane, diesel and petrol), with over $100 million being spent on fuel imports every year since 2007 (Department of Statistics 2009a), and the equivalent of 4,500 barrels of oil per day imported in 2007 (CIA n.d.). Overall use of fuel is not expected to decline as a result of additions to housing stock, steady possession rates of road vehicles, as well as the development of new energy consuming private sector (e.g. hotels) and capital projects such as reverse osmosis plants that consume considerable amounts of power. Monopoly in energy provision is also a key vulnerability common in Small Island States and this can further exacerbate issues such as local energy price due to a distinct lack of competition as well as labour and employment issues, as human resource diversity and volume is often relatively low. Again, Bermuda's energy infrastructure may be deemed vulnerable in this regard as it is characterised by such a monopoly in that the island's electrical supply has been historically dominated by one company, the Bermuda Electric Light Company (BELCO[12]).

Despite these vulnerabilities, BELCO had over 35,755 electricity customers in 2008 with over 728 million kilowatt hours (kWh) generated and 165 MW of generating capacity installed, all from various types of fossil fuel generation plants. Compared to larger and more populated locations such as the UK, this may not seem like much, however when compared on a per capita basis[13] the energy consumption of Bermuda far exceeds that of many larger national counterparts. Locally, consumer spending on the combined categories of housing, light and power is a predominant expense (Department of Statistics 2009b) and electrical consumption trends on-island continue to show a steady climb (See Figure 1), although with a somewhat decreasing rate from 2008 possibly in relation to the impact of the start of the global recession. In relation to emissions on a per square area and per capita basis, Bermuda contributes extremely high amounts of greenhouse gas emissions in relation to its size (BDA DOE 2009) with the Bermuda Government Energy White Paper stating

[12] BELCO is an acronym for the 'Bermuda Electric Light Company' See http://www.belco.bm)
[13] UK total generation = 376 TWh with a population of 63,181,775 (2012 Census & https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/279546/DUKES_2013_Chapter_5.pdf: Accessed June 2014)

"...Bermuda's emissions per person are relatively high at 14.44 metric tonnes per capita, more than twice the worldwide average (ibid, p.5)."

Figure 1: Electricity consumption in Bermuda (Bermuda Government Department of Energy 2009).



Significantly, islands often need to maintain much larger margins of capacity in order to be reliable, specifically to provide for infrastructure maintenance or malfunction issues (Stuart 2006). However, Stuart (2006) also expresses that in small islands, such challenges may be lessened due to an increased flexibility in generation plant as a result of the heavy use of smaller distributed engines and gas turbines, which are more modular and can be replaced or interchanged more easily. This holds true for Bermuda's utility whose generating plant is made up of a "maximum capacity of 165 megawatts, consisting of diesel engines and gas turbines with individual engine capacity ranges between 4.5 and 14.5 megawatts[14]." Stuart (2006) describes a so-called 'Virgin Islands paradox' in which as islands become more developed, the demand for energy increases along with its cost and the need for, and cost of, energy infrastructure. Reflecting this, energy price in Bermuda is also far higher when compared with larger nations[15], especially when additional fuel surcharges imposed by the utility are considered. Weisser (2004) states that where growth of electricity consumption rises beyond and unequally with GDP such situations regarding the cost of energy can worsen. It is also interesting to note that Kaza et al. (2011) assert that energy factors, such as energy price may affect 'urban form'. For example, disruption in energy

[14] www.belco.bm (Accessed: June 2014)

[15] For electricity, Bermuda unit price = $0.34 per kWh whereas UK unit price = $0.24 per kWh.

supply, whether economically or as a result of availability, could result in the disruption of vital water supplies, as island-specific challenges such as the provision of fresh water through desalination is an energy-intensive activity usually based on fossil-fuel sources.

1.4.2 Adoption of Renewable Energy as a Sustainable Development Strategy in Bermuda

Recognising Bermuda's vulnerabilities along several fronts regarding its environment, economic and social context, the concept of sustainable development has been promoted as an approach by which Bermuda can attempt to address these challenges relevant to its national development. In April 2005 at the 13th session of the UN Commission on Sustainable Development (CSD-13), UN Headquarters, New York, then Premier of Bermuda Alex Scott, encouraged by the international deliberations at the 2002 World Summit on Sustainable Development and the associated Johannesburg Declaration on Sustainable Development, officially announced the intention for Bermuda to develop a comprehensive national sustainable development strategy (Government of Bermuda 2005). Cited as chief motivations for this new thrust towards a sustainable development agenda were the maintaining of Bermuda's economic success and to address new social changes, as well as the Premier's expressed desire to see the international vision expressed towards sustainable development, such as what had been expressed at Johannesburg, translated into local action. Premier Scott envisioned the formation of a Bermuda Sustainable Development Strategy and Action Plan and in June 2006, after much public consultation, Bermuda's first national sustainable development strategy, entitled *Charting Our Course: Sustaining Bermuda – Sustainable Development Strategy and Implementation Plan for Bermuda* (Bermuda Government 2006), was created. In forming the plan the Government of Bermuda attempted to adhere to international standards on the construction of national sustainable development strategies. Many of the developmental challenges described earlier in this chapter where highlighted in the 2006 plan.

The chief motivations as to why a sustainable development strategy was needed for Bermuda, as described in the 2006 document were:

- Bermuda's lack of ability to influence global affairs but the strong influence by these global affairs on local matters.
- Bermuda's inherent vulnerabilities due to size and isolation making the island susceptible to changes.
- A desire to keep Bermuda apace with modern trends in technology, global economy and global trends.
- A desire to sustain Bermuda's prosperity.
- A desire to attempt to forward plan for inevitable island change.
- An attempt to institutionalize the needs of the island's local people.

In recognition of unsustainable consumption patterns of the island, the sustainable development strategy paid specific attention to the issue of energy supply and fossil fuel dependency in Bermuda. It identified the question of "how could the island meet its energy needs without relying almost entirely on imported fossil fuels" (Government of Bermuda 2006:115) as a key issue relating to energy supply. As a specific objective towards this end, the strategy recommended the development of a more 'secure' energy supply, specifically referring to a reduction in fossil fuel dependency, increased energy efficiency and an increase in energy self-sufficiency (ibid.). Key actions suggested by the strategy to achieve this increased energy security where (a) the setting up of an Energy Unit within government, (b) the development of an energy strategy for Bermuda (Government of Bermuda 2006:116,118). Both efforts were expected to facilitate the increase integration of renewable energy systems on-island as a method to promote greater energy security.

In an effort to move further towards the vision expressed in the 2006 sustainable development plan, in 2008 the Bermuda government created a new Department of Energy (BDA-DOE) to centralize energy policy structure. In February 2009, after much public consultation, the BDA-DOE would publish the 2009 Bermuda

Energy Green Paper (BDA-EGP)[16], as a national consultation on energy and first step to developing a national energy strategy. The 2009 BDA-EGP would outline Bermuda's dependency on fossil fuels as well as make a case for increased exploitation of renewable energy and the integration of renewable energy systems. Primary motivations given by the BDA-EGP for moves towards renewable energy use were:

- Reduction in the dependence on expensive and unpredictable supplies of imported fossil fuels.
- Reduction in the emission of GHG and other pollutants.

The 2009 BDA-EGP saw significant potential in the use of solar energy for both solar PV and solar hot water heating based on Bermuda's favourable solar energy profile. Additionally, wind energy was also suggested as a strong resource base for renewable energy use with the caveat of onshore placement of wind turbines being limited and offshore placement being expensive and ecologically unfavourable. Technologies such as ocean wave and ocean current renewable energy systems were also seen as having a strong resource base in Bermuda but with the technology still at a relatively immature stage and not viable for readiness to realistically invest in at the current time. Tidal energy was ruled out as Bermuda did not seem to have a favourable tidal regime for this sort of energy extraction. Geothermal energy was also seen to have limited potential in Bermuda and most of the potential use would be in the form of ground source heat pump application. Ocean Thermal Energy Conversion (OTEC) was seen as having significant potential for Bermuda due to the proximity of deep offshore ocean basins, but the investment needed to construct such technologies was seen as being prohibitive. The 2009 BDA-EGP saw significant potential in energy from waste (EfW) processes such as the use of horticulture waste, collection of landfill methane for combustion and the de-manufacture of automobiles, many of which are currently landfilled in Bermuda. Nuclear and co-generation (combined heat and power) applications were also reviewed by the 2009 BDA-EGP but not promoted as being significant to a renewable energy regime.

[16] Since the time of initial writing of this chapter the Bermuda Government has published the 2011 Energy White Paper as the next step to the publication of the BDA-EGP.

Since the publication of the 2009 BDA-EGP, the Bermuda Government has moved to create favourable policies designed to encourage the use of renewable energy and renewable energy systems locally. The BDA-DOE has encouraged the development and implementation of reductions in duty rates of various products to encourage the importation of energy efficient products and renewable energy systems as well as a Photovoltaic Rebate Initiative to encourage local installation of solar PV technology. The on-island utility, BELCO, has also begun movements to prepare for renewable energy systems integration. The utility has invited and entertained proposals from companies in the areas of solar PV, wind, ocean power, biomass and municipal waste[17]. They also set up a sister company in 2008 called PureNERGY[18] that specialise in renewable energy installations. PureNERGY have developed what they term a renewable energy test "beta site" in which they hope "to glean information about regulatory interface, installation, aesthetic impact, performance and interface with the BELCO grid"[19], specifically for domestic integration of renewable energy systems. BELCO also announced (2010) a trial program to purchase energy generated from home owners who have renewable energy installed capacity with a net metering and 'energy buy-back' plan. However, the utility has been criticized in the local media and by local NGOs[20] for the limitations of the program, specifically for allowing no more than 750 registrants into the trial and restricting the net-metering agreement to projects of 10 kilowatts or less (Johnston-Barnes 2009). Most recently, BELCO has announced it will be conducting a local resident's survey on domestic electricity use as well as residential openness to green technology so as to help shape the company's strategy on renewable energy.

Bermuda has also seen a rise in companies that install renewable energy systems. However, there are no current large-scale renewable energy installations on the island. Although some renewable energy installations have been welcomed, government has turned down the applications of residents in the past. The failed

[17] See BELCO website: http://www.empoweringprogress.bm/renewable/soi/index.html
[18] http://www.purenergy.bm/
[19] See BELCO website: http://www.empoweringprogress.bm/renewable/soi/index.html
[20] http://www.greenrock.org/projects/248-net-metering-agreement.html

applications have been mostly concerned with issues of aesthetics, a concern related to Bermuda's very unique traditional architecture and the fact that tourism is a critical industry on-island (Dale 2007). There may be other barriers to renewable energy integration in the island but there is little academic or publicly available research on the subject and most information is anecdotal.

Although published as a Master's degree level work, as one of the very few academic research works available on renewable energy and the use of renewable energy systems in Bermuda as well as for its comprehensive treatment of the subject, the work of Worboys (2009) deserves special mention. Worboys (2009) focused on the reduction of fossil fuel dependency in Bermuda and looked at a cross-section of areas including energy use, energy conservation and non-fossil fuel based (renewable energy) energy resources. Worboys (2009) suggested that there may be substantial room for reducing fossil fuel dependency on-island, both through energy conservation and the use of non-fossil fuel based energy resources. Significantly however, while Worboys (2009) recommended further research into the economic implications of renewable energy systems integration and energy conservation strategies, he gave no mention of the socio-environmental impacts of such strategies. However, judging by the recent debates on the issue of renewable energy and renewable energy systems integration in Bermuda, socio-environmental issues may play a more important role than just understanding of the techno-centric concerns of such renewable integration strategies. The current local debate is primarily being engaged by the political parties, local NGOs and the sole electrical power provider, BELCO. Supporting the aforementioned concern for sustainable development strategies to be concocted without attention to localised needs at the grassroots level, BELCO has historically looked outside of the country for consultant advice in regard to its policies on renewable energy use and renewable energy systems integration, an issue examined more in detail further in this study (See Section 3.6), giving rise again to the issue of potential lack of indigenous authenticity involving these types of technological solutions towards sustainable development

1.4.3 A New Small Island Context – 'Urban and Developed' Small Island States

The relatively recent news headlines at the opening of Section 1.4 suggest that there is clearly much progress still to be made locally in accomplishing one of the 2005 Bermuda National Sustainable Development Strategy's key aim of 'achieving greater energy security', and implementing a chief objective towards this goal, namely the increased integration of renewable energy technology. Predictably, the news headlines show that matters relating to affordability regarding energy security are often those that reach the headlines first as well as those that seem to prompt the most public engagement. However, the headlines also show that economic-related energy security issues are far from the only ones of concern and that the island's current energy security challenges emanate from across the range of themes that sustainable development is concerned with. It also becomes clear how understanding and researching the role of renewable energy technology in respect of sustainable development increases in significance, as it is these technologies that are being expected to play a role in helping to address such energy security issues across these aforementioned range of themes.

The news headlines also confirm how such energy security/renewable energy research would be wise to consider the multi-disciplinary nature of energy security problems and to adopt a research approach that is multi-disciplinary in nature. Reflective of this realisation, such a multi-disciplinary approach was adopted in the research methodology and analysis employed in this thesis. With its underlying aim being focused around a critical examination of the validity of generalised models of sustainable development for Small Island States, specifically those that call for the generalised promotion of renewable energy technology integration, this study calls into question policy documents and approaches such as the Bermuda National Sustainable Development Strategy. In many of these policies seeking to adopt a sustainable development approach, much attention has been given to the promotion of increased integration of renewable energy as an important energy security strategy. However, this review has made it clear that many of the policies incorporating renewable energy integration associated with a ‘pro-environment/pro-growth’ development agenda (i.e. sustainable development) seem to also have evolved primarily as an energy security strategy promulgated by stakeholders representing mainly larger international interests, not smaller, local ones like Bermuda (McVeigh et al. 2000; McLauchlan & Mehrubeoglu 2010). The researcher asserts that ‘one size fits all’ approaches may actually be ineffective, and in some cases, inappropriate, towards achieving holistic sustainable development across their range of local development needs. In this case then, it is critical for Small Island States to inform their policy momentum towards further integration of renewable energy with considerations and context that is mindful of the social, environmental and economic needs of its local population.

Unfortunately, many of the policy directions and published academic research continue to focus primarily on how renewable energy integration could act as an alternative energy solution towards greater energy security mainly from techno-centric or economic points of view. Recent studies such as Segurado et al. (2011) on the role of renewable energy on the Small Island State of S. Vincent, Cape Verde is a good example of this preoccupation. Jaramillo-Nieves et al. (2010) assert that it is the economic dimensions that have received predominant coverage whereas other considerations such as social and environmental have been largely absent or given less priority. They assert that this has produced a significant lack of multi-criteria based research on how renewable energy technology and its integration can contribute to the multiple components of sustainable development. Such multi-criteria analysis has proven very useful in generating a more comprehensive picture of the role of renewable energy technology in Small Island States, such as the work of van Alphen et al. (2007) on the Maldives. Local advice was critical to incorporate local concerns and legitimate knowledge. However, impacts are often only considered from primarily economic points of view and not often from the perspective of inter-twining social paradigms and its emanation from energy use behaviour and interior energy geographies. Understanding interior energy geographies is also important (Shirley et al. n.d.) as they may impact the role that energy plays inside homes and businesses as well as influence energy use behaviours.

Bermuda has a unique developmental profile (See Table 6) which separates it from other Small Island States and makes it significant as a case study towards understanding the role of renewable energy towards sustainable development in these locales. Its high GDP per capita, high energy consumption and high urban-like population density separates it economically from not only Small Island Developing States but most other Small Island States in general. These aspects of urban-like island-wide conditions, accelerated economic and material development emanating from the high GDP per capita and a resulting intense energy demand historically reliant on fossil fuel imports makes Bermuda a pertinent case study for understanding the role renewable energy systems can play in Small Island States with such unique developmental characteristics (identified further as 'urban and developed'). This research can then be particularly useful in better understanding how socio-economic conditions in Small Island States, in particular those of being 'urban and developed', may influence energy use and energy use behaviour.

Table 6: Comparisons of relevant development data between three island states of various sizes and the UK. (Data source[21]: National census data, World Bank and United Nations.)

	Bermuda	Barbados	Malta	UK
Population	64810	283,200	419,500	63,610,000
Land Area (km^2)	53.2	432	316	243,610
Population Density (persons/km^2)	1341	643	1320	261
GNI (USD$ per capita)	104590	15080	19,730	40332
Energy production, primary (000 mt oil equivalent)	0	56	0	147423
Energy Use per capita (MW per head)	2375.0	1742	1967.0	3024
Energy Price ($ per unit)	0.34	0.24	0.14 - 0.83	0.24
Greenhouse Gas Emissions (metric tons per capita	7.3	5.4	6.2	7.9
Internet Users (per 100 inhabitants)	88.3	71.8	69.2	82

N.B.: Closest years to present date (2014) were used as available.

[21] http://data.worldbank.org/ & http://data.un.org/

Additionally, as an 'urban and developed' Small Island State with a plethora of possible renewable energy resources to utilise, determining what role various renewable energy systems can play and how this role may be impacted socially, environmentally and economically is crucial before integration of renewable energy systems are specifically designated as a viable sustainable development approach. Bermuda as a Small Island State, as with many others, clearly sees a potential role for renewable energy and renewable energy systems, as demonstrated by their national sustainable development strategy and 2009 BDA-EGP and 2011 BDA-EWP. Any research conducted on these topics can help to assist island nations on the way forward concerning issues such as energy security, energy policy and the role of renewable energy and renewable energy systems, as well as furthering the understanding of how varying aspects of socio-economic development may influence the role of renewable energy systems and the policy and technical approaches to further its integration.

Both quantitative assessments on the level of renewable energy resources available such as in Worboys (2009), investigating how the island can make use of these renewable energy resources to enhance energy security and exploring which renewable energy systems would be most appropriate, are all important research topics, not only in answering the challenges faced by Bermuda, but potentially common challenges faced by Small Island States globally. Possibly of greater significance is assessing the social understanding and attitude towards renewable energy by the various communities, business and government stakeholders involved, which can serve to provide a critical background for development of future sustainable development strategies involving renewable energy and renewable energy systems going forward. Keeping the hesitations of Brookfield (1993), Connell (1993) and UNCTAD (2004) in mind as to whether islands truly can serve as 'laboratories of development', Bermuda and this research may or may not serve as a model for other Small Island States and other larger states internationally; however any information provided in the research process will inform the deliberations of other locales. From a wider outlook towards the global context in respect of the diverse range of Small Island States, it is these above perspectives concerning the overall problematic nature of the sustainable development discourse itself and more specifically, the appropriateness of the promotion of increased renewable energy integration towards sustainable development in the local context of Small Island State locales, that frames the larger debates surrounding this particular research.

For the reasons above, in combination with Bermuda's unique national social, economic and environmental attributes, the island nation seems to provide an excellent case study subject towards informing the role of renewable energy and renewable energy systems in efforts towards sustainable development in Small Island States. Uniquely, the island provides a variation from many other Small Island States, particularly those Small Island Developing States (SIDS) where most of the research into sustainable development and the role of renewable energy seems to have been concentrated on in the past. Bermuda is extremely densely populated, giving it characteristics more in common with an urban city centre.

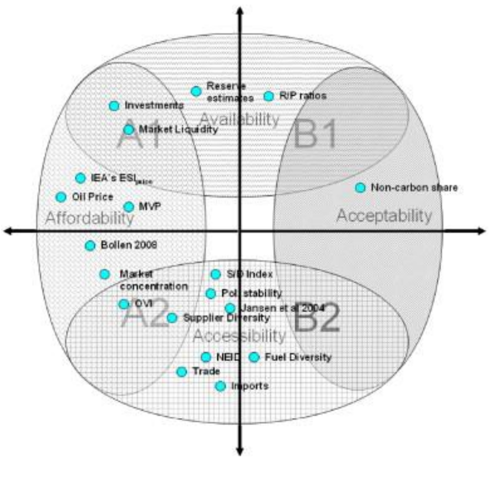
1.5 Analytical Epistemology

In consideration of the multi-disciplinary approach necessary to understanding the role of renewable energy towards sustainable development as described in the previous section, a unique analytical epistemology has been developed that attempts to integrate what is thought to be the various determinants of the role of renewable energy in these locales within the context of a sustainable development. This way of framing the research came directly as a result of adopting a grounded theory approach whereby the analysis of the data through coding called into play a need to organize and examine how the research data linked across three key distinct paradigms: sustainable development, energy security and the integration of renewable energy. By having a framework such as this, a more constructivist extraction of meaning from phenomena relating to energy such as relationships and behaviours could take place, especially important since the multi-methodological approach employed incorporated both qualitative and quantitative techniques.

Although originally looked to for practical methods in assessing energy security, the researcher returned to Kruyt's et al. (2009) energy security spectrum (Figure

2) in an effort to understand how core components of sustainable development (environmental, social, economic) linked and related to energy security, with a hope of being able to effectively organize the research data into a merged analytical framework involving both paradigms as suggested above. In Kruyt's et al. (2009) model, four dimensions are proposed as the core areas of global energy security: accessibility, availability, affordability and acceptability. Availability refers to a consideration of whether there is enough supply to meet demand, i.e. "elements relating to *geological* existence (Kruyt et al. 2009)", and generally refers to energy security concerns upstream of production activities. Accessibility refers to the ability to access energy in the face of challenges resulting from social, economic, political and technological factors, i.e. "*geopolitical* elements (ibid)", and such factors may impact energy security at any point along the energy services spectrum through the networks of human and non-human actors (technologies, infrastructures, regulations, etc.) that comprise it. Acceptability refers to considerations of energy-related environmental impacts and attempting to avoid such impacts as much as possible in the provision of energy, i.e. "*environmental* and societal elements (ibid)." Affordability refers to the cost of energy, i.e. "*economical* elements (ibid)." Including within the energy security spectrum, Kruyt et al. (2009) outlines several key energy security indicators in relation to the four core dimensions of energy security, acknowledging however that there is no concise interpretation of the term energy security and thus no ideal indicator by which to measure it as "the indicators themselves are context dependent (Kruyt et al. 2009:2171)."

Figure 2: The 'energy security spectrum': the four dimensions of energy security containing relative energy security indicators in their relation to four distinct global orientations (Kruyt et al. 2009).



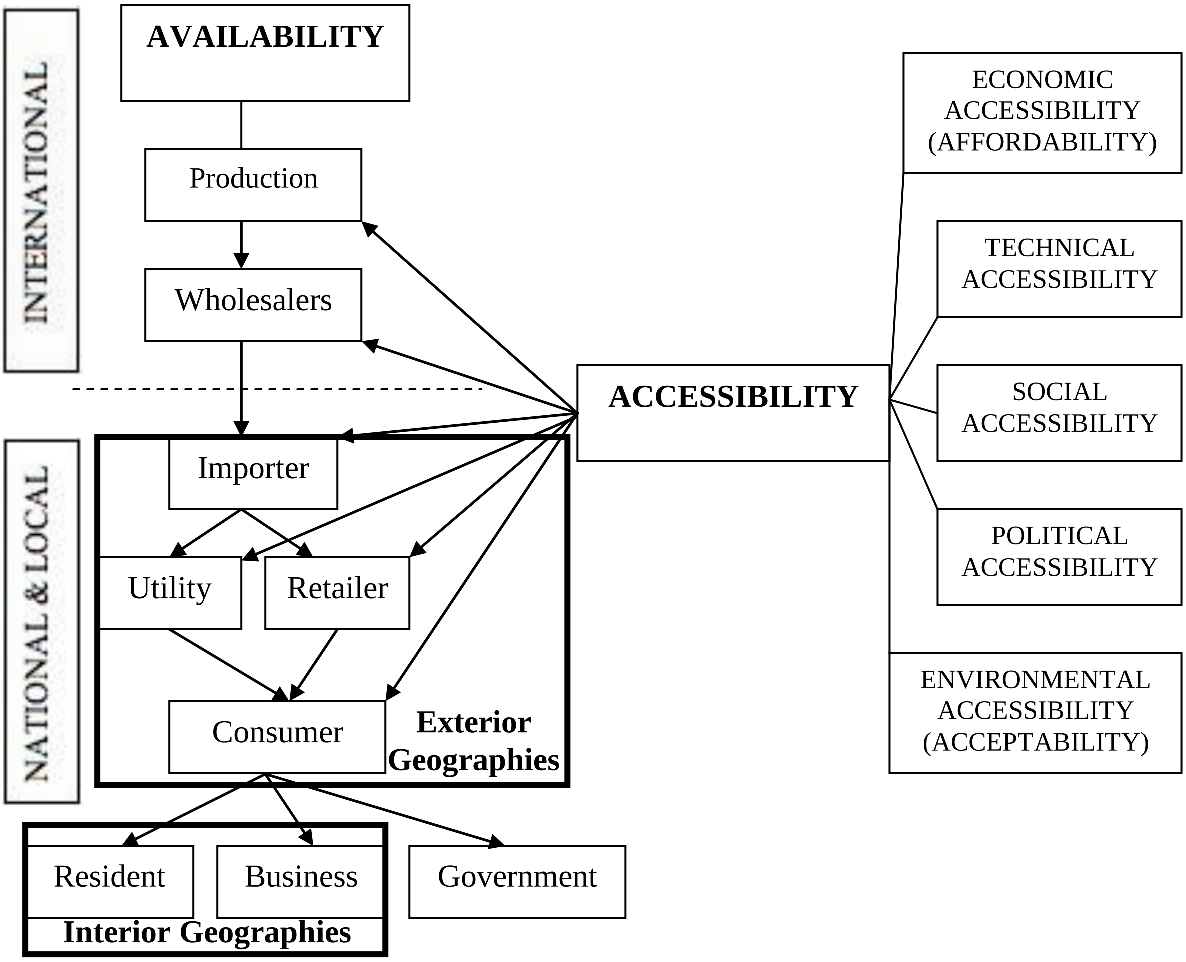
This examination of Kruyt's et al. (2009) model proved worthwhile as the researcher was able to find synergy between the four dimensions of Kruyt's et al. (2009) energy security spectrum and the three core components of sustainable development (See Table 7). However, upon efforts to find a working conceptual framework that successfully integrated Kruyt's et al. (2009) energy security spectrum and sustainable development from the perspective of the research data, it was realized that as this research was based specifically within a 'local' context as a case study, only one particular dimension of Kruyt's spectrum, *accessibility*, could realistically apply to framing the data. This realization merged well with the researcher data as the core dimension inclusive in the accessibility component of Kruyt's et al (2009) energy security spectrum (A2-B2) in regards to *accessibility*, affordability and acceptability, also matched closely with core indications being revealed in the research data.

Table 7: Linked areas between Kruyt et al. (2009) energy security dimensions and the core areas of sustainable development.

Four dimensions of energy security (Kruyt et al. 2009).	**Core areas of sustainable development.**
Availability	Environmental
Acceptability	Social & environmental
Affordability	Economic
Accessibility	Social, Environmental and Economic

It is important to note that while the dimension of *availability* in Kruyt et al (2009) energy security spectrum, with its reference to more upstream production related activities based primarily on elements relating to *geological* existence, was not needed as a primary part of analytical framework for framing the research data, it is undoubtedly recognised that the notion of accessibility in regards to local and national energy security has influences that interact across these two boundaries. As such, the research must consider accessibility across multiple perspectives, including not only the influence of international issues beyond the national and local but also disparities that may arise between geographies of space at the national and local level, i.e. interior and exterior geographies. It was also recognised that the two dimensions of availability and accessibility are fundamentally interrelated (See Figure 3), as intimated on Kruyt's et al. (2009) model, with the local accessibility of energy supply being dependent on its overall availability. Owing to this interrelated nature, any issues affecting energy security from the perspective of either of these two dimensions can have impacts across the aforementioned ranges of geographical scale - international, national, local and sub-local. However, while the availability of energy resources is fundamental to ensuring energy security, consideration of this particular component as a separate and discrete function (i.e. peak oil[22], etc.) beyond any linkages related to the national or local scale was beyond the scope of this research. Thus, in terms of this research, which sought to focus on the national and local scale for Bermuda as a case study, accessibility in its diverse nature can be considered the primary dimension of energy security.

Figure 3: Notions of availability and accessibility as dimension of energy security and sustainable development across the geographic scale (Author 2011).



22 'Peak oil' refers to a time when the maximum rate of global petroleum extraction is reached.

This structure follows others that have been proposed in order to assess energy security, such as Kruyt et al. (2009), but differs from the perspective that they are chiefly composed in order to consider energy security from the context of inter-linkages with the sustainable development paradigm and primarily on a national and local level. By using such dimensions relating to energy security across the economic, environmental and social divide, the research framework finds some synergy with similar frameworks proposed to conceptualise sustainable development (Hermans & Knippenberg 2006; de Vries & Petersen 2009). In this regard, clear linkages can be established between renewable energy and energy security with a view to understanding how they may impact on the corresponding areas of sustainable development in respect to 'urban and developed' Small Island States.

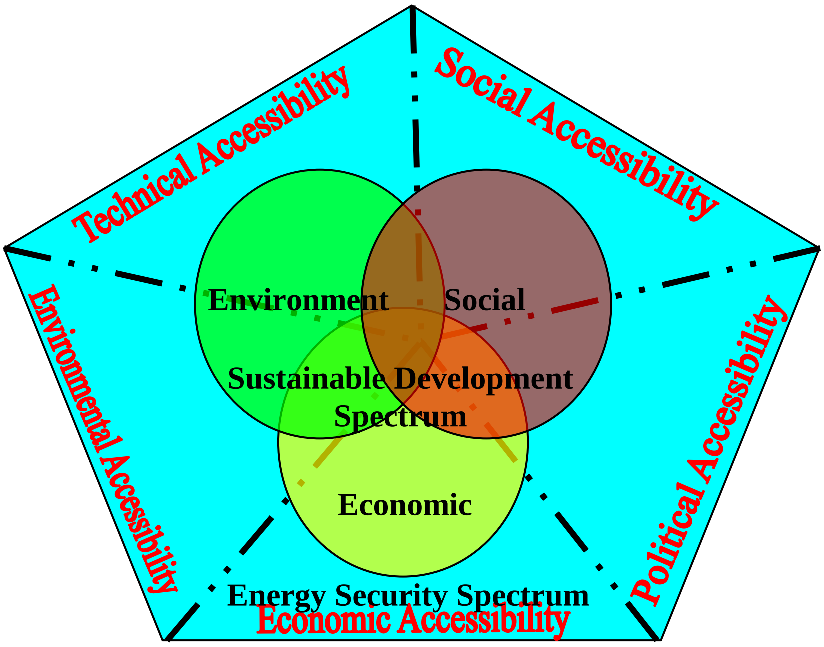
Using this understanding as a basis, five sub-dimensions relating to the social, economic and environmental spectrum of sustainable development as it relates to the energy security dimension of accessibility were proposed as research indicators. They were: technical accessibility, economic accessibility (i.e. affordability), social accessibility, political accessibility and environmental accessibility (i.e. acceptability) (See Figure 3). Social accessibility refers to not only how energy is differently accessible to people and society based on social identity such as demographic differences but also how social phenomenon such as energy use behaviours may have different roles in people's lives. Technical accessibility refers to ways by which physical technologies and technology infrastructure are involved in making energy accessible. Economic accessibility refers to roles influencing or involving the affordability of, inclusive of all stakeholders along the energy services spectrum such as consumers, suppliers and the impact of government regulators. Political accessibility refers to the influence on energy roles in society by political institutions larger than the individual, but rather groups of individuals organised in distinct political structures. Environmental accessibility refers to how a particular energy role may influence its acceptability specifically in regards to the sensitive nature of the natural environment and any impacts thereof.

With these five sub-dimensions established, any relative quantitative and qualitative research data gathered could be assessed and organised using the sub-dimensions as a framework for organisation. This assessment took the shape of posing two fundamental questions in respect of the research data:

1. Is there any impact on energy security particularly in the context of the 'urban and developed' nature of Bermuda as a Small Island State?
2. Does renewable energy integration play any role in this impact in regards to energy security, specifically in the context of Bermuda as an 'urban and developed' Small Island State?

It was also recognised that some data may not fit neatly into any one specific sub-dimension and indeed may span across multiple aspects of both the energy security and sustainable development spectrum (See Figure 4). The 'fuzzy nature' of these two paradigms in relations to their discrete components has been described by others previously (Kennelly et al. 1995; Krueger & Gibbs 2007; Valentine, S.V. in Benjamin 2011) and further provides testament to the interconnectedness between issues within, relating to and potentially influenced by these two paradigms, including of course the integration of renewable energy.

Figure 4: Considering the relationship between aspects of accessibility as a dimension of energy security and the sustainable development paradigm (Author 2011).



1.6 Conclusion

This literature review has first sought to outline the evolution of sustainable development as a modern, contemporary environmental problem solving discourse and how it has become important as a policy direction in Small Island States internationally. A review on why renewable energy integration is associated with sustainable development as an energy security strategy is given and in particular how many of the vulnerabilities of small islands in regards to energy can be potentially addressed by this specific alternative energy strategy. Islands that have adopted such renewable energy integration to varying degrees are examined and the island of Bermuda in particular is presented as a unique case study towards a new context of Small Island States, that being those that are urban and developed. The literature review ends by posing the central research question of whether the role of renewable energy integration towards sustainable development in Small Island States such as Bermuda are justified and proposes a unique analytical epistemology for integrating energy security dimensions with the themes of sustainable development which can be used to frame data emanating from research of this central research question.

The remainder of the thesis is structured by way of a presentation of methodological considerations in which the approach towards collecting both quantitative and qualitative data is outlined. This is followed by a presentation of the results, which have been organised in a framework categorised in local energy security dimensions associated with the range of themes that sustainable development is concerned with. Finally, conclusions are offered in which the thesis' contribution to the fields of sustainable development for Small Island States is given, particularly in regard to the need to develop new understandings of the distinct differences in the roles of renewable energy integration in 'urban and developed' Small Island States when compared to other culturally and geographically similar but economically different Small Island Developing States.

2 Methodology

2.1 Introduction

This chapter seeks to outline the overall research design of this thesis and the specific methods that were used to conduct relevant research. The chapter first describes how the research design emanated primarily from a central research question (Section 2.2) and how the process of answering this central research question served to form the main aims of the research. Second, a description of how this central research question was used as the basis for developing a research theory (Section 2.4), which could be tested, and thus serve as a basis to further inform the central research question is then presented. Third, the chapter provides a description of how this research theory was used as a basis by which to operationalise the research through the development of a set of research objectives (Section 2.5), which could be used to test the theory. Following this, a section is provided on the specific research methods (Section 2.6) that were chosen by which empirical data could be obtained so that each research objective could be achieved. Finally, an attempt to conceptualize the research's methodological approach is provided in Section 2.6.

2.2 Central Research Question

This thesis seeks to answer the primary research question of 'what is the role of renewable energy (and renewable energy systems[23]) in the efforts of Small Island States towards sustainable development. The three fundamental subjects of this research are 'Small Island States', the 'roles of renewable energy and renewable energy systems' and 'sustainable development'. This primary research question was initially proposed as a research topic primarily due to the relevance of these three fundamental subjects as important topics of interest in current global and local environmental, social, economic and political contexts as discussed in the introductory chapter as well as secondarily, the topic's personal relevance to the researcher. Providing an answer to this research question involved both a review of past research literature on these three fundamental subjects as outlined in the

[23] Renewable energy systems are also sometimes referred to as 'renewable energy technology' such as in Weisser (2004).

introductory chapter as well as the formulation of a new research methodology inclusive of any pertinent information garnered from the literature review process, both integrated and infused with the researcher's own study intent. The study of each one of the core research topics alone could easily be considered disciplines unto themselves and copious amounts of information have been produced on their study resulting in the formation of vast, yet still somewhat defined, discourses on each area. As a result, the methodological approach of this new research was inevitably influenced by this type of diversity and necessarily took on a multi-disciplinary nature in order to successfully consider each topic as an inter-related research subject.

The arrival at this central research question was heavily influenced and directed from issues related to the researcher directly. The researcher is a "son of the soil" of the island nation of Bermuda, a Small Island State where efforts towards renewable energy systems integration has gained momentum in governmental policy (BDA DOE 2009) as a growing economic market[24] and as a sustainable energy solution being promoted by various stakeholders[25]. As a geographer[26] and environmental scientist, experience on the ground as an observer of the political movements serving to advance the promotion of renewable energy systems integration, combined with the promotion of renewable energy systems integration as a potential "new way" towards sustainable energy provision by both businesses, non-governmental organizations and other community stakeholders as described above, prompted the researcher to question the potential that renewable energy systems integration could, and even more so *should*, truly play in a Small Island State like Bermuda. In recognition of this interest, the island of Bermuda was chosen as a case study in hopes of allowing the researcher to both examine the research question in general reference to understanding the role of renewable energy towards sustainable development in Small Island States as well in hopes of providing more clarity of the particular

[24] See http://www.solarbermuda.com/ as an example.

[25] See http://www.empoweringprogress.bm/renewable/renewable.html for an example. Also local Bermuda non-governmental organisations such as the Bermuda Environmental Sustainability Taskforce (B.E.S.T.) and Greenrock have publicly supported initiatives towards renewable energy systems integration

[26] The term "geographer" could have easily been substituted by the term "environmental scientist", again reflecting how this research topic crosses disciplines.

role that renewable energy can play in Bermuda's specific case.

Of additional value in selecting Bermuda as a case study is recognizing the unique position Bermuda holds as an 'urban and developed' Small Island State. By further developing an understanding on the role of renewable energy in efforts towards sustainable development in such an 'urban and developed' Small Island State locale, some comparative insight may be obtained on how different socio-economic conditions that exist across the range of Small Island States may affect the role of renewable energy in their efforts towards sustainable development.

Choosing Bermuda, the researcher's place of birth, as a research case study location was of obvious benefit in many aspects of designing and conducting research related field work, especially in relation to issues of access. However, it is worth mentioning that such familiarity may also work against the researcher. For example, human research subjects may deem the researcher or the research "too close to home" and thus be reluctant to share information. Also, issues that may impact the researcher personally or those of family or friends have the potential to be treated with cognizant or non-cognizant bias (Bryman 2008). Acknowledging the potential for this type of bias was an essential part of being reflexive to the 'positionality' of the researcher and reflections on how issues of positionality, situatedness and ethics played into data collection methods are outlined in Section 2.6.2.4.

2.3 The Case Study Approach

An important overlying characteristic of this research is the use of a case study approach. Case study research tends to be appropriate "when investigators desire to (a) define topics broadly and not narrowly, (b) cover contextual conditions and not just the phenomenon of study, and (c) rely on multiple and not singular sources of evidence (Yin 1993:xi)." Relating to the desire to "define topics broadly and not narrowly", the case study approach becomes particular relevant to this research as the main discourses relating to this research topic, renewable energy systems, Small Island States and sustainable development, are part of *both* local and global environmental discourses. By using knowledge gained through the examining the unique circumstances of one particular Small Island States locale, the island of Bermuda, insight may be gained in the application to the experiences of other Small Island States globally.

Secondarily, the research theory associated with this research aligns with an investigative desire to "cover contextual conditions" (ibid.) such as the social, political and economic factors impinging on the role of renewable energy systems and "not just the phenomenon of the study" (ibid.), which in this case would be identified as renewable energy resource availability and 'obtainability'. Finally, as described in the sections following, answering the central research question will rely on "multiple and not singular sources of evidence" (ibid.).

2.4 Research Theory

To achieve the task of answering the central research question, it was not only helpful, but most probably necessary, to orientate the methodological approach in a direction that is somewhat focused and directed. Research is "theory dependent" (Miller & Brewer 2003:326), as theories offer new ways of looking at the social world, drawing together seeming unrelated fragments of empirical evidence and research (Miller & Brewer 2003:326). Metaphorically likening the process of so-called 'middle range' theory (Miller & Brewer 2003:325) formation to that of a germinating seed, the process of refining one's research theory, through adding and subtracting context, until it truly reflects the research question is an ongoing one, with the finality being the existence of a statement that can be verified through methodology. Thus, it is theory that "operationalises" (Miller & Brewer 2003:326) research and it is in this context that the research theory proposed below and the research objectives following are based.

The formation of this research theory was proposed both as a result of the researcher's own aforementioned 'situatedness' as well as secondarily from a more "grounded theory" (Denzin & Lincoln 2000:509) approach. A "grounded theory" process may be described as "collecting and analyzing data to build middle-range theoretical frameworks that explain the collected data" (Denzin & Lincoln 2000:509) and the data collection relevant to the development of the research theory described below was obtained through preliminary literature reviews as well as pilot field research (described further in Section 2.6.2). This grounded theory approach necessarily continued throughout the research process, being used as "a way of thinking about and conceptualizing the data" (Denzin & Lincoln 1994:275) that was collected.

The general position observed in the available research literature on the three core subjects at the heart of this research describes the role of renewable energy for Small Island States mostly as a function of the following specific determinants: (1) the potential for renewable energy to contribute to increasing energy security in Small Island State locales by way of providing a renewable energy supply as an alternative to incumbent fossil fuel use; (2) the assumption, based on factors associated with islandness, of the physical availability of renewable energy resources from which an alternative supply could be obtained; (3) the availability of renewable energy technology suitable to harvest these renewable energy resource; (4) the perceived "green[27] and clean[28]" credentials of these renewable energy systems which add to their attraction as a techno-centric solution to sustainable development; (5) the affordability of renewable energy system integration in Small Island States due to the high energy cost associated with traditional imported fossil fuel use in many of these locales and (6) the perception that the integration of renewable energy can act as an economic stimuli to aid in the economic development and diversification of Small Island States.

Approaches using the determinants outlined above are those that are often used in validation of renewable energy systems integration in global politico-environmental discourses (for example see EU 2009; Parry et al. 2007; Scherer & Steinmetz 2010) as well as in much of the academic research about renewable energy system integration that predominates the literature (Beller et al. 1990b;

[27] Green-tech' may be defined as "environmentally conscious" technology, both in terms of the technology manufacturing process and the way it operates (Billatos & Basaly 1997:3).
[28] 'Clean-tech' may be defined as technology that "avoids environmental damage at source" (Kirkwood & Longley 1995:174).

Ma et al. 2010; Demiroren & Yilmaz 2010; Dalton et al. 2009; Weisser 2004a). Also, from the researcher's own experience[29], much of the work of management and engineering consultancies providing assessments of the potential for renewable energy systems integration on the behalf of various stakeholder clients also focused mainly on feasibility studies based largely around these same determinants (See 2.6.2.5).

However, although seemingly diverse in nature, upon reflection these determinants are rather positivist in nature and in some way miss a critical component associated with sustainable development - the context of the social. The research theory proposed here acknowledges the absence of the 'social' and necessarily takes on a critical approach to researching the role of renewable energy in efforts towards sustainable development in Small Island States. The researcher proposes that the role of renewable energy is shaped not only by these generally positivist determinants cited above but by a complex interaction between them in conjunction with social determinants as well – a sustainable development and energy security ecology. These social determinants include existing social roles of energy, social influences such as public understandings and opinions, socio-political influences such as regulatory frameworks and relationships of power. The researcher advances the theory that assessment towards the role of renewable energy systems integration in Small Island States needs to consider the confluence by which these complexities inter-relate in order to more accurately and comprehensively understand the potential role that renewable energy may play in efforts towards sustainable development in Small Island States locales.

Understanding the role of renewable energy in efforts towards sustainable development in Small Island States as a function of this complex interaction between determinants involving all three core components of sustainable development – environmental, economic and social, becomes even more relevant when considering the diverse range of socio-economic conditions that

[29] The researcher was employed as a graduate energy policy analyst from September 2008 - September 2009 in which he was able to conduct "participant observation" of many renewable energy systems feasibility studies and their rationale. This experience is detailed further in Section 2.6.2.5.

characterize Small Island States. How the unique socio-economic characteristics of Bermuda as an 'urban and developed' Small Island State influences the complex interactions between the various determinants of the role of renewable energy in that particular island location becomes useful in broadening this understanding as well as a useful indicator to addressing the validity of this theory in general.

2.5 Research Objectives

In their publication entitled Energy Research – Directions and Issues for Developing Countries, the Energy Research Group (1986:145) writes that "informed research direction requires the study of the environment of research, especially of the emerging needs of research users, and its translation into problems that can be solved by researchers and build their capacity." Embracing this need to 'translate the environment of this research and its needs' into tangible problems to be solved so as to further inform the research, the following primary research objectives were proposed as a textualised statement of the explicit empirical intent of the research, that is, a translation of the research question and research theory into problems that can be solved. Each objective was formulated so as to validate or make invalid some aspect of the research theory leading ultimately and hopefully to an answer to the central research question. In this way, the research objectives also served as a platform for the development of an effective research methodology.

The principal objectives of the research were to:

1. Assess the current level of energy security in Bermuda in relation to the role of renewable energy and renewable energy systems.
2. Investigate what potential social, economic, political and environmental roles renewable energy might play in Bermuda through:
    (a) Evaluating the role that energy currently plays in Bermuda
    - Evaluating the current role of energy to residents in Bermuda.
    - Evaluating the role of energy in current business practices in

Bermuda.

(b) Evaluating public understanding of their current provision of energy and of renewable energy systems.

(c) Evaluating public opinion of their current provision of energy and opinion towards renewable energy systems and its potential integration.

(d) Evaluating the future role that renewable energy systems may play for businesses in Bermuda.

(e) Evaluating the expectations of government for renewable energy systems integration through thematic policy analysis.

(f) Investigating qualitatively and quantitatively selected renewable energy resources that may exist.

The formation of these objectives was based on two different research approaches; a positivist approach and a constructivist approach. The first part of the research theory proposed in Section 2.4 hypothesizes that the potential role of renewable energy systems in Small Island States is shaped partly by the availability of renewable energy resources, the availability of appropriate renewable energy systems and the need for an alternative energy source. Research objectives 1 and 2(f) have been formulated to determine the role of renewable energy systems in regards to this aspect of the research theory. These objectives were proposed based on a review of academic literature relevant to these aspects of the research theory, work experience/participant observation opportunities that can be considered a part of the researcher's pilot studies and through data obtained from pilot social research fieldwork. These objectives are primarily positivist in nature in that they seek to utilize empirical evidence based on physical observation and physical or numerical measurement of phenomena; "the reality out there to be studied, captured and understood" (Denzin & Lincoln 1994:5).

The second part of the research theory proposes that in contention with the predominate approaches to determining the role of renewable energy systems in Small Island States in their efforts towards sustainable development, that this role is not only shaped by these determinants but also as well as determinants arising from complex social interactions with existing roles of energy, public understandings and opinions, regulatory frameworks and relationships of power. As described in Section 2.4, this aspect of the theory emanates partially from a grounded theory approach – an approach by which theory is generated from data in the process of conducting research. As a result, the formulation of objectives to test this aspect of the theory must be fluid and reflective of the original theory being proposed. In addition, concepts such as roles, understandings and opinions are primarily social constructs. Political dynamics and power relationships amongst social actors are also socially constructed. The evaluation of social constructs as it relates to social actors is essentially a search for '*verstechen'* (meaning) that social actors dynamically proscribe to these social interactions or social phenomena (Miller & Brewer 2003:338). A constructivist approach seeks to embrace this understanding, and uses empirical approaches that look to extract meaning from social phenomena such as social relationships and social interaction. Research objectives 2(a)-(e) have been formulated to determine the role of renewable energy systems in regards to this aspect of the research theory.

2.6 Research Methods

In answering the central question of this research, testing its research theory by way of carrying out its research objectives, the research methods needed to be employed were necessarily multi-discursive in origin and multi-disciplinary in nature. As described in Section 2.5, the research objectives incorporate empirical investigations of both an objective positivist and subjective constructivist nature. The research methods chosen are those that were able to effectively achieve each research objective and as a result involved both quantitative and qualitative methods. Those research objectives of an objective nature will be assessed using quantitative methods looking to establish "the reality out there to be studied, captured and understood" (Denzin & Lincoln 1994:5). These quantitative methods are based on: (1) methods identified through both a review of academic literature where previous research in these topics has been recorded and, (2) through participant observation/work experiences by the researcher in companies involved in renewable energy systems integration feasibility studies.

In this respect, Mazur & Rosa (1974:608), in their study on energy consumption and lifestyle, in which the researchers used only readily available statistical data, by their own omission affirmed that using quantitative data alone proves problematic to gaining insight to the social perspective. The researchers cited that much of the "relevant aspects of lifestyle" were not held in quantitative secondary data forms they were using and they were not able to obtain a complete understanding of the problems due to the limits they encountered from the use of quantitative data alone. With this type of understanding to inform the social aspects of the research methodology, those research objectives of a subjective nature will be assessed using qualitative methods, with some quantitative considerations where relevant. In commonality with the quantitative methods, these qualitative methods were also chosen based on methods identified through a review of academic literature where previous research in these topics has been recorded as well as the association of the selected methods as approaches that not only seek to establish *verstechen* (i.e. 'meaning') through simply discovering and recording social behavior but rather link this behavior with socio-economic and cultural contexts (Miller & Brewer 2003:60). Table 8 provides a summary of the quantitative and qualitative methods that were used as research methodologies.

Table 8: A table summarising what research methods were used.

Quantitative	**Qualitative**
- Secondary data analysis - Survey questionnaire spreadsheet analysis	- Semi-structured interviews - Survey questionnaires - Participant observation - Coding

The use of multiple methods not only assists in addressing the multi-discursive and multi-disciplinary nature of this research but also aids in the process of research 'triangulation'. The process of triangulation in regards to empirical research involves "the use of multiple methods to try to maximize an understanding of a research question (Clifford & Valentine 2003:7)." The following sections outline the specific methodological approach employed in this research and the rationale behind the choice of each methodology. The methodological framework presented here (See Table 9) conceptualises the relationship between the research objectives, the energy security dimensions of accessibility and the methodologies that were identified in pursuit of an answer to the central research question.

Table 9: A conceptualisation of the methodological framework for this research (Author 2014).

Research Objective	Accessibility Dimensions	Research Method	Evidence Gathered	Results Section
- **Current level of energy security** - **Roles of energy**	Social	Secondary Data Analysis Semi-structured Interviews Coding Survey Questionnaires	- Energy intensity - Energy diversity (interior and exterior) - Political stability of energy supply - Energy user grounded-ness	3.1
- **Understanding of energy** - **Opinions on energy**	Technical	Secondary Data Analysis Semi-structured Interviews Coding Survey Questionnaires	- Fuel import transportation and storage risk - Energy redundancy - Enviro-technical barriers - Socio-technical understanding - Electric vehicles	3.2
- **Roles of energy** - **Opinions on energy**	Economic	Secondary Data Analysis Semi-structured Interviews Survey Questionnaires Participant Observation Coding	- Socio-economic impacts on accessibility o Domestic uptake o Business uptake - Energy efficiency	3.3
- **Opinions on energy** - **Quantitative assessment of renewable energy resources** - **Future roles of energy**	Environmental	Secondary Data Analysis Semi-structured Interviews Survey Questionnaires Participant Observation Coding	- Fossil fuel use - Climate change - Environmental Geography ('Islandness') - Physical renewable energy resource availability o Solar o Wind o Wave o Biomass (Horticultural waste)	3.4
- **Expectations of government concerning renewable energy** - **Opinions on energy**	Political	Semi-structured Interviews Participant Observation Coding	- Interest to installation pathways - Actor/Agent Silos as Barriers - Colonial Considerations	3.5

2.6.1 Quantitative Methods

Using the methodological framework described above, aspects of two areas of accessibility were directly assessed using quantitative methods: environmental accessibility and economic accessibility. However, it should be noted that issues regarding all the indicators described in the analytical epistemology above were also revealed and extracted by way of qualitative methods as well, which is discussed in Section 2.6.2. In this case, the quantitative assessment of environment accessibility refers to research objective 2(f), that is, investigating quantitatively selected renewable energy resources that may exist. It is also worthwhile noting here that some studies use a "retrospective" approach to examine energy security while others choose a "prospective" approach (Greene 2010). A retrospective approach generally involves looking at energy security from past conditions with a view to understanding the current state of security of supply of that particular entity being studied while a prospective approach often attempts to model expected security of supply based on assumptions as a function of current or past conditions, as well expected future market conditions.

While the energy security spectrum developed by Kruyt et al. (2009) is made up of multiple components and contains multiple indicators, there is an aspect of energy security that does not receive adequate attention in this framework. Energy security can also refer to a more sociological understanding of the term, i.e. reflecting the feelings and welfare of the social actor in regards to energy supply or lack of it. This aspect of energy security along with the latter treatment of the term is an extremely important aspect of this research as the research intends to understand energy security in the context of sustainable development, wherein the social paradigm is extremely relevant and important. Studies considering this aspect of energy security study are scarce, with those that do approach it in some way (e.g. Baarsma & Hop 2009) still relying primarily on quantitative methods rooted in socio-econometrics.

As a function of research objective (1), this research proposed to use both types of approaches to energy security, quantitative methods focused on aspects of physical supply and energy price from a retrospective prospective and the assessment of qualitative data for insights into aspects of energy security associated with social phenomenon, acknowledging the relevance of both to the sustainable development paradigm. From a quantitative perspective, researchers examining the role of renewable energy systems as a function of energy security tend to use broad "high-level" studies at the macro-scale which rely on secondary data, which is used as a forecasting tool, to generate scenarios and to future map infrastructure, capacity and stakeholder considerations (Weisser 2004a; Shupe 1982; Weisser 2004b; Weisser 2004b; Beller et al. 1990a). In commonality with this, the research's quantitative methodological approach to energy security assessment also primarily relied on secondary data used in this case to portray a retrospective picture of Bermuda's security of supply. This retrospective quantitative assessment of energy security was used to establish a reference energy security base case in the hopes of clarifying whether one of the key roles of renewable energy occurs as a function of a need based on a current unsustainable energy supply. This acknowledges one aspect of the research theory, whereby the desire/need for an alternative energy source to the predominate use of non-renewable fossil fuel sources may be a key determinant in the role that renewable energy systems may play in Small Island States.

2.6.1.1 Quantitative Energy Security Assessments

Specifically, secondary data was sought in two main areas, energy imports – present and historical data on types and volumes of imports, and energy price - present and historical data on energy price. Geo-political accessibility and environmental acceptability, including greenhouse gas (GHG) emissions considerations, was inferred through a post-data collection analysis of this secondary data relevant to the type and source of imports. This secondary data was obtained from both government records, fuel supply/import company sources and the major energy utility as well as through archival work. Information on historic energy demand was also collected. This type of data and the analysis conducted on it relates most closely to the following "simple indicators" as presented by Kruyt et al. (2009): diversity indices, import dependence indices, political stability, energy price, share of zero-carbon fuels and demand-side indicators. The majority of the quantitative results concerning energy security are based on these simple indicators as they fit within the five energy security dimensions of accessibility (See Section 1.5.1) and are presented in Section 3.1.

Limitations of this quantitative energy security assessments were the reliance on secondary data as a primary data source for the research. The accuracy and reliability of such data could not be verified independently as that was outside of the scope and means of the research. There was also a dearth of information that the various stakeholders described above were able to share as, until recently, such information was not regularly archived for public sharing as part of the commercial operations of the energy companies and the Department of Energy is only a relatively newly formed government body, with also limited data collection.

2.6.1.2 Quantitative Renewable Energy Assessments

As a large range of potential renewable energy resources that could be investigated exist, a target group of those that were deemed to have the greatest potential to small islands was examined (W. Beller, D'Ayala & P. Hein 1990a; Lent et al. 1997; Raymond M. Wright 2001; Duic et al. 2008; Weisser 2004c; Eize de Vries 2008; Sam Hopkins 2009). This research focused on Bermuda's solar, wind and bio-energy (horticultural waste tippings) resources. Quantitative assessment of wave and tidal energy was initially considered as part of the research study but has not been pursued based on information gained as a result of the researcher's participant observation work experiences as well as the initial pilot research fieldwork into these areas.

All of the quantitative assessment of physical renewable energy resources involved the collection and processing of secondary data from various relevant sources and are aimed primarily at a high-level/macro scale. This approach is in line with these types of assessments outlined in the literature (Ramachandra & Shruthi 2007; Dalton et al. 2009) as well as reflective of the renewable energy assessments observed based during the researcher's participant observation work experience.

2.6.1.3 Measuring the Solar Resource

"Interest in solar energy has prompted the accurate measurement and mapping of solar energy resources over the globe (Boyle 2004:22)." Determining the solar energy resource available to Bermuda as a Small Island State is important to including this renewable energy resource as a potential sustainable energy source. The recent Bermuda Energy Green Paper (Bermuda Government Department of Energy 2009) and

Worboys (2009) have suggested a key role for solar energy in reducing fossil fuel dependence in Bermuda. The basis of using solar energy as a usable energy source is determined by the amount of solar radiation that reaches the surface of the Earth (Boyle 2004). Renewable energy systems utilising solar energy as a heat source depend mostly on the ability of such devices to use glass and surfaces with selective properties which allow solar radiation to pass through but block the re-radiation of long-wave infrared (heat) (Boyle 2004). Renewable energy systems utilising solar energy as a photovoltaic[30] (PV) energy source depend also on the solar radiation impacting on the device surface (Boyle 2004). However, the energy generated by photovoltaic renewable energy systems is directly proportional to the frequency of light striking its surface and is not reliant on a re-radiation of heat (Boyle 2004). The potential for use of both solar heating renewable energy systems and solar PV renewable energy systems depends on the availability of solar radiation at a particular locale (Boyle 2004). Measuring this solar radiation provides a first step to determining the available quantity and quality of the solar resource.

The measuring of solar radiation is normally done using a solarimeter (also called a pyranometer) (Boyle 2004). These devices measure the solar radiation by using carefully calibrated thermo-electric elements fitted under glass covers, producing a voltage that is measured as a proportion to total incident light (Boyle 2004). A comparison of this measured solar radiation, usually in watt-hours per square meter ($W/hr/m^2$) with values in other parts of the globe can provide a view as to the quality and usefulness of Bermuda's solar resource. Solar radiation varies throughout the course of a day as well as seasonally (Boyle 2004). The lowest values are recorded at the extremities of the day and increases until the middle of the day (assuming no cloud cover) (Boyle 2004). Seasonal variations mean that the highest values of radiation are recorded in the summer (Boyle 2004). When radiation values are combined with the performance ratio of particular renewable energy systems, the energy yield of a solar renewable energy systems may be predicted (Boyle 2004).

The Bermuda Weather Service (BWS) monitors climate data on a constant basis and secondary data to be used for analysis of the solar resource was obtained from this

[30] Photovoltaic refers to a light energy to electrical energy conversion process (Boyle 2004).

agency. This data includes solar radiation data dating back to March 2007. This type of data (See Table 10 for an example) was provided for the purposes of this research from the Bermuda Weather Service as ASCI files containing information on solar irradiance in W/m^2 and also a watt-to-joule conversion. Daily sun hours, also calculated by the Bermuda Weather Service with data available on their website[31], was also used in this aspect of the research. As the start of this research begin in 2008, with the data collection aspect in terms of this quantitative renewable energy assessment only beginning in 2010, it was decided to use 2009 as a “model year” for these renewable energy assessments, as this was the only full year worth of data that the Bermuda Weather Service had by that time in terms of solar irradiation. The use of only one specific year as a model year imposes obvious significant limitations on the ability to infer any meteorological patterns that were indicated as a result of the solar irradiation data analysis. However, it was beyond the scope of this study to consider any larger amounts of data due to their unavailability at the time as well as other time constraints, in addition to the realisation of the multiple methods focus of the research, in which quantitative renewable energy assessments were only a part of the overall research objective. This solar irradiation data was collated and mathematically analysed in a descriptive manner inclusive of calculating yearly, monthly and daily mean solar irradiation values for Bermuda. This solar irradiation data was also used in making energy calculation estimates where relevant.

Table 10: An example of actual Bermuda Weather Service Solar Irradiation Data (Accessed online (2011): [www.weather.bm]).

Date	Site	Instant Solar Radiation (W/m^2)	Solar Radiation OnSR_ON	Solar Radiation Minutes	Watt to Joule	Watt to Joule Previous Day
2009-01-01 00:00:00	12	0.0	0	0	3497.0	3442.9
2009-01-01 00:01:00	12	0.0	0	0	3497.0	3442.9
2009-01-01 00:02:00	12	0.0	0	0	3497.0	3442.9

[31] http://www.weather.bm/

The processed solar irradiation data was also compared to proprietary software (Meteonorm®) models of the solar energy resource available for Bermuda (See Figure 5). Meteonorm® is software package that uses satellite based solar measurement to estimate solar irradiation levels for areas around the globe. By utilising the local weather service data as described above and comparing it to available Meteonorm® data, a more accurate description of the solar resource may be provided for the case study location. This may be considered an additional aspect of method 'triangulation' described in Section 2.6.

Figure 5: Meteonorm® data showing solar irradiation for Bermuda (Meteonorm® Software 2010. Provided courtesy of Mott MacDonald Ltd.)

2.6.1.4 Measuring the Wind Resource

Due to its geographical position, the island of Bermuda is impacted by significant meteorological wind systems. As a result, the wind resource in Bermuda may be a significant source for renewable energy if able to be harnessed. The recent Bermuda Energy Green Paper (Bermuda Government Department of Energy 2009) and Worboys (2009) have also suggested this possibility in a recent study on reducing fossil fuel dependence in Bermuda. However, the harnessing of wind energy depends on the construction of wind turbines, which in order to significantly contribute to the electrical demand of local energy needs, must be of significant size.

Calculating the power of wind in a particular locale is done by assessing the kinetic energy of the wind in this area and mathematically converting this kinetic energy factor into power (Boyle 2004). The potential power that can be obtained from the wind is proportional to several factors, namely, air density, the area that the wind is passing through and wind velocity. The following formula is used to calculate wind power:

Equation 1: $P = 0.5\,\rho A V^3$

Where P (power in watts), ρ (density of air), A (area through which the wind is passing) and V (wind velocity).

While this research aims to understand the wind regime available in Bermuda so as to assess the overall potential for the use of wind energy as a renewable energy resource, it was beyond the scope of this study to provide comprehensive power assessments of wind energy levels as a function of the above detailed calculations which necessitate the identification of specific wind turbine technologies desired to be used. Rather this study aimed to understand the role of wind energy as a potential renewable energy source for Bermuda. The potential for wind energy as a power source may be divided into five categories (World Energy Council 1994:151):

- Meteorological potential – the available wind resource.
- Site potential – Based on the meteorological potential but restricted to those sites that are geographically available for power production.
- Technical potential – Calculated from the site potential, taking into account available and appropriate technology (efficiency, turbine size, etc.)
- Economic potential – The technical potential that can be realised economically.
- Implementation potential – Constraints and incentives taken into account, such as the amount of capacity that can be implemented within a certain time frame, regulatory environment, etc.

This research method in terms of data collection focused on the meteorological potential of wind energy as a renewable energy resource and as a result of assessing this meteorological potential, subsequent data analysis was able to provide an assessment of the other potential factors described above, specifically general aspects of site potential and technical potential. It is noted that the neither the average wind speed, nor the power contained in wind is in practice the amount of power that can be extracted using renewable energy systems such as wind turbines (Boyle 2004). This is due to the impact of losses in the energy conversion process as a function of the design of the wind renewable energy systems (Boyle 2004). However, as indicated by the above formula, wind velocity has a strong influence on wind power due to it being a cubed determining factor. As a result, assessing the wind velocity in any location is the first step in determining the potential for using wind as a renewable energy resource. Renewable energy systems using wind such as wind turbines are rated for various wind speeds (European Wind Energy Association 2009). Again, this indicates that assessing general wind speed is a key first step for determining the potential to use wind as renewable energy resource for any particular locale.

The use of local data such as that that has been measured at a local meteorological centre or at a local airport can be used to provide measurements of wind speed and direction for a location (European Wind Energy Association 2009). If necessary, various formulas and algorithms have been derived to convert this type of data into a more accurate and representative data that can be used to account for the potential wind climate at the heights normally used by typical wind turbines (Ramachandra & Shruthi 2007). Also, there is proprietary software that makes use of long term satellite data such as the WindPro® Wind Atlas Analysis and Application Program (WAsP) or that can provide accurate prediction of wind climates, wind resources and power productions from wind turbines and wind farms on a global basis.

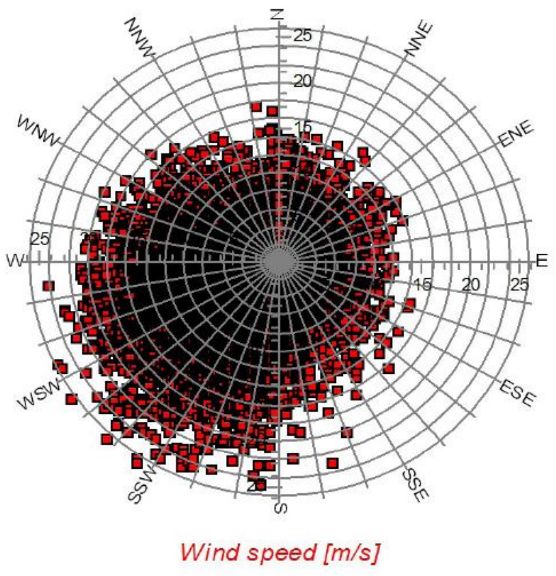
For this research, the locally available meteorological data from the Bermuda Weather Service was used towards an analysis of potential wind power available used locally available meteorological data from the Bermuda Weather Service (See Figure 6). It was decided to focus on the year 2009 as a model year in alignment with the approach described in Section 2.6.1.3 on measuring the solar resource. As with the use of this one year as a model year for measuring the solar resource, this imposes significant limitations on the ability to infer any meteorological patterns that were indicated as a result of the wind data analysis. However, it was beyond the scope of this study to consider larger amounts of data due to time constraints as well as the multiple methods focus of the research, in which quantitative renewable energy assessments were only a part of the overall research objective.

This wind data was collated and mathematically analysed in a descriptive manner inclusive of calculating monthly mean wind speed values for Bermuda. Average wind direction obtained from the Bermuda Weather Service data was also used to infer conclusions on the site and technical potential factors described above by comparing available sites and environmental and social implications. This data was compared with that provided by wind modelling software such as the WindPro® WAsP program (See Figure 7). WindPro® is a software program is a Microsoft Windows based modular based software suite for the design and planning of both single wind turbine generators as well as multiple turbine wind farms.

Figure 6: Screenshot from the Bermuda Weather Service website showing wind data (Accessed online: [http://www.weather.bm/]).

	Hours Of Sunshine	Mean R.H. %	Absolute Max. R.H. %	Absolute Min. R.H. %	Mean Max Wind knots / °	Peak Wind knots / °	Sky Conditions / Weather Notes PN PC MC OV DZ SH RA GR TS FC HZ BS BR
Total	95.1						10 10 13 8 0 10 5 0 3 3 0 0 0
Mean	7.3	81.2	89.1	73.2			
Departure from Norm.							-2
Max	12.3		92.0		24	30	
Min	1.6			67.0			
	Hours Of Sunshine	Mean R.H. %	Absolute Max. R.H. %	Absolute Min. R.H. %	Mean Max Wind knots / °	Peak Wind knots / °	Sky Conditions / Weather Notes PN PC MC OV DZ SH RA GR TS FC HZ BS BR
6/1/2009	2.8	84.5	91	78	10 / 210	13 / 280	PC MC OV
6/2/2009	7.1	80.8	92	70	8 / 090	16 / 070	PN PC MC SH
6/3/2009	8.2	79.7	92	68	10 / 220	14 / 220	PC MC FC

Figure 7: A wind rose from the WindPro® software (Windpro® Software 2010. Provided courtesy of Mott MacDonald Ltd.).



2.6.1.5 Estimating Energy Potential from a Waste Biomass Source

Bio-energy is the use of plant or animal based material to produce energy (Boyle 2004). This bio-energy can be sourced directly, such as the use of food crop waste or indirectly through the processing of bio-stocks in order to make some form of bio-fuel (Rosillo-Calle 2007). The bio-fuel can be utilised through many methods such as direct combustion such as in an energy to waste (EfW) plant, or through the process of gasification or anaerobic digestion and the subsequent production of fuel gases from the bio-fuels or through other chemical processes such as trans-esterfication and esterfication in order to create bio-diesel or other oil type products (Rosillo-Calle 2007). Municipal waste contains large amounts of potential organic waste products that can be burned in an EfW plant or that can be separated via municipal solid waste separation (MSW) and processed in the methods just described (Boyle 2004).

Like many small islands, Bermuda has to import a considerable amount of its retail and food products into the island (Chapman 2008). This results in substantial amounts of waste being produced on a per capita basis (Chapman 2008). In historical times in Bermuda, this municipal solid waste separation would have been directed to local landfills (Chapman 2008). Landfills pose their own challenges, specifically in regards to the production of harmful GHG and potentially dangerous flammables like methane, the leaching of heavy metals and other contaminants into the soil and hydrology as well as the chief limitation factor of space requirements (Chapman 2008). These factors become even more sensitive in small island locations due to their sensitive environmental considerations as well as their extremely limited space available.

Some island locations like Bermuda have moved away from the landfill concept and are utilising EfW plants. The Bermuda Tynes Bay EfW Facility takes municipal solid waste of a combustible nature and burns it to produce both electricity and fresh water. Inert waste, metal waste, hazardous waste and non-combustible waste are sent to a landfill site. Also, a large tipping facility is used for Bermuda's horticultural waste (See Plate 1). This horticultural waste may be able to be utilised as a source of biofuel to produce bio-energy, specifically in the technology already available at the Bermuda Tyne's Bay EfW plant. The recent Bermuda Energy Green Paper (2009) BDA DOE (2009) and Worboys (2009) have suggested this possibility in a recent study on reducing fossil fuel dependence in Bermuda. It must be noted that plants such as these have specific ranges in terms of the calorific value, moisture content and particle sizes that can be accepted into its feeders.

As a result, an assessment of the renewable energy resource potential from the municipal horticultural waste tippings on Bermuda will not necessarily provide an exact statement as to the amount of potential energy that can be possible derived from this resource, specifically by way of combustion processes in the local Tyne's Bay EfW facility. More so, this assessment will only serve to indicate the relative level of potential energy in regards to the interest for this horticultural biomass waste resource to be used as a potential renewable energy resource. Post-data analysis using the performance efficiency of the local EfW and its specific combustion parameters could have yielded more specific estimates on the yearly potential for biomass energy to contribute to the energy generation from the plant, however, due to the amount of additional research required for these sorts of assessments, this aspect of research was not carried out.

Plate 1: A large pile of processed horticultural waste at the Bermuda Marsh Folly tipping site (Author 2011).

Measuring this bio-energy resource as a potential renewable energy resource is important to determining the diversity of renewable energy resources available on Small Island States like Bermuda. This measurement in dependent on two factors: the volume of resource available (Boyle 2004) and its physical-chemical characteristics (Rosillo-Calle 2007). The physical chemical characteristics that are important in measuring the energy contained in organic material such as horticultural waste is a function of its calorific value and its moisture content (Rosillo-Calle 2007). Physical characteristics such as particle size and particle shape also affect how a material combust and what type of equipment or processes it can be most effectively utilised in (Twidell & Weir 2006).

Secondary data from the gate records at the Marsh Folly tipping site were used in order to determine the mass of the horticultural tippings deposited on an annual basis. Problematically however, only numbers of truck loads were recorded on a regular basis and not the volumes or mass of the tipped loads per truck. As a result of this challenge, it was decided to use a proxy truck type[32] as a model representation of the largest commercial tipping truck that can be used in Bermuda. These trucks have a recommended payload value 4695 kg and the model used in the results assumed this mass for each load tipped at the Marsh Folly horticultural waste drop-off. Obviously, using this proxy mass representation, any potential energy yield calculated will be a large over-representation of what may be actually available, however, as this study only hopes to understand the potential for biomass energy from this type of waste resource, a generalised figure is deemed useful in this case.

The Marsh Folly site is also required to conduct annual sampling of the physical and chemical parameters of the homogenised samples of the compost product. It was hoped that factors such as calorific value, moisture content and ash content were determined in these annual sampling reports so as to be utilised in the biomass energy calculations. However, these types of chemical data were not contained in the reports and as such an online biomass energy estimator model software tool called PHYLLIS[33] was used to provide an estimate for the energy potential contained in the type of horticultural waste characteristic of that deposited at the Bermuda landfill. Again, as a result, it is important that the limitations of using such estimates are recognised in the scope of the potential for this type of energy as presented in this study.

2.6.1.6 The Potential for Wave Energy – A Commentary

Although it was decided not to proceed with any wave energy calculations once research pilot studies were carried out in this area, it is important that the potential for this resource is mentioned, especially in the context of how it may be assessed in the future. The presence of the ocean surroundings in the environments of Small Island States leads to great potential for the harnessing of renewable energy from the medium

[32] http://www.hwponline.com/content/cars/Nis-Diesel-Dumper-2007-02-28.swf

[33][http://www.ecn.nl/phyllis/info.asp]: Using the designation of the horticultural waste as untreated wood, Subgroup - other soft wood, soft wood, Material - mixed.

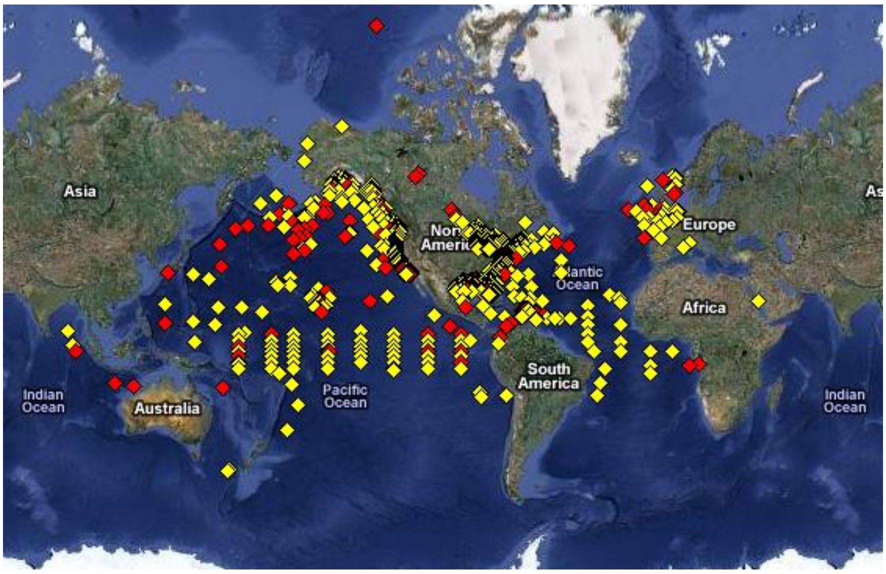
of wave energy. The relationship between the sun as the primary driver of atmospheric circulation due to heat exchanges driving air mass movement results in a large transfer of this energy to the ocean surface (Boyle 2004). This energy becomes manifest in the form of waves, both those that are readily visible to the eye as high frequency waves and those not as easily distinguished such as low frequency, long amplitude waves (Boyle 2004). The movement, both vertical and horizontal, of an object on the water's surface is the primary factor by which energy from these waves can be harnessed (Boyle 2004).

There are currently many devices being experimented with in order to attempt to harness the power of the waves[34]. Although most of these devices are still at the prototype stage, many are functionally able to provide energy converted from wave power. Regardless of the design, the formula to derive the energy in waves is a function of the frequency of the waves, the height of the waves, the density of seawater and the acceleration of the wave due to gravity (Boyle 2004). As ocean water has a very consistent density globally as well as the acceleration due to gravity being constant, by understanding the two parameters wave heights and frequency (period), wave power in watts can be calculated (Boyle 2004).

Usually these parameters are measured either directly by in-situ monitoring devices such as directional recording buoys (Boyle 2004) however wave measurements from in-situ instrumentation are relatively sparse around the world's oceans. There are organisations that maintain buoys around the world such as the US National Data Buoy Centre[35]. The National Oceanographic Atmospheric Association National Data Buoy Centre (NDBC) designs, develops, operates, and maintains this network of data collecting buoys and coastal stations as part of the US National Weather Service (NWS). NDBC provides hourly observations from a network of about 90 buoys and 60 Coastal Marine Automated Network (C-MAN) stations to help meet these needs (See Plate 2). On the buoys, wave data are collected using an accelerometer which measures the vertical acceleration every 2/3 of a second for 20 minutes. Wave heights and periods are mathematically calculated from these time-series accelerations.

[34] See http://www.bwea.com/marine/devices.html
[35] http://www.ndbc.noaa.gov/

Plate 2: NDBC buoy stations globally (Accessed online (2011): [www.ndbc.noaa.gov/]).

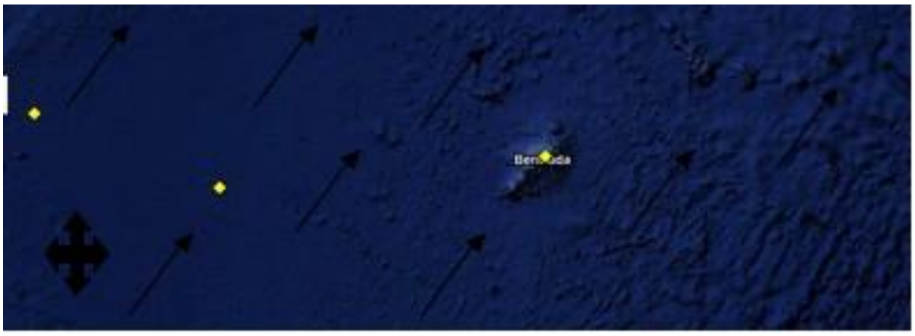


Bermuda's prevailing winds are south-westerly (See Plate 3) (BIOS 2004). This means that the most probable areas for wave energy harnessing would be on the southern side of the island and on-island visual evidence from long-term residence seems to attest to this fact as the southern and south-easterly coast have much wave action. NDBC Station 41038 is the closest marine buoy to Bermuda in terms of oceanic positioning (See Plate 4) and could prove useful in deriving wave energy calculations for the area of ocean relative close to Bermuda's proximity. This station is some 200 miles west of Bermuda in the open ocean. By using this data, an estimation of potential energy in the ocean around Bermuda, specifically that unimpeded by geological land formations can be determined such as the fetch to the south and south-west. In saying this, the information gained from the southerly located NDBC buoy would seemingly be relevant to this end, although it is located at some distance away from the island's shore. This data can then be compared to the data obtained using the Radar Altimeter Database System (RADS)[36] described below, which can help determine potential wave energy for areas much closer to Bermuda shores.

[36] http://rads.tudelft.nl/rads/index.shtml

Plate 3: The Island of Bermuda and predominant wind direction (Google Earth 2011 - Authors own demarcations.)

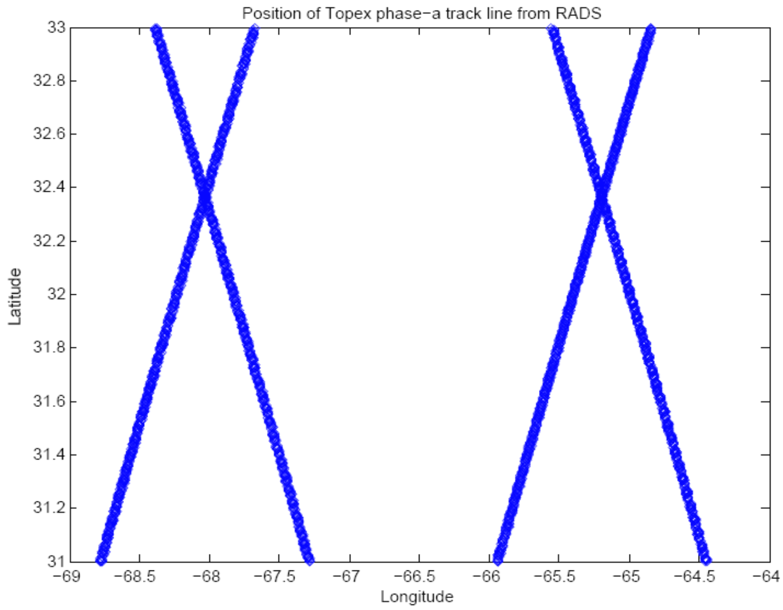
Plate 4: NDBC Station 41038 to the west of Bermuda (Accessed online (2011): [www.ndbc.noaa.gov/] Authors own demarcations).



In regards to the RADS system mentioned above, wave energy developers wanting to know the resource in locations without nearby in-situ measurements are left to choose from other information sources such as numerical wave model data or satellite remote sensing measurements. Indirect measurement devices such as radar altimetry can be utilised or bottom mounted sonar devices (Aucan 2006; E. Mackay et al. 2008). Satellite altimetry has been employed to investigate and record wave dynamics on a global basis such as the Radar Altimeter Database System. These systems are composed of satellites owned and maintained by various international bodies. Wave model data is normally purchased on a point-by-point basis and spatial mapping of the wave resource can be a large cost for a feasibility study. The global coverage of satellite altimeter data provides an alternative to the use of model data, albeit with spatial and temporal limitations as the satellites have orbital periods of 10 to 35 days and widely-separated ground tracks –

over 300 km for TOPEX/Poseidon (See Figure 8) and Jason satellites (E. Mackay et al. 2008). With the application of proper linear calibrations, altimeter measurements of wave height (Hs) are of comparable accuracy to that of in-situ measurements (E. Mackay et al. 2008). It is also possible to estimate wave energy period (Te) from altimeter data by using an algorithm developed by Mackay et al. (2008).

Figure 8: Topex satellite tracks over the geographic coordinates near Bermuda (Provided by National Oceanographic Center - University of Southampton 2010).



2.6.2 Qualitative Research Methods

Identifying the "emerging needs of research users" and translating these needs into problems that can be solved are vital in carrying out research in an informed direction (ERG 1986:145). Part of these research objectives sought to use a grounded theory approach so as discover theory associated with the social aspects of the central research question. This theory has emerged in the assertion that accurately understanding the role of renewable energy systems in Small Island States efforts towards sustainable development depends on understanding the public, business, industry and governmental attitude, as expressed through policy, towards renewable energy and renewable energy systems integration. As this aspect of the theory is subjective in nature, testing the theory must use methods that are able to extract the subjective meanings assigned by these various social actors. As discussed previously in Section 0 on research objectives, the research objectives of a subjective nature will be assessed using qualitative methods, with some quantitative considerations where relevant. In commonality with the quantitative methods, these qualitative methods were also chosen based on methods identified through a review of academic literature where previous research in these topics has been recorded as well as the association of the selected methods as approaches that not only seek to establish *verstechen* (meaning) through simply discovering and recording social behavior but rather link this behavior with socio-economic and cultural contexts (Miller & Brewer 2003:60).

This type of social research when associated with energy studies can loosely be labeled as energy social science. Interestingly, Lutzenhiser (1993:281) speaks to the dilemma of mixed disciplines faced by this research, stating that "Research that is considered "too applied" may be pursued only at some risk in academic social science, and research that is "too theoretical" is often unacceptable to technically trained energy analyst." Most of the literature tends to focus more on roles of energy as defined by patterns of consumption (Mazur & Rosa 1974; Hackett & Lutzenhiser 1991) or how energy consumption affects social behavior (Mazur & Rosa 1974; Lutzenhiser 1993). However most of these types of studies, although primarily concerned with the social actor, primarily used quantitative research methods.

As the objective of this aspect of the research is intending more to extract and understand meanings assigned and constructed by the relevant social actors, qualitative methods that stress "quality and not quantity" will be relied on (Miller & Brewer 2003:238). Again, a process of triangulation was applied here, as multiple methods were used. Primarily, three key qualitative social research methods were utilized towards extracting and assigning meaning – semi-structured interviews, survey questionnaires and participant observation and these methods are detailed in the following sections. Reflections on how issues of positionality, situatedness and ethics played into these methods are outlined in Section 2.6.2.4.

2.6.2.1 Pilot Studies

Pilot studies in the course of empirical research have multiple purposes. For example, in quantitative research involving sampling, pilot exercises can be used to inform sampling strategies for a larger sampling program (Bryman 2008). In qualitative research such as interviews or questionnaires, pilot exercises can be a method to pre-test research questions with the view to modifying questions for more intensive qualitative research later on (Bryman 2008). In regards to this research, two separate research experiences were considered as being part of the researcher's pilot studies, two participant observation work experiences (See 2.6.2.1.1) and a pilot social research fieldwork study (See 2.6.2.1.2). Both experiences resulted in the gaining of new research data as well as impacting on the methodological approach going forward.

2.6.2.1.1 Participant Observation/Work Experience

Participant observation is essentially a qualitative data collection method wherein the participant observer conducts social research by actively observing, and recording, in a research field while participating in it (Miller & Brewer 2003). Although the term has various definitions it is generally meant to refer to cases when a researcher purposely immerses in a social setting for an extended period of time so as to observe behaviour or practices while simultaneously participating in it (Bryman 2008; Miller & Brewer 2003). This observation may be overt or covert and is most often associated with ethnographic studies focusing on observing culture and extracting social meaning in various human societies (Miller & Brewer 2003). One of the values and justification use for participant observation is that it allows the in-depth study of everyday processes in a social system that ordinarily could not be studied in depth without the researcher being in close proximity (Miller & Brewer 2003). Vidyarthi (1985) used participant observation as one their multiple methods in their research on identifying indicators for renewable energy policy concerning rural village experiences. The use of this method would have been particularly useful to his research objective which was to determine the social nature constraining successful policy implementation in regards to renewable energy.

Two work experiences opportunities were participated in at two companies involved in aspects of renewable energy systems integration that related to issues relevant to the central research question. These experiences were considered as not only opportunities for work experience in the conventional sense but also as a direct opportunity to conduct participant observation research relevant to this thesis as they allowed the researcher to gain information from the status of an insider. By using these work experiences as a form of participant observation, the researcher was able to increase overall understanding of the relevant research topics from both a global and more case study specific level. The experiences not only helped increase the researcher's overall understanding of many topics relevant to the research but also provided data that was relevant to several of the research objectives. Since one of the companies in particularly was involved in renewable energy systems integration consultancy for the case study location Bermuda, the collection of data that was relevant to several of the research objectives was facilitated, particularly renewable energy physical resource assessment and assessment of energy security. Additionally, as a result of the insights gained directly from the participant aspects of the work experience, data collection on the rationale behind renewable energy systems integration for both commercial entities and residents in a related but separate jurisdiction was accomplished. The researcher was also able to map the implementation framework by which renewable energy systems are achieved from inception of a desire for such systems to actual installation.

2.6.2.1.2 Pilot Social Research Fieldwork

A pilot social research fieldwork exercise was conducted to test specific qualitative social research methods, namely the use of semi-structured interviews and survey questionnaires. The selection of these methods were used as part of the grounded theory process spoken of earlier in Section 2.4, in which this pilot research not only helped to inform sampling strategies for a larger sampling program and pre-test research questions with the view to modifying questions for more intensive qualitative research later, but also assisted in the further formation of a research theory emanating from the central aim. This pilot social research field work was particular directed at informing the social theory aspect of the research and the testing of methodology relevant to social research; this was important because the quantitative assessments necessary to inform the more objective, quantitative aspects of the research theory were being addressed through the work experience opportunities and literature review process as described above. A more detailed description of the qualitative methodologies used, semi-structured interviews and the completion of survey questionnaires is provided in the following sections.

2.6.2.2 Semi-structured Interviews

While quantitative interviewing uses a clearly specified set of research questions designed to be answered exclusively, a semi-structured interview is more qualitative in nature and is designed to help better understand the interviewee's point of view (Bryman 2008). The semi-structured interview is a flexible one with the researcher being able to allow the interviewee to frame events, patterns and forms of behaviour in their own way. Questions in a semi-structured interview are generally open-ended allowing the researcher to gather richer information about social phenomena (Miller & Brewer 2003). McKenzie & Howes (2006), in their study on the barriers to uptake of renewable energy in remote Australian communities, found that the use of semi-structured interviews allowed a deeper understanding of the barriers to uptake than what they had gained from a review of the literature. The researchers utilised semi-structured interviews to engage stakeholders on their research question and an attempt was made to have a diverse representation of respondents, drawing from government, NGO groups, businesses and indigenous organisations. Anonymity was deployed and interviewees were given pseudonyms for identification purposes.

This research also adopted a similar approach as was taken by Miller & Brewer (2003) by using semi-structured interviews to engage a diverse range of stakeholders. Anonymity was guaranteed for the interviewees and this is reflected in the research results were pseudonyms have been used. For residents, adapting from Kempton et al. (1992) work on key strategies for analysing home energy behaviour was used as a guide to form an aide de memoir for the interview process (See Section 5.4 - Appendix IV for final version). Specifically Kempton et al. (1992) suggest a framework of questions focusing on where energy is used, how energy is managed (energy taxonomy), who makes the decisions on energy use, what investments are made in regard to energy, what behaviours towards energy conservation and energy efficiency are made in the home, how do energy and comfort relate in the home (i.e. self-sacrifice), and what psychological strategies enter the space of the home in regard to energy, its role and energy behaviour (information, feedback, incentives, commands, persuasion, new technologies, etc.) This list is not an exhaustive adaptive analysis of Kempton et al. (1992) treatment on the behavioural structure of energy use. Other key considerations that may arise are the importance of understanding the effect of values, social movements and government policy on behaviour.

The semi-structured interviews were adjusted according to the respondent being interviewed when relevant. An initial pilot study was conducted of 20 interviews and from this several initial *aide de memoirs* with open-ended questions were designed according to the principles of semi-structured interviewing described above. These responses were reviewed and subsequent editions of the *aide de memoirs* were modified and used when relevant. Final version of the aide de memoir was completed for both business and residential stakeholders. A copy of the final semi-structure interview *aide de memoirs* questions can be found in Appendix IV in Section 5.4 . A dictaphone was used in most cases to record the responses of the respondents while notes were also taken.

If only a selected sector or segment of a larger population is intended to be characterised, than a small sample of that population, either targeting a whole sector or a portion of it, may be used. This was the desire for the semi-structured interview aspect of the social research and in line with such a purposive sampling strategy, semi-structure interview opportunities were sought with a targeted variety of social actors including individuals, families, businesses and government officials. A total of 51 interviews were conducted from various sectors of the community (See Table 11). A register detailing information about the interview participants is provided in Appendix V in Section 5.5.

Table 11: Summary of research interviews conducted (Author 2011).

Stakeholder Type	**Interviews**
Home	
Residents	11
Disabled Residents (via email)	2
Residents with renewable systems installed (1 via email)	3
Business	
Small Business	4

Medium Business	2
Large Business	11
Special Section: Taxi Business (2 via email)	3
Special Stakeholder Interviews	
Government Bodies (1via email)	4
Utilities (1via email)	2
Major Support Services	1
NGOs (2 via email)	3
Renewable Energy Installers (2 via email)	5
Total	**51**

The interview data obtained from the semi-structured interviews was processed with the aid of coding software NVivo®. Independent thematic codes were initially generated using the research objectives as a basis for construction. An open coding approach was then taken as the interviews were analysed. Excerpts of these interviews are provided when useful and relevant throughout the discussion of results.

2.6.2.3 Survey Questionnaires

Questionnaires are an extremely widely used survey instrument in social research (Burton 2000). In terms of social qualitative research, questionnaires have both advantages and disadvantages; an extensive review of both these categories is provided in Bryman (2008:133-134). Key to using questionnaires effectively for qualitative social research is that they should be constructed so as to optimally match the questions being asked, answers being recorded and what the researcher is trying to measure (Burton 2000). Central to successful questionnaire design is the use of the correct questions and question structure (Miller & Brewer 2003). Two main types of questions can be included, those meant to attain data on socio-demographic characteristics or routine behaviour and those designed to be answered more subjectively by the respondent and useful for providing insight into experiences and attitudes (Miller & Brewer 2003). These two main categories can then be expanded into either open-ended or closed questions. Open-ended questions allow the respondent to give an answer to the question in their own words and allowing for elaboration, and potentially insight, into the respondents actions and beliefs (Miller & Brewer 2003). Closed questions give the respondent only a defined option to select and thereby aid in establishing a more defined coding of the respondent's answers (Miller & Brewer 2003).

An example of the use of survey questionnaires towards energy social science can be seen in the work of Welsch & Kuhling (2009). The researchers conducted a useful study on the determinants of pro-environmental consumption, including so called 'green energy' options. In their study, they attempted to assess what role reference groups and routine behaviour have on the pro-environmental consumption habits of consumers. Their methodology provides a good insight into the usefulness of secondary survey data analysis; their survey data consisted of 494 valid questionnaires that were originally disbursed from green energy providers to their customers. The questionnaires included questions on people's pro-environmental behaviours, potential determinants as well as socio-demographic information. The survey questions were of singular response types, bi-modal types having either yes or no responses and multi-modal types involving more than two possible answer choices.

As a key factor in qualitative social research work is to assess what population the social research is intending to characterise (Burton 2000), the study population should be consistent with the target population desired to be understood (Burton 2000). However, as directed by Burton (2000), the most desirable sample strategy for representation of whole populations is 'probability sampling' whereby each person in the population has an equal, or at least a known chance of being selected. In terms of survey questionnaires, targeting a small, isolated group of locals as representative of the whole population would be erroneous. If, as is the case in this research, the whole population is intended to be characterised, than a larger sample size is needed, selected according to the size of the population. In order to be a probability sample, random selection of participants allows for an equal chance of selection. All of these types of considerations described above were taken into account in designing a survey questionnaire for use in this research.

As such, purposive sampling was employed for this research as it allows correspondence between research questions and who needs to be sampled (Bryman

2008). By purposive sampling, it is meant here that the researcher had to take care to attempt to obtain access to a wide range of residents (ethnic and socio-economically diverse) in the community and in this regard had to specifically move to different areas of the island to facilitate this. To accomplish this, the researcher solicited the completion of questionnaires in multiple locations. A survey table was set up at two of the larger supermarkets on-island, with both known to cater to different ethnic groups and economic classes of people. The researcher also visited a large public worker depot to obtain survey responses from those in this socio-economic bracket, one which included multiple local ethnicities. A survey table was also set up at the western end of the island, so as to obtain responses from residents from multiple geographic locations on-island. Finally, survey questionnaires were also delivered and collected via email where necessary. There were some barriers encountered in regards to this aspect of soliciting responses to the survey questionnaires, which are detailed further in Section 2.6.3.4. However, upon moving to these areas, requests to members of the public for survey questionnaire completion was attempted on a random selection basis (i.e. those that wanted to participate were free to do so).

Bermuda has a population of approximately 67,000 people[37] so undertaking a census for the purposes of this research would not be possible with the resources and time available. Using this number as a population size, and the assistance of an on-line sample size calculator[38] with a 5% margin of error and a confidence level of 95%, approximately 382 people would have to be surveyed to account for a representative sample of Bermuda within +/- 5 %. This number presents a sizable resource needed to survey and was ultimately beyond the scope of this research. However, it is felt that the widespread and relatively diverse nature of the respondents who did complete the surveys can serve to give a good reflection of information on the research topics. Table 12 outlines the demographic ranges associated with those participants who responded to the survey. In total, 156 survey questionnaires were responded to.

[37] CIA World Fact Book – Accessed March 2010

[38] Creative Research Systems - http://www.surveysystem.com/sscalc.htm

Table 12: Demographics of survey questionnaire respondents (Author 2011). (NG – Not Given)

Gender		Ethnicity		Age		Highest Education Level Achieved		Income	
Male	76	Black	118	<20	1	Primary	2	<20	14
Female	73	White	16	20-30	18	Secondary	52	20-30	7
(NG)	7	Portuguese	4	30-40	42	Diploma	40	30-40	16
Total	**149**	Other	11	40-50	31	Undergraduate	26	40-50	14
		(NG)	7	50-60	30	Postgraduate	30	50-60	21
		Total	**149**	60+	27	(NG)	6	60-70	18
				(NG)	5	**Total**	**150**	>70	47
				Total	**151**			Retired	2
								(NG)	17
								Total	**139**

An initial questionnaire was developed to address the central research question, using past qualitative research studies on the differing roles in energy use such as Welsch & Kuhling (2009). The main themes of the survey were: roles (past, present and future) of energy, understanding of energy and energy infrastructure, and opinions on energy. Questions were then developed based on how energy and energy management is viewed in the home, the role of energy efficiency and energy conservation, their familiarity with technical aspects of their energy supply and renewable energy, how they receive information related to energy and renewable energy, and views on the use of electric vehicles. Key demographic information was also collected inclusive of age, gender, ethnicity, education level and income.

The approach to data collection, especially in research such as this which incorporates aspects of a grounded theory approach, was an iterative one – one in which there was a movement backwards and forwards between sampling and theoretical reflection or until theoretical saturation was achieved (Bryman 2008). In order to facilitate this iterative process, the initial questionnaire underwent a pre-testing stage during pilot social research field work and subsequent editions were modified (questions were made more multi-modal in some cases, demographic information not collected was asked for) to reflect the inadequacies found to be present during this process. A copy of the final survey questionnaire can be found in Appendix III in Section 5.3.

One limitation of the survey questionnaires that is important to note was the challenge of completing forms for those with low levels of literacy. This was particularly a problem for some elderly respondents as well as some less educated participants. Some of the less educated participants felt uncomfortable answering the questionnaires out of fear that they would not be able to understand the questions. In both cases, the researcher offered to assist the respondents in completing the survey forms.

2.6.2.4 Positionality, Situatedness & Ethics – Critical Considerations in the Qualitative Research

Aspects of the researcher's postionality and situatedness did affect aspects of the qualitative methods of the researcher. Firstly, in terms of access general, gaining access to residents, businesses and members of government was not problematic. Bermuda is a relatively small community and the researcher, although not seen as an insider in most cases, was able to secure interviews quite freely in most cases. However, in regards to the collection of survey questionnaire data during public solicitation efforts, challenges did arise.

In particular, gaining access to some sectors of the local population for data collection was particularly challenging (See Table 12). Accessing a larger portion of Bermuda's white and Portuguese community proved difficult, even when the researcher attempted to solicit survey questionnaire responses in public places. Although Bermuda has a higher proportion of persons[39] who class themselves as Black (54%) to white (31%), these ratios were not in line with the higher proportion of Blacks able to be reached (83%) when compared to Whites (11%) during this research study. This may reflect the researcher's outward ethnicity as a black Bermudian, which may have seen some white Bermudians less desirous of participating in the survey due to a misaligned perception of relevance on their part. Such demographics and the limitations they suggest should be taken into context when considering the results and conclusions drawn from this study in reference to the use of data taken from the survey questionnaires.

[39] See Bermuda Government Department of Statistics: http://www.seaexpress.bm/portal/server.pt?open=512&objID=227&mode=2

This limitation potentially continued in terms of being able to capture a demographically inclusive sample of all of Bermuda’s diversity, including ranges in persons in regards to age, wealth and education, especially considering the small sample size able to be surveyed and interviewed in relation to Bermuda’s overall population size. The researcher’s own position as a young Bermudian of middle-class/working class background imposed a limit on the number of residents that could be reached in either side of these positions such as the elderly, those in extreme poverty or those extremely wealthy. However, fortunately the researcher was able to have captured some participants from the extremes of these demographic ranges in the semi-structured interviews and survey questionnaires that were conducted.

Gender positionality as a male researcher may have played a part in influencing the responses to research questions during the semi-structured interviews, potentially having an influence on what information was shared by the participants, however the nature of the questions asked did not particularly probe deeply into home life scenarios whereby sensitive issues may have arisen. The researcher’s gender may also have swayed members of the public from participating in the survey questionnaires during public solicitation efforts.

There were no significant issues in regards to ethics that the researcher was particularly concerned about during the collection of qualitative data, however the researcher maintained an awareness that ethical considerations needed to be made during various aspects of the qualitative data collection. In terms of the semi-structured interviews and survey questionnaire collection, the use of anonymity for both survey and interview participants was guaranteed as well as the promise that any information gained from these methods would not be shared with anyone outside of an academic, research context. One aspect in terms of ethics that did have to be considered was the researcher’s use of data and experiences during home visit for purposes of conducting semi-structured interviews. The researcher visited several homes to conduct semi-structured interviews and thus had to adopt a neutral stance in terms of any home conditions or situations that were observed and that may have been outside the purview of the research aims. In some cases, such as in the case of interview 8H (See Section 5.5 for detailed list of interview participants), the social conditions that the researcher observed could have warranted a suggestion of action to the research participants in regards to improvement of their living situation. However, the researcher had to adopt a position of a neutral research academic so as not to interfere with the personal lives of the participants.

The researcher also had to consider the ethics of his participant observation experiences (See Section 2.6.2.5), particularly the experience at Mott MacDonald Ltd which saw him working as an intern while at the same time gathering information and experience in terms of renewable energy technology and its use in Small Island States like Bermuda. As part of this consideration, the researcher's status as a full time academic was declared to both organisations that he worked with for the participant observation experience. Data or information that may have been useful in the researcher's research was suitably identified and permission obtained from the organisations involved before its use or inclusion into this current research. However, such data was very limited and has been identified in this research accordingly where relevant, while the participant observation experiences were more valuable in regards to learning more about the technical aspects of renewable energy technology and how that technology field relates to Small Island States in the modern world. These experiences and their overall value is explained in much more detail in the aforementioned Section 2.6.2.5 below.

2.6.2.5 Reflections on Participant Observation Experience

Participant Observation I - Renewable Energy Policy Analyst

During the course of my PhD research, I was able to become involved in two work-based participant observation opportunities, one at a large international engineering consultancy firm and the other at a local UK-based solar energy installation company. Although the two participant roles were rather different from each other in many ways, one being as a graduate renewable energy policy analyst at a large international engineering consultancy firm and the other as an observer at a local UK-based solar technology installation company, both opportunities afforded me useful, direct experiences to engage in specific activities relevant to issues surrounding the potential for increased renewable energy integration in Bermuda. Through these experiences I was able to gain real-world insight into both technical and regulatory factors regarding contemporary use of renewable energy technologies as well as use the experiences to directly influence my research methodology and serve as a source of research data.

September 2008 marked the beginning of my enrolment as a PhD candidate at Royal Holloway University of London. As a student, I probably would be best described in the category of "mature", based not only on my age, my past academic and professional experience, but also as well as my family situation as my son of 10 years old was under my sole care at the time when I began my PhD studies. These mature student dynamics would be an important factor in how my studies would be structured as I wanted to make sure I gained the most from my experience as a PhD student in terms of future career opportunities as well as having to ensure that my son and I could be provided for financially in the best possible way within the constraints of my academic commitments. I felt that the best way I could accomplish my goals of both gaining relevant experience in the field as well as possibly gaining some supplementary income was to try to obtain a part-time position in the renewable energy industry, ideally as a consultant.

As a result of seeking such a work experience opportunity and with the additional support of a recommendation from a Bermudian contact, an interview was arranged with a UK-based global engineering and management consultancy firm in October 2008. I was successful in obtaining a post at the company and was given a role as a Graduate Renewable Energy Policy Analyst working in their Renewables Division. After some negotiating based on university attendance policies, I was able to arrange for the post to involve a four-day work week with working hours between 10 am and 4 pm. This was an ideal arrangement as it would allow me to achieve direct experience of the renewable energy industry, acting as a participant observer, as well as earn supplementary income for any work completed.

The company operated on an international basis and employed over 14,000 worldwide with its chief divisions being in North America, Europe, the Middle East and Asia. The firm's field of expertise historically was primarily that of providing engineering consultancy services with management consultancy in a diverse range of fields including education and the health sector also being a part of their business model. The engineering arms of the company were diverse in scope with its core areas of operation being within transportation, civil engineering, buildings and infrastructure and the power and energy sectors. An added benefit of relevance to my research and involvement at the company was their history of consultancy work in my case study country of Bermuda, particularly with the local electrical utility BELCO. This past consultancy work with the local electrical utility involved both the thermal power generation sector, specifically in regard to BELCO's diesel fuel power plant, as well as projects involving renewable energy.

Working at the company brought with it opportunities for both technical-based learning in the wider field of energy services as well as the development of further insights into the corporate culture present in a global consultancy firm. While the opportunity to increase my understanding of technical-based matters was understandably an obvious benefit to my research, the insight into understanding corporate consultancy culture also became relevant to my research. From this observation experience, I was able to learn how the use of external international consultants were significant actors in the shaping of local energy policy and energy services, including Small Island States like Bermuda, far removed from the actual physical locations of the consulting organisations themselves (See 3.5.3). Indeed, I was able to work on some of the projects involving small islands like Bermuda and Malta.

In this regard, at times I was dismayed by the realisation that much of the consultant advisory work was done without even actually making site visits to their client's areas of concern. Instead, macro-level technical approaches including the use of published literature and generalised proprietary software was highly depended on. In my view, this may at times give rise to unsustainable projects being considered in the path towards renewable energy integration, specifically in terms of local social, environmental and economic impacts that may result from any solutions offered.

The experience also helped to reveal a clear dichotomy in the consultancy sector between staff concerned with the generation of power through fossil fuel use (thermal power) and those involved in renewable energy. The thermal power generation division were often referred to as the "hot" side or the "dark" side by those in renewables while the renewable generation division were given names such as the "cold" side or the "fairies" by those in thermal power. Many of the staff who worked in the Thermal Power Division were of an older generation and had migrated into consultancy from the industrial energy and power generation sectors of coal and other traditional fired power plants.

As a result of this dichotomy, there was a potential that techno-centred solutions emanating from these consultancy firms could lack momentum towards synergies that would try to bridge the gap between the two fields of power generation in the pursuit of sustainable development. Having said that, many of the "old-guard" were not sceptical to the impact that renewable energy could play in displacing fossil fuel generation, but could be more accurately described as being more pragmatic and realistic as to the real future potential. Indeed, the knowledge of those working in traditional power generation and the transmission and distribution of that power became clearly essential to any efforts towards renewable energy integration that was being encouraged for the future.

In reality, it became clear for me as an observer that although renewable energy was needed to play a role in the displacement of the world's dependency on fossil fuel based generation of energy in pursuit of global sustainable energy solutions, the current energy demands of both developed and less developed nations were not going to be met by renewables alone and in totality. The potential for integration of some renewables with thermal power generation was learned as well, in particular the potential to use bio-fuels in replacement or combination with coal-fired plants, natural gas power plants or in high energy industrial processes such as cement manufacturing. Where the displacement of fossil fuels could not be accomplished, I was able to learn about the critical need for further development in other areas that could aid the reduction in global emission of greenhouse gases such as carbon capture and sequestration and the increased need for power plants that used the most efficient and cleanest burning technologies such as combine cycle gas turbines with supercritical steam output, clean coal technology and flue (exhaust) gas cleaning and processing.

It also became clear ultimately that, after the initial process of generation of energy was accomplished, there was really very little difference between the transmission and distribution of energy to the end user whether that energy came from renewable sources or traditional fossil fuel sources. This was an important revelation for me as the 'downstream' aspects of energy services, including the transmission and distribution of power, economic considerations such as pricing and regulatory practices were revealed as incredibly crucial for the provision of energy to the end user once initial generation had occurred, a revelation that would shape the direction of my own research. Indeed, it became clear how a focus on renewable energy generation alone from a techno-centric point of view would be remiss as critical supporting roles needed to be considered in providing effective access to renewable energy, a chief theme underlying the central research question of this thesis.

Related to this, I was able to observe and participate in the process by which renewable energy projects were financed and as a result see the truly international scope where interest in renewables is taking place. The various hierarchies of stakeholders that were involved ranged from entities such as small states and their governments, other public sector bodies such as local UK councils and international such as the World Bank, as well as private corporations such as multi-national banks, private equity firms and utility companies.

From a technical point of view, I was also awoken to the reality that many of the renewable energy devices that are well known to the public such as wind turbines, solar photovoltaic panels, bio-energy plants, hydropower dams and tidal power devices are only a small *representation of the diverse range of renewable energy technologies that currently exist and/or being developed. Lesser known technologies such as various micro wind designs, concentrated solar photovoltaic panels, Linear Fresnel and Parabolic Trough concentrated solar power devices, micro-hydro and micro-tidal devices and the myriad of technologies used to extract energy from biomass such as anaerobic digestion, gasification and pyrolysis all add significantly to the technology options that Small Island States may be able to utilise towards as alternatives to fossil fuel use. This swathe of "hidden" technologies became clear not only for the purpose of energy generation but also for supplementary applications towards the more sustainable use of energy, many of which the general public and indeed many professionals in the field may not be exposed to, especially in Small Island State locales. Key examples were the use of waste heat sources to provide cooling (e.g. absorption chilling), additives that could be added in-situ to fossil fuels to increase power generation efficiency and chemical based systems that could be used in place of traditional electrical chilling appliances (desiccant systems), all of which would ultimately mean some aspect displacement of dependency on fossil fuel use through traditional generation.*

Although the work experience afforded me at the company had obvious very tangible benefits in the form of compensation for my time, I sincerely feel that the insight into the power generation industry from the perspective of a consultant was extremely valuable to my research. I was able to be informed on issues commented on above such as the role of external consultants on influencing international energy policy in other national jurisdictions, the potential technological solutions that may be applicable in alternative energy scenarios in Small Island States as well as the becoming more aware of the differing needs of Small Island States according to their physical, social and political characteristics.

Participant Observation II - Solar Energy Installation Company Observer

My second participant observation experience was achieved through becoming a volunteer observer at a local UK-based solar energy installation company. The company operated on a regional basis and was primarily involved in the installation of solar photovoltaic panels, solar thermal technology and solar thermal under-floor heating applications. I actively sought out an experience to be involved in such a company as during the writing of my research methodology I realised that it would be an advantage to be better informed of the technical considerations involved in the installation of renewable energy devices such as solar photovoltaic panels. This realisation was in large part precipitated by my prior involvement at the engineering consultancy spoken about above, as many of the renewable energy projects had an element of *engineering and technical aspects that I was under prepared for from a technical perspective. As I am not an engineer or electrician by training, I hoped to use the observational experience at a solar installation company to at least gain some insight into the technical considerations that would be important in the role of renewable energy integration in Small Island States like Bermuda.*

I was fortunate to locate a company nearby my university involved in such installation work and was given the opportunity to shadow the staff in their various company roles, all important to the installation process. These roles ranged from site surveyors who performed initial site investigations to ascertain the specific unique requirements of each individual solar project, warehouse managers whose responsibility it was to order, inventory and dispense the various components needed to install a solar energy system, joiners charged with physically mounting the devices on roofs and electricians responsible for ensuring the electrical connections between the various components of the energy systems were complete.

It was from my time spent at this company that I was able to map the 'interest to installation' pathway that is presented in 3.5.1 and to realise the level of regulatory infrastructure that is needed to really incentivise and motivate further integration of renewable energy. A particularly valuable aspect of this observational opportunity was the chance to visit installation sites, both domestic and commercial, as well as being able to speak directly with some of the clients who were having renewable energy systems installed. These site visits and conversations provided real insight into the rationale behind some of the installations that were taking place, particularly revealing in that similar installation motivation patterns observed in Bermuda were seen in the UK. In particular, it was learned that many of the clients who were seeking the installation of renewable energy systems were those either approaching or of retirement age and who saw an investment in solar energy systems as a long-term investment vehicle, especially considering the level of government financial incentives available at the time (i.e. solar feed-in tariff and solar grant scheme).

While I was not able to gain as much specific technical knowledge as I thought I might be able to during this observation experience, the insights were just as valuable if not more.

3 Results & Discussion

These results are drawn from the range of methodologies discussed in the previous chapter. The results are presented in the structure afforded by the researcher's adoption of an analytical epistemology that juxtaposes energy security dimensions on a sustainable development framework as described in the previous section. The five dimensions of social accessibility, technical accessibility, economic accessibility (affordability), environmental accessibility (acceptability) and political accessibility are used as categories by which to frame both the quantitative and qualitative results data that emanated from the research methods outlined in the previous methodological chapter. Each separate section of results information outlines the data that has been gathered during the research, analyses its significance in the context of the disparate research objectives as well as discusses their implication in terms of the overall research question and wider research context.

3.1 Social Accessibility as a Function of Energy Security

In the context of an energy security dimension as used here, the term 'Social Accessibility' refers to not only how energy is differently accessible to people and society based on social identity such as demographic differences but also how social phenomenon such as energy use behaviours may have different roles in people's lives. Energy use behaviours generally occur as a function of energy users' supply and demand needs. The researcher's use of term 'energy user' is somewhat misleading here as it is not only meant to reflect those users who are consumers (i.e. residents, businesses, governments, etc.) but also the utility and importers as well, who must be considered users in their own right. It is felt that a focus on the supply and demand needs of the local community of energy users in consideration of energy security is justified as it is the diverse community of energy users that are at the absolute core of both global and local energy networks and the demand created by these energy users provides the fundamental momentum leading to primary production of energy resources and the eventual movement of these resources along energy supply chains (See Figure 3).

On a national and local level, this 'demand effect' becomes important as a driver and shaper of supply and the local and national energy services used to deliver it. As a result, developing an understanding of how these supply and demand needs relate to issues of energy security and shape energy supply and energy services is important to understanding how supply options such as renewable energy may play a role in 'urban and developed' Small Island States like Bermuda. Data that emanates from these aspects of national and local supply and demand needs from the perspective of this diverse community of energy users can reflect their relative exposure to disruptions in supply and the potential impact of energy shortages, serving to highlight areas of unsustainability and energy insecurity and again suggest potential roles for renewable energy integration.

3.1.1 Energy Intensity

Notions of social accessibility as they relate to energy security can be indicated by measures of relative 'energy intensity' (Kruyt et al. 2009), based on demand, to indicate the relative exposure of a location to potential energy shortages and the importance of energy to the overall economy. Bermuda has seen clear patterns of increasing energy demand over time. From a quantitative perspective, this pattern is reflected in rising demand for electricity (See Figure 9) as portrayed in BELCO's 2006 Electric Systems Discussion Document (BELCO 2006) and also more recently in the Bermuda Government's 2009 National Energy Green Paper (Bermuda Government Department of Energy 2009) (See Figure 10). Demand for transportation fuels has also increased over time as reported in the 2009 National Energy Green Paper (See Figure 11).

Figure 9: Historical Customer Count (Metered Customers) (BELCO 2006).

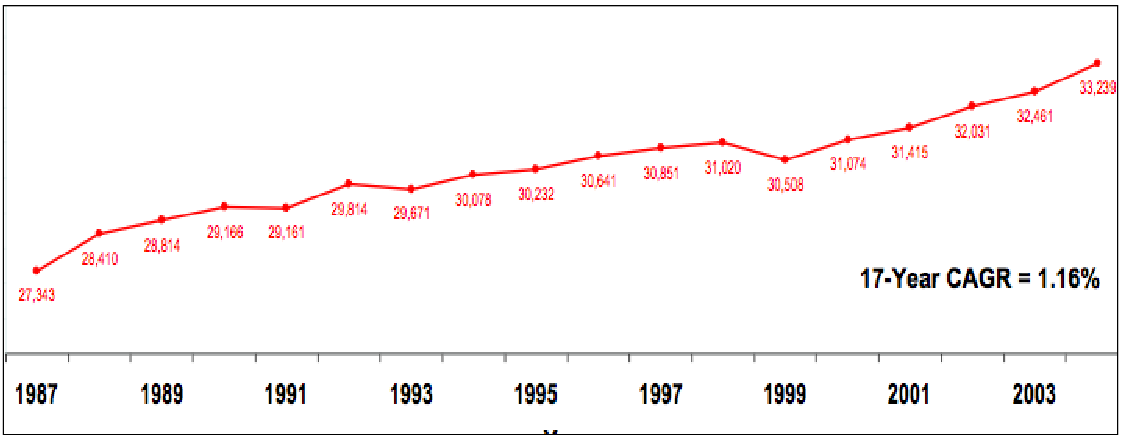


Figure 10: Electricity Sales by Customer Type (Bermuda Government Department of Energy 2009).

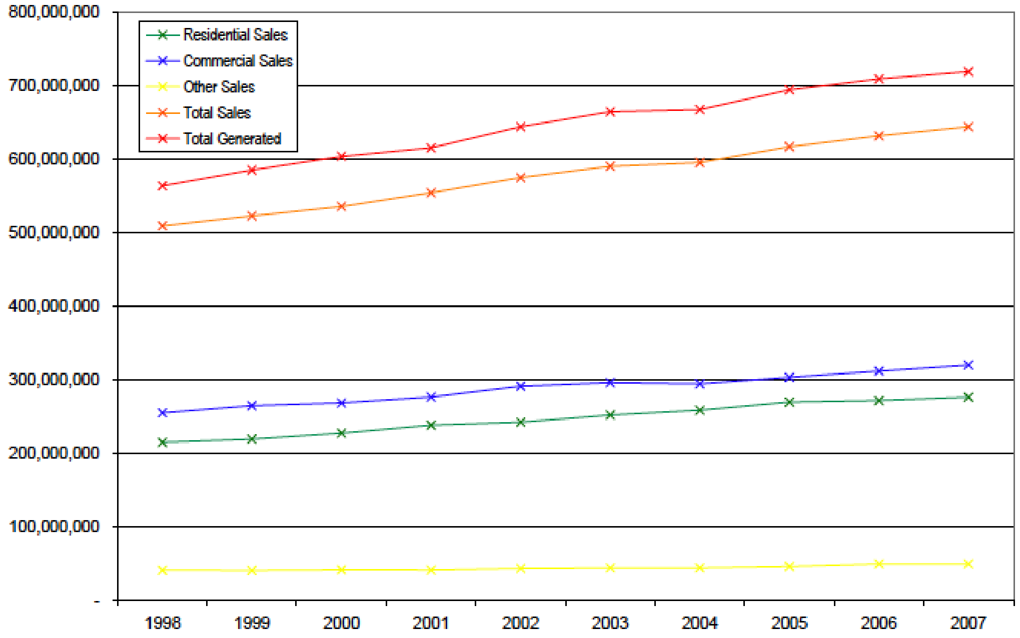
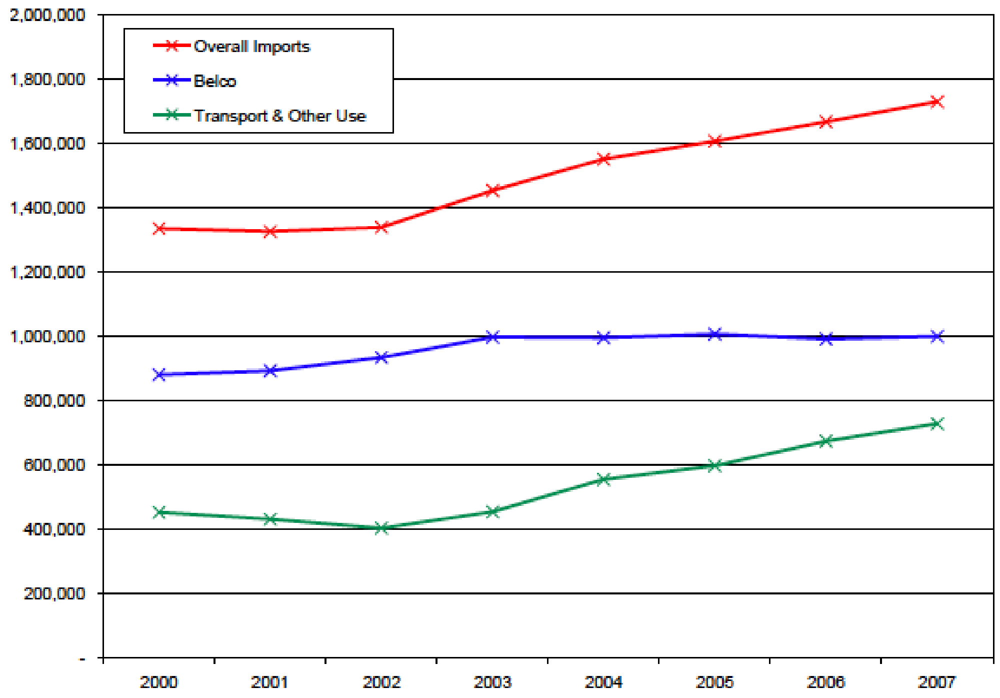
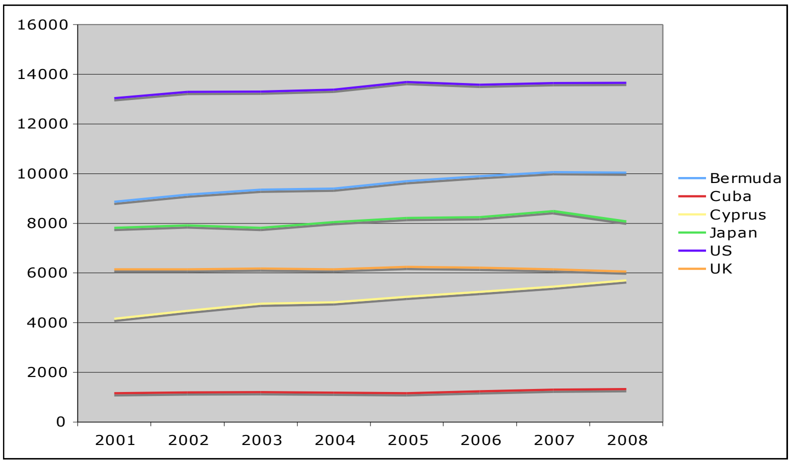


Figure 11: Bermuda's Oil Imports for the Electric Utility, Transportation and Other Uses (Bermuda Government Department of Energy 2009).



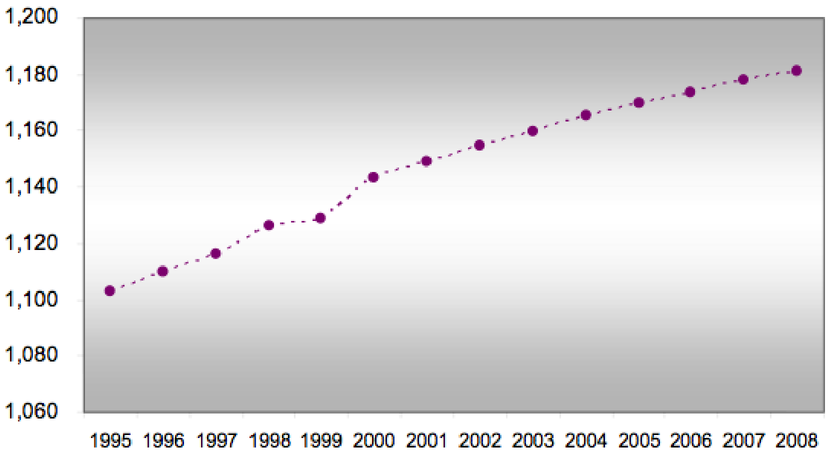
Used as measure of energy intensity, Bermuda's electric power consumption per capita[40] (in kWh) far exceeds those of large OECD developed nations such as the United Kingdom, larger island nations such as Japan and Cyprus as well as other Small Island Developing States such as Cuba (See Figure 12).

Figure 12: Electric power consumption[40] (kWh per capita) (Data taken from World Bank Indicators [http://data.worldbank.org/indicator]. Author's own chart.)



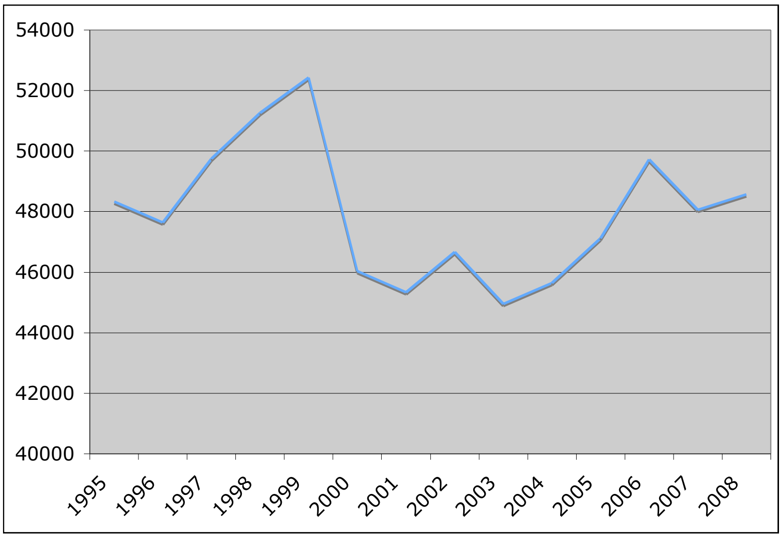
Population on the island is continuing to grow (See Figure 13), although at a somewhat decreasing rate, and coupled with the aforementioned demand for electricity as well as with relatively stable rates of vehicle use (See Figure 14), the island stands to have its considerable demand needs for both electrical and transportation-based energy continue into the foreseeable future. These patterns of demand play a key role in shaping supply, a relationship reflected in the increases of imported fossil fuel volumes over time (See Figure 12).

Figure 13: Population Density - Persons per km², 1995 – 2008 (Department of Statistics 2009b).



[40] Source: World Bank Indicators [http://data.worldbank.org/indicator]

Figure 14: Registered road vehicles, 1995 – 2008 (Data from the Bermuda Department of Statistics (2009b). Author's own chart.) .



Viewing these trends alone provide an indication of the relative importance of energy resources to the island and the potential for energy shortages to have significant impacts on the local community of energy users. Collectively, these measures of high energy intensity reflects both the ‘urban and developed’ nature of the island - its particularly high housing density and well-developed economy both creating a demand for a high level of complimentary energy services. This reinforces the need to classify Small Island States like Bermuda in the unique category of ‘urban and developed’ differing from most other Small Island States especially when considering the roles that renewable energy can play in strategies towards improving energy security and overall sustainable development.

3.1.2 Conclusion

The observed pattern of rising energy demand, shaped as a function of Bermuda’s ‘urban and developed’ nature, imply that there would be significant risk to Bermuda’s national energy security from any disruptions in supply. It is these demand needs that help to shape local energy services and influence energy supply chains as is clearly attested to in the following statement by a key executive at the island’s sole electric utility (See Quote 3.1.1).

> *“Our goal is to stay ahead of this (demand) curve and make sure we have capacity”* (Quote 3.1.1 - Extract from an interview with an executive at the sole local electric utility BELCO, 30/12/09).

Along with the general exposure to disruptions in supply due to increasing demand for energy, the reliance on imported fossil fuels in order to satisfy demand needs adds further energy security concerns linked to sustainable development. These linked concerns of social accessibility to energy supply as a function of increasing demand and strained supply, and the unsustainable nature of a dependency on fossil fuels all act as key drivers towards the integration of renewable energy specifically as a part of a national effort toward sustainable development (See Quote 3.1.2).

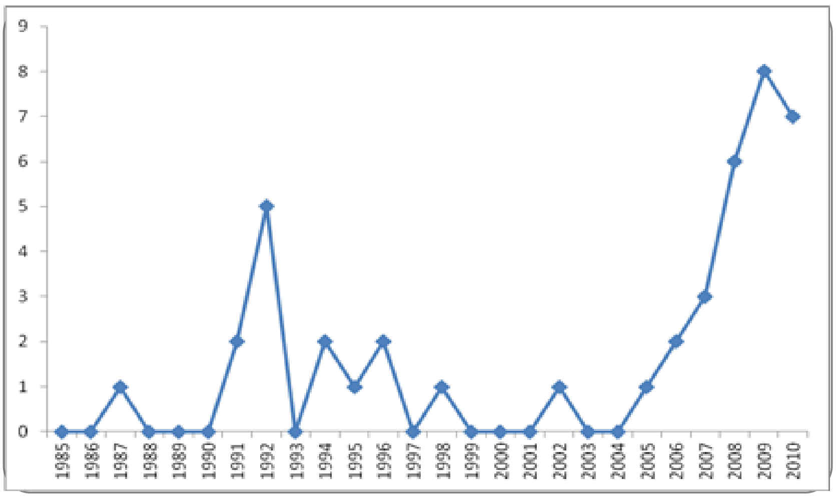
> *"The forecasted demand is significant. We cannot live with BELCO's current capacity. It is not going to allow us to fuel this current activity and so we need to do something about it. Part of doing something about it was to establish a Green Paper, which speaks to government's commitment to renewable"* (Quote 3.1.2 - Extract from an interview with the Director of the Bermuda Government Sustainable Development Unit, 30/12/09).

The local utility seems to be recognizing this fact and has begun a process that involves considering how they can move away from being totally dependent on fossil fuel generation methods to alternative generation such as renewable energy (See Quote 3.1.3).

> *"Going back about 5 years to 2004, we were in a position where we saw the need to evolve BELCO's historical business model and move into more of what we saw as an alignment with our sustainability in the future, which was diversifying away from what was our historical 100 year model of a diesel plant"* (Quote 3.1.3 - Extract from an interview with an executive at the sole local electric utility BELCO, 30/12/09).

As a result of such interest from the electrical utility as well as recent efforts by the government in regards to its sustainable development initiatives, interest and uptake in renewable energy has seen a clear rise (See Figure 15).

Figure 15: Numbers of renewable energy installations over time in Bermuda (Data obtained from Bermuda Government Department of Planning 2011).



Although this may be the case, local stakeholders have expressed feelings of suspicion on the ability of the utility to diversify successfully and its willingness to fully relinquish its monopoly, especially in the face of historically light regulation (See Quotes 3.1.4 - 3.1.6).

> *The respondent also expressed that the expansion by other businesses into energy provision was limited because BELCO was a monopoly* (Quote 3.1.4 - Extract from researcher's notes from an interview with a resident [2H], 23/12/09).
>
> *"I think having a good regulatory environment is important and that would permit you to adapt quicker. For example, if oil hits $300 a barrel next week, at the moment, it would be difficult to react quickly to that, because we have a monopoly provider….so you talk to BELCO and they would say yes, we have always been regulated but as far as we are aware that was a very light regulation"* (Quote 3.1.5 Extract from an interview with a representative of the Bermuda Government Department of Energy 23/12/09).
>
> *"BELCO are still talking about putting more energy but where are they going to put it*!" (Quote 3.1.6 - Extract from an interview with a resident with a renewable energy system installed [RESI 2]).

Furthermore, a more significant barrier to the widespread uptake of renewable energy technologies may actually result from the effects of technical lock-in to an energy services system primarily based on an incumbent imported fossil fuel base. The effects of this technical lock-in are exacerbated as result of the notions of power derived via proxy from having access to energy, which is connected directly to socio-economic standing, both influenced by the 'urban and developed' nature of Bermuda. The next section examines how technical accessibility significantly affects roles of energy specifically in the context of renewable energy as an energy security strategy towards sustainable development.

3.2 Technical Accessibility as a Function of Energy Security

Obtaining physical access to energy supply is only accomplished through having a reliable and functional technical energy supply and delivery system. In this way, the technical aspect of the energy system both in terms of supply and demand underpins social accessibility to energy as a function of energy security. Small Island States have many inherent traits associated with their island geography (environmental conditions, spatial considerations, etc.) that lead to special considerations in terms of technical aspects of energy security and may act as barriers to sustainable development. Many Small Island Developing States do not have a well-developed energy service infrastructure and the development of such infrastructure is a priority in regards to achieving increased levels of energy security. The lack of infrastructural development on islands at this level of socio-economic development may act as somewhat of a 'blank slate' and may provide for less physically and technically challenging experiences in efforts being made to develop such energy infrastructure improvements, including the introduction and integration of renewable energy technology.

Counter to this, for 'urban and developed' Small Island States like Bermuda, elevated constraints on space and the existence of an already well-developed energy infrastructure may actually act more as a barrier to improvements to energy security of incumbent energy services as well as to innovation in regards to potential low carbon energy reform. These two factors, that is constraints on space and the existence of an already well-developed energy infrastructure, may often be inter-related and act as aspects of technical energy insecurity that have impacts across the range of the energy security spectrum linking with distinctive components within the sustainable development paradigm.

3.2.1 Energy Diversity

In the face of such high demand, assessments of energy diversity, including diversity in utilised energy types (Jansen et al. 2004), geographical fuel source locations (APERC 2007) and the local range of energy suppliers (IEA 2007) can be used as an additional measure of energy security risk in regards to the social accessibility of energy supply. In order for such diversity assessments to be more relevant, it is argued that three attributes should be considered (Stirling 2007): variety (the number of categories), balance (the spread across categories) and disparity (the degree to which the categories are different from each other). The Shannon–Wiener Index (*H*) (See Equation 2 & Appendix 5.2) can be used as a simple measure of diversity based on the two categories of variety and balance, with p_i representing the share of fuel *i* in the energy mix or the market share of supplier *i* (Bhattacharyya 2009; Jansen et al. 2004). The higher the value of *H*, when compared to an assessment of *H* with equal distribution across *I*, the more diverse the system is. This index rises with increasing variety and balance, a so-called "dual-concept" diversity assessment (See Figure 16) (Kruyt et al. 2009).

Equation 2: Shannon-Wiener Index (Kruyt et al. 2009)

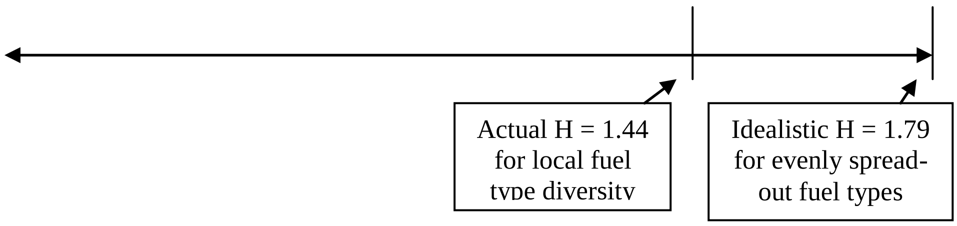
$$H = -\sum_i p_i \ln p_i$$

Figure 16: The range between high diversity and low diversity within systems based on the three attributes of diversity (Author 2011).

3.2.1.1 Available Fuel Type Diversity

The recent figures on imported fuel volumes provided by the 2009 Bermuda Government Energy Green Paper provides the most comprehensive and up to date compilation of fuel data that may be used in a dual-concept diversity assessment on available fuel types. If the proportion of use was spread out evenly across fuel types (See Appendix 5.2 & Figure 17), H would equal 1.79, the highest value of diversity (*H*) to be expected based on the number of fuel types, all having equal market share. As a function of the actual reported fuel shares for 2007, *H* is returned as 1.44 indicating a relatively diverse fuel spectrum in terms of energy imports based on variety and balance.

Figure 17: Actual and idealistic values for diversity (*H*) in regards to local fuel type availability (Author 2011).

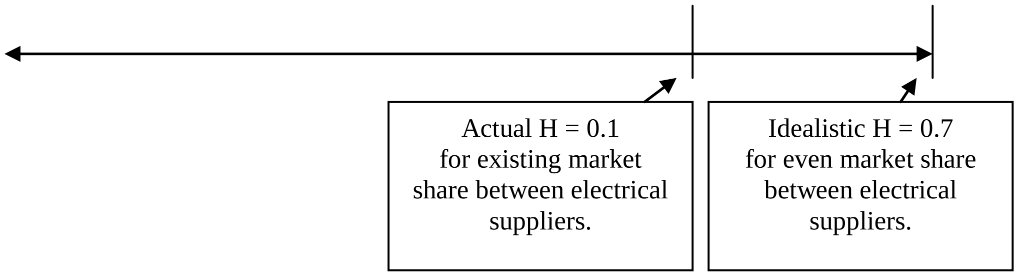


However, assessing diversity from this perspective is misleading, as it does not take into account the aspect of '*disparity'* as a third component of diversity. In particular, the fact that all of the fuels being utilized are fossil fuels detracts from their disparity to each other and thus represents a further significant risk in regards to energy diversity in the respect of fuel types. Measures of import dependence are commonly used as energy security indicators, particularly towards the consideration of the diversity of net fuel imports (APERC 2007; Kruyt et al. 2009). For Small Island States like Bermuda, net import of energy is 100% of all fuels used on-island and clearly indicates a high level of import dependence, and again, detracts from the disparity between available fuel types in regards to energy diversity.

To be fair, however, there is another source of fuel being utilized on the island besides imported fossil fuels, not including renewables. Municipal waste is collected and burned at the local Tyne's Bay Energy from Waste (EfW) facility and converted into electricity, which is then distributed by the local electrical utility via the local electrical grid network. According to the 2009 Bermuda Energy Green paper, this accounts for some 2.2% of Bermuda's electricity production. This represents a very small amount relative to overall demand and so does not present a convincing case of adding confidence to energy insecurity concerns associated with import dependence. Additionally, it can also be argued further that this energy source does not decrease fuel import dependency and thus energy diversity as the waste utilized at the EfW facility does not include domestic and commercial biodegradables, recyclables or inert aggregates and, as such, is predominantly made up of consumer goods brought into the island through imports.

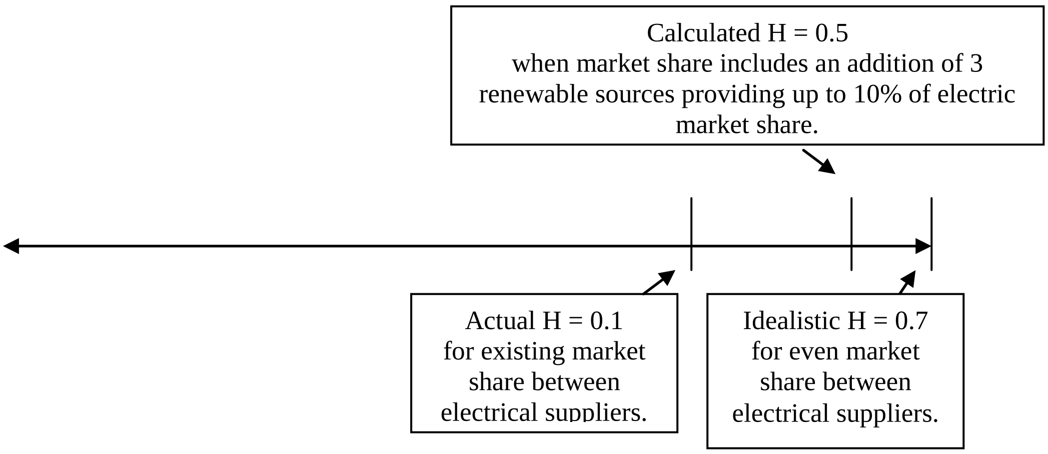
Nevertheless, using the Shannon Weiner index of diversity as a measure of diversity in the generation of electrical energy (See Appendix 5.2 & Figure 18) from this perspective yields an extremely low figure of H = 0.1, compared to an even distribution of H = 0.7 if these two electrical energy sources had an even distribution of contribution to electrical power generation. This lack of diversity in power generation supports the notion that Small Island States like Bermuda are predisposed towards the development of monopolies (Hein 1990) and suggests that high levels of energy demand and intensity as a result of an 'urban and developed' nature may exacerbate such 'institutional lock-in" (Foxton 2002), again adding a further barrier to the uptake of renewable energy technologies.

Figure 18: Actual and idealistic values for diversity (H) in regards to local market share between electricity suppliers (Author 2011).



It is interesting to note that if a model scenario (See Appendix 5.2 & Figure 19) of just 10% of that power generation was taken up by renewables (i.e. wind, solar PV and solar thermal), with an equal contribution of the 10% each, this would increase the diversity factor by five (5) times giving an H value of 0.5, again providing an important argument for the integration of renewable energy technology.

Figure 19: Actual, idealistic values and modelled values for diversity (H) in regards to local market share between electricity suppliers and a theorised 10% input of electrical supply from three renewable energy sources (Author 2011).



3.2.1.2 Political Stability of Fuel Supplier Countries

Various other enhancements to the use of diversity assessments in respect to utilized fuel types can be made in order to make such indexes more realistic to the particular situation of countries dependent on imports. The consideration of political stability of fuel supplier countries is one measure that becomes extremely important in regard to Small Island States as they depend solely on imports. It is surmised that the "political situation in supplier countries is of importance to the security of the energy supply because governments control either the actual energy supply or the conditions under which other parties develop these (Kruyt et al. 2009:2169)." Various methods have been used as a measure of political stability such as the use of the Political Risk rating of the PRS Group[41] (Gupta 2008), the use of the Human Development Index[42] (Jansen et al. 2004) and the use of World Bank's Governance Indicators[43] (International Energy Agency 2007a).

Interview research found that currently Bermuda's fuel imports rely on three main importers - Rubis, Exxon Mobil (formerly Esso) and BP. In turn these three importers rely on three main supply countries, St. Croix in the US Virgin Islands, Trinidad and Tobago and the USA. As some of the aforementioned political risk indictors did not have data available for all of these supplier countries relevant to Bermuda's fuel imports, it was decided to use the World Bank Governance Indicators[44] as a measure of political stability, which did have data for all three locations. The World Bank Political Indicator, particularly its sub-indicators of ranking countries[45] based on political stability as well as according countries a Governance Score[46], seemed particularly useful in this regard.

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[41] http://www.prsgroup.com/

[42] http://hdr.undp.org/en/statistics/

[43] http://info.worldbank.org

[44] http://info.worldbank.org/governance/wgi/index.asp

[45] Indicates rank of country among all countries in the world. 0 corresponds to lowest rank and 100 corresponds to highest rank. By comparison, Bermuda is 72.2 (+/-0.37) and the United Kingdom is 54.7 (+/-0.24).

[46] Estimate of governance measured on a scale from approximately -2.5 to 2.5. Higher values correspond to better governance. By comparison, Bermuda is +0.72(+/-0.37) and the United Kingdom is +0.30 (+/-0.24).

When viewed from the context of percentile rank, all countries seem to enjoy a relative good position in the ranking according to political stability, although the relative scores according to the criterion of a Governance Score is quite varied (See Table 13). This suggests an environment of relatively good political stability for the fuel supplier countries supplying Bermuda. However, this approach is not an absolute measure of political stability in regards to the imported fuel supplies emanating from such supplier countries, as such imports may also be subjected to instability due to the effect on supplies to those refining countries such as St. Croix and the USA. For example, much of the raw petroleum product used to manufacture gasoline in the St. Croix Hovensa refinery is sourced from Venezuela (Shore & Hackworth 2003), which has a much lower percentile ranking (11.3 [+/- 0.21]) and relative Governance score (-1.41). Again in regards to insecurities associated with social accessibility to energy supply, Bermuda's dependence on imported fuel supply will continue to be at possible risk based on factors such as the political stability of supplier countries and suggests again that renewable energy may be able to play an important role in mitigating such risks in this respect.

Table 13: Political stability of imported fuel supplier countries to Bermuda according to the World Bank Governance Indicators (Accessed online (2011): [http://info.worldbank.org/governance/wgi/index.asp]).

Fuel Type	**Importer**	**Supply Country**	**World Bank Governance Indicator – Political Stability**	
			Percentile Rank (0-100)	**Governance Score (-2.5 to +2.5)**
Gasoline	Rubis	St. Croix, US Virgin Islands (Refinery)	40.1 (+/- 0.4)	-0.11 (+/- 0.4)
	Exxon Mobil	*	-	-
Low Sulfur Diesel	Rubis	St. Croix, US Virgin Islands	40.1 +/- 0.4	-0.11
	Exxon Mobil	*	-	-
High Sulfur Diesel	Exxon Mobil	*	-	-
Liquid Petroleum	Rubis	Trinidad and	44.8	+0.02 (+/- 0.24)

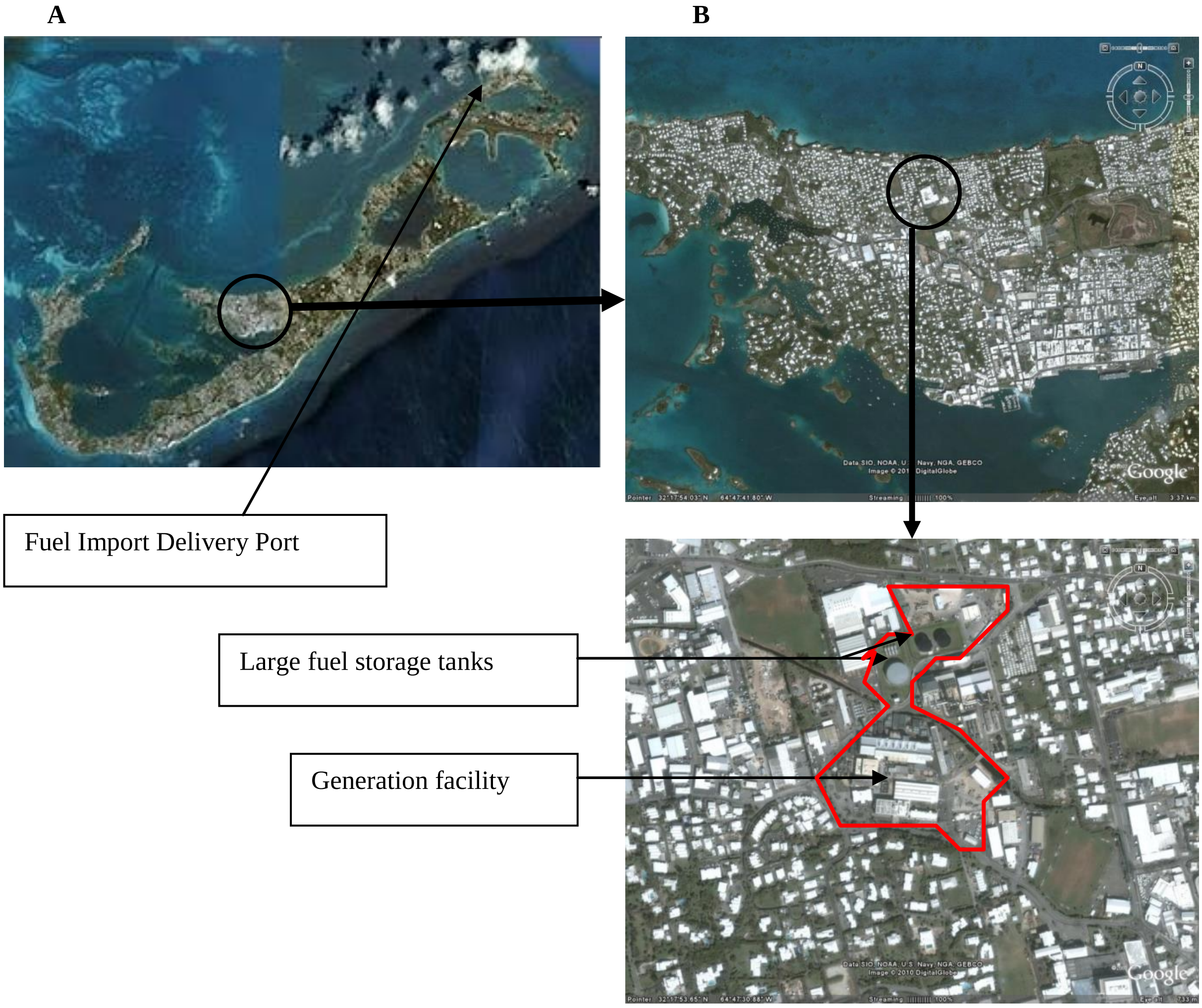
Gas / Propane		Tobago	(+/-0.24)	
Heavy Fuel Oil	BP	USA	59.0 (+/-0.21)	+0.41 (+/-0.21)
Jet-A	Exxon Mobil (Esso)	*	-	-

*** Not Known**

3.2.2 Fuel Transport and Storage

It has already been established that Small Island States like Bermuda are heavily dependent on imports of fuels as an energy resource, both in terms of fuels needed for electricity generation as well as transportation fuels. On-island pipelines play a key role in the movement of these fuels from their point of delivery (See Plate 5A) to their points of use.

Plate 5: Images of the location of Bermuda's fuel imports delivery port in relation to the island's sole electrical utility (Aerial Photos from Google Maps 2011. Author's demarcations.)



The actual size (diameter) of a pipeline has implications on the type, amount and speed (as a function of its viscosity) at which fuel can be transported. As a result, the existing characteristics of pipeline networks influences the cost of fuel and also impacts on dynamics associated with its procurement. Cheaper fuels are less refined and, as a result, are more viscous and need larger pipelines in order to transport. These types of fuels are also less environmentally friendly and burn less efficiently. More refined fuels are more environmentally friendly and less viscous. They are more expensive to purchase but burn at a much higher efficiency than fuels of higher viscosity and less refinement.

An executive at the local utility highlighted the relationship between the fuel pipeline infrastructure and cost of energy (See Quote 3.2.1):

> *"One of the limiting factor that drives why our fuel prices are as high as it is that the pipeline is limited in size. It is an old pipeline and because of its bore diameter and lack of ventilation you can only send a certain amount of fuel type down the pipe line because of the heating limitations and the viscosity, so our heavy fuel oil up to 15-20 % of it is diesel oil cut down to give it an improved viscosity. So if the pipeline was upgraded, you could get a lower cost fuel that was readily available because our fuel has to be formulated in a special combination. That also provides a level of concern regarding the security of those options. Yes, there are few places that do that but it generates another level of security risk because it takes time to produce that amount because we are a small volume so we are only producing limited amounts of shipments. The heavy fuel oil comes from the Gulf of Mexico and some of the mixing is done on the islands on the way here, I think in the Bahamas, so they try to do it in a couple of places. In Trinidad where the light fuel oil comes from, it's all prepped there. Our new plant is designed to burn a range of fuel options. In the event of an emergency, we wouldn't be limited to BELCO spec; we could get spec that was available in the Caribbean in general. We are also held to ransom by it: one due to the delivery options due to specifications and two the local infrastructure in regards to the pipeline limits the quality of fuel you can get…" (Quote 3.2.1* - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

Such fuel transport pipeline networks are of major importance in Bermuda and it is through a pipeline network that fuel for the island's main electrical utility is transported from the delivery port. The whole pipeline network is subterranean with sections being above or below sea level at times along its length (See Plate 5A). Bermuda is already incredibly dense as indicated earlier, both in terms of population and building units, so placement and movement of the pipeline is severely restricted. The characteristics of the existing pipeline network has played a major role in raising the price of fuels for the electrical company, which in turn has impacted on the price of electricity for consumers. The constraints on the diversity of fuels being able to be procured and transported along the pipeline network has also had environmental implications as the fuels able to be transported along the existing pipeline network are less efficient. This constraint on diversity of fuels available may also affect energy security from the aspect of the geo-political stability of supplier countries as the constraint restricts the location options from which fuels can be accessed.

The island's small size and 'urban and developed' nature also puts constraints on the ability to store fuel resources (See Table 14). This is from the perspective of both amount and length of storage as well as security of storage. The utility also spoke about these constraints between fuel storage and space (See Quote 3.2.2):

> *"Storage is balanced between the BELCO site and the oil docks. We keep about 6 weeks minimum supply on island but in times of concern such as a pipeline issue, delivery of that fuel to the BELCO site can be compromised if we are pumping fuel for example. There is a very carefully orchestrated balance between the amount of fuel we keep here and the amount we keep at the oil docks and how much of that is moved through the system. Part of our long term plan for the site was to look at what was the optimum amount of fuel that we should keep there. When we hear about the infrastructure discussions regarding the country, we hear about discussions regarding a new docking facility on North Shore. That's a stone throw from BELCO and would be a perfect landing site for a new oil dock, a short pipe line and even storage. The storage site could be freed up for generation or other purposes. We have a pretty large footprint of fuel right now and will need an even larger footprint soon"* (Quote 3.2.2 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

Table 14: On-island long term high volume fuel storage capability (Data obtained from various sources as indicated, directly from the Bermuda Government Department of Energy and also Department of Energy 2009 and Department of Energy 2011)

Storage Agent	Fuel Type	Storage Capability
Rubis	Gasoline	9 months supply
	Diesel	12 months
	Liquefied Petroleum Gas and Propane gas	7-8 week supply
Exxon Mobil	Heavy Fuel Oil	6 weeks
	Diesel	12 weeks
BELCO	Heavy Fuel Oil / Diesel	25 days

As space is limited, the utility in particular finds itself constrained by the level of urban development occurring around its site (See Plate 5B & 5C). This places not only its physical plant, such as its generation and storage facilities (fuel vulnerability), at risk from a security perspective but also places the population living around the site at an increased environmental and health risk (See Quote 3.2.3). The environmental risk has already been documented in regards to environmental fallout from smokestack emissions landing on the roofs of residents and businesses, for which the local utility has a remedial roof repair compensatory program.

> *"That leads to another one of our biggest balances here which is the environment. We are putting together for our sustainability model; we are looking at implementing an environmental management system, which only the Cayman Islands have, to an ISO 14001 standard. That will be quite an achievement for BELCO but it looks that we recognise our environment impact and aspects and we have implemented controls to minimise that. One of the biggest risks from safety and environment is fuel – fuel storage and fuel spills. The more you can mitigate that from this site, the better"* (Quote 3.2.3 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

Due to the growing electrical demand, the existing energy generation infrastructure is under pressure and needs to grow in order to meet projected needs. The utility reported that by 2030 they would be saturated at their current plant (See Quote 3.2.4).

> *"That resulted then to show that by 2030 we would be basically saturated there. There could be no more development. We had an 8 phase development plan proposed which looked at about 230 MW capacity installation here on diesel and gas turbine. That based on the current island's growth would hold us to about 2030. That submission was put forward in a holistic approach to say we wanted the whole site developed. The country had to embrace the fact that we had no other solutions on the table. Last year, we were forced to submit a particular phase, which we refer to as the emergency option which was the gas turbine complex. So the large scale development of the site has been put on hold and we ultimately submitted and got approval for the gas turbine expansion project, which will only get us another 2-3 more years beyond the 2011 timeline"* (Quote 3.2.4 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

However, the constraint of space is a real threat to the ability of the utility to meet this need to extend capacity. The lack of space has also contributed to the electrical generation system being less energy secure in terms of its environmental accessibility (acceptability) as the utility has had to employ the use of smaller but less efficient gas turbine generation units which emit substantially more greenhouse gases. Such space constraints unfortunately may also extend to the integration of renewable energy systems, whether on an island-wide basis or directly for entities like the utility, a consequence discussed further on in Section 3.5 - Environmental Accessibility.

As the demand for fuel grows so does the need for greater fuel storage areas, especially in light of the lack of distributed generation and the need for those with independent generation reliant on fuel storage. Only a few of the large businesses with independent generation reported having fuel stores on sight, with many of these also registered as priority fuel receivers in the event of a national emergency (See Quote 3.2.5).

> *"If we have a massive outage, we also have a base down at Cable and Wireless. We also have an emergency resource from Shell that if we need fuel we are one of the first in line. If there is an emergency looming like a hurricane, Shell will take a truck and park it at Excel and ACE, Excel and Chartis are one of the first three customers to be serviced" (Quote 3.2.5 -Extract from an interview with a large business* [LB 8], 23/12/09).

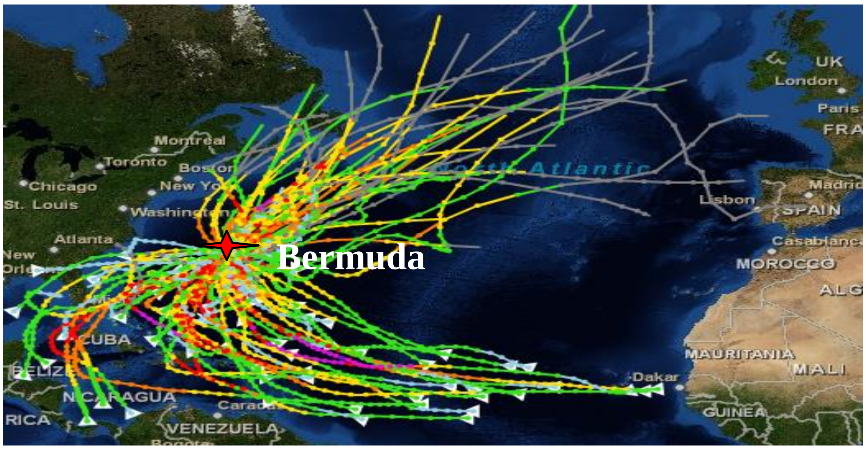
Again, underscoring the importance of energy to these large businesses, many of them also had electrical grid redundancy infrastructure by way of alternative feeds to the utility's main power source. However, the effectiveness of such redundancy was ultimately tied into the operation of the main utility. The integration of renewable energy for such entities could bode well in this respect as an additional form of energy security and energy redundancy.

3.2.2.1 Fuel Import Transportation and Storage Risks

Dependency on imported fuels also carries risks associated with its transportation and storage (Farrell et al. 2004) and can be used as an additional consideration in diversity assessments (Jansen et al. 2004). From a general overview, the closer primary fuel sources are to the point of use, the less risk implied. Additionally, in cases not involving extraneous factors such as natural disaster, war or terrorism, overland transportation would generally be considered of significant less risk than transport occurring over water for obvious reasons. Bermuda's isolated position in the mid-Atlantic[47], its historical hurricane risk (See Figure 20), increases the transportation risk in both respects of distance and land vs. sea considerations. As with the additional risks associated with dependency on imported fuels as a function of the political stability of supplier countries, Bermuda's isolated nature also carries obvious risks as a function of its dependency on fuel imports, again suggesting a potential role for renewable energy in this regard of providing a more sustainable energy platform.

[47] Bermuda is 284 km from the USA, 2278 km from Trinidad & Tobago and 2407 km from St. Croix, US Virgin Islands.

Figure 20: Historical hurricane paths (1858 – 2010) (Source - National Oceanic and Atmospheric Administration. Accessed online: [http://csc.noaa.gov/hurricanes]).



3.2.3 Technical Accessibility as a function of Energy User 'Grounded-ness'

Related to energy security from the perspective of the user and interior energy geographies are the connections pathways between this level of scale and the wider scale of supply. The connection between the user and the differing parts of the energy service spectrum important for obtaining supply is a critical facet of guaranteeing technical accessibility to energy. This connection can be thought of both in terms of physical connection (technical access to quantitative supply) as well as of social aspects of connection (energy use behaviours, patterns of use, payment methods, etc.).

From a technical aspect of connection, the 'urban and developed' nature of the island seems to be contributing to a widening disconnect between the energy user and the primary (local) energy supply over time. This widening disconnect is exemplified in personal accounts of older residents as they shared their experiences of the historical evolution of residential electrical services over time. As modernisation in residential electrical services in Bermuda progressed, locals saw a transition in residential service change from the use of self-payment 'shilling meters' to 'meter man-read' electrical meters to now, in its most modern form, 'read-at-distance' meter man-read meters (See Quote 3.2.6 – 3.2.7).

> *BELCO would come to collect the respondent's shillings from the respondent shilling meters twice per week* (Quote 3.2.6 - Extract of researcher's notes from a historical recollection being given during an interview with resident [1H], 23/12/09).
> *The respondent didn't remember the transition between the shilling meter and the electrical meter* (Quote 3.2.7 - Extract of researcher's notes from a historical recollection being given during an interview with resident [6H-B], 23/12/09).

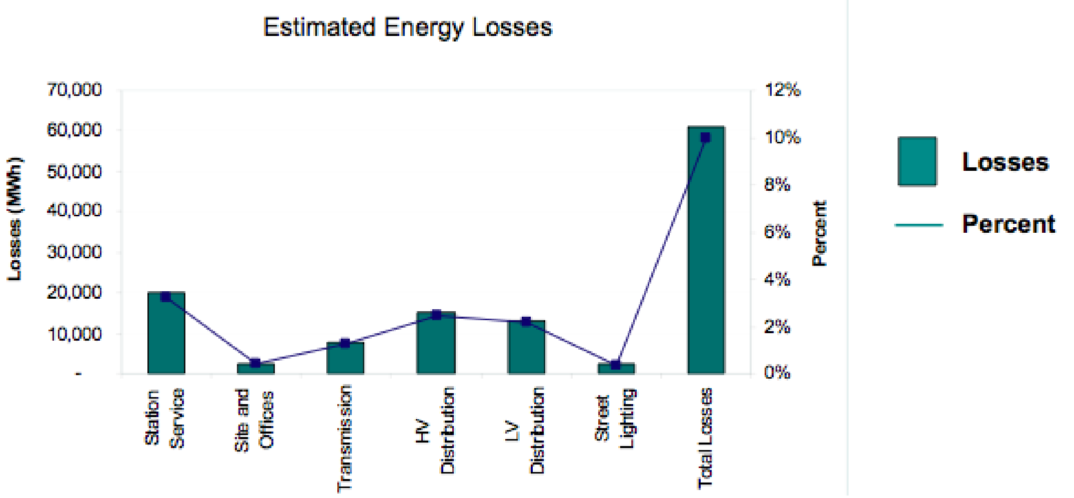
This change in meter type was also accompanied by changes in methods of payment, evolving from the direct ‘point of use’ payment of electricity in the home based on household need (household shilling meter) to residents having “unlimited” access to electricity on demand with post-use payment made at centralised utility billing centres. Such widening disconnects may act as sources of energy insecurity as it serves to lengthen the chain of connection between users and the energy supply source, energy types and their own user demand patterns (See Figure 22), thereby dulling the sensitivity of users to associated issues of energy security and sustainable development (See Quote 3.2.8 – 3.2.9). This type of energy insensitivity may act as a barrier to developing personal impetus by residents towards residential renewable energy integration, personas which may carry over to influences on energy reform at work.

> *Resident also spoke about the fact that energy is seen as something people can come and switch on:* “That’s the extent of people’s thinking” (Quote 3.2.8 - Extract of researcher’s notes from an interview with a resident [17H], 23/12/09).

> *Resident explained that BELCO gives monthly bills on what energy is used but not on conserving energy* (Quote 3.2.9 - Extract of researcher’s notes from an interview with a resident [4H], 23/12/09).

Now, in its most modern form, the disconnect has widened even further with residents no longer having to visit billing centres but instead being able to pay using online methods. It is interesting to note that in larger nation states such as the UK and the USA, many utilities have put in place payment methods reminiscent of the older ‘shilling meter’ concept, such as the use of ‘top-up electrical keys’, as a way of reducing the debt experiences of lower income customers and increasing convenience and affordability of energy, with customers being able to access electricity based directly on household need. These methods not only help users to better manage their energy needs from an economic perspective but also serve to make the connection between personal energy use and the user more intimate and tangible. In this same way, home-orientated renewable energy devices also have the potential to shorten the disconnect between energy user and energy source (See Figure 22), potentially making the connection more intimate and giving the user more knowledge of their generated supply and demand through the use of net metering systems and computerised generation monitoring software. There are also considerably energy losses (See Figure 21) that occur as a result of transmission of electrical energy along complex grid networks from the point of generation to points of consumption. Renewable energy here also may serve to beneficially bring the points of generation closer to those points of consumption and thus reduce levels of energy losses, which is a concept in line with the ideals of sustainable use of energy towards sustainable development.

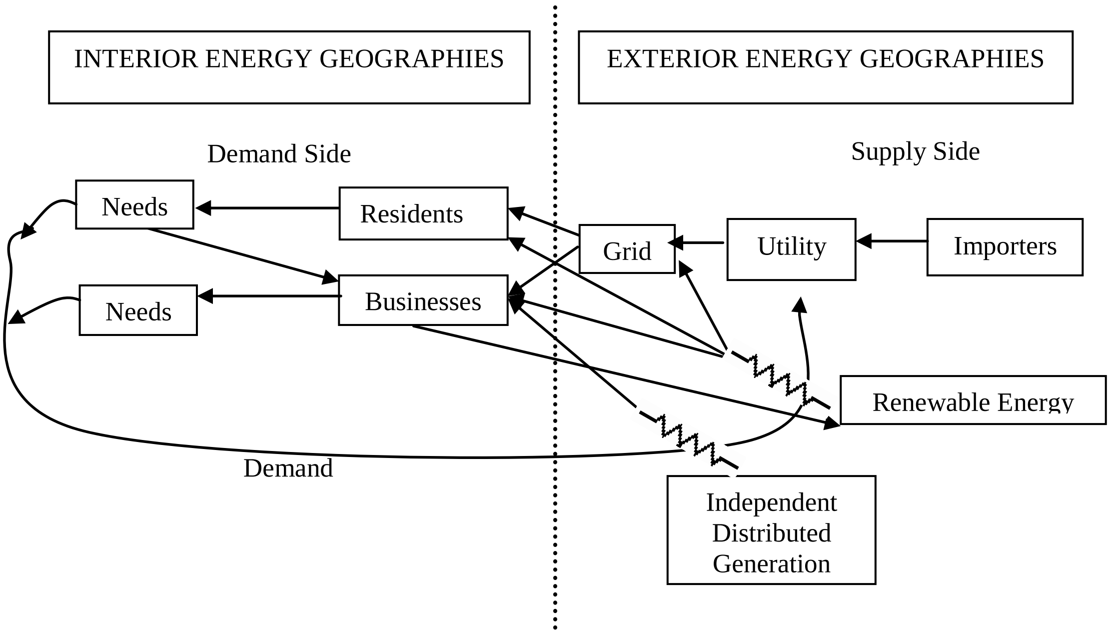
Figure 21: Estimated energy losses characteristic of the Bermuda electrical transmission grid network (BELCO 2009).



3.2.4 Interior Energy Diversity

The issue of diversity as a function of technical accessibility in respect to energy security can also be scaled down and viewed from the household level, so-called interior energy geographies (See Figure 22). The value in this approach is that it allows the consideration of energy security concerns as they relate to the user and sustainable development across geographies of scale. This approach is particularly useful in the context of this research as it is the needs of local stakeholders that are at the heart of the sustainable development paradigm. In this respect, while energy security is often looked at from a quantitative perspective especially in terms of supply and demand influences on security of supply as in the preceding approaches, a user-based qualitative perspective towards energy security within interior geographies may be more useful in understanding the needs of stakeholders at the local level, how they influence supply and thus how renewable energy integration may play a role. Additionally, influences on the supply and demand needs associated with the 'urban and developed' nature of Small Island States like Bermuda should be visible at the local level and help to shed light on how this developmental state may add unique attributes to the potential role of using renewable energy towards improved energy security and sustainable development.

Figure 22: A conceptualisation of the relationship between interior and exterior energy geographies (Author 2011).



3.2.5 Interior Energy Geography – Domestic Arena

From a social aspect in terms of the diversity of physical energy resources used in the interior geographies of the home, when asked what are the energy sources used in their homes (See Table 15), homeowners responded with a clear indication towards natural gas and electricity.

Table 15: Energy Sources used in the Home (Author 2011)

Energy Sources	Cited References
Natural gas (propane)	15
Electricity	13
Batteries	2
Animals	2
Biomass	1
Coal	1
Manual Labour	1
Petrol	1
Kerosene	1

Although this indication of gas and electricity being the majority used may seem somewhat counterintuitive based on the reality of imported supply availability, this pattern also reflects the influence of technical lock-in to imported fossil fuels on interior geographies in the home and the overall 'urban and developed' nature of the island. Energy consumption is a consequence of needing and wanting energy services and the consumption of energy creates a feedback loop (i.e. lock-in) by which a lack of diversity in supply is reinforced (See Figure 22). This type of lock-in will also promote associated lock-in scenarios to energy paths and services also dependent on the use of incumbent unsustainable energy sources. It is valuable to note that renewable energy presents a potential to change this lock-in but due to the supply and demand patterns induced by Bermuda's 'urban and developed' nature as revealed earlier, this type of energy lock-in presents a significant resistance to change.

3.2.5.1 Residents with Disabilities – Interior Energy Geography Challenges

> *"My scooter requires charging daily (usually). However, if I didn't venture out too far the previous day, I won't charge it."* (Quote 3.3.1 - Extract from an e-mail interview with a resident with disability [RESI 1D].)

Residents with disabilities shared by and large the same traits in regards to energy supply and demand needs as all the other residents that were interviewed. Electricity was the predominant energy source utilised and similar concerns were expressed on the high cost of energy provision in the home. The use of renewable energy was an initiative that would be welcomed, especially in regards to the environmental sustainability properties that such integration may bring to their current energy consumption.

However, these residents also had special and additional needs in regards to their interior energy paradigm (See Quote 3.3.1). The positioning of energy interaction devices such as light switches was modified to allow access due to issues of mobility. Batteries and battery charging were also an added energy infrastructure that was required in the home for those disabled residents that had electrical mobility scooters.

The need for adjusted energy infrastructure suggest that the integration of renewable energy devices in the home for these residents may also come with the need for technical adjustments or assistance to be made in cases of need, i.e. cleaning of solar PV panels or the retraction of mini-wind turbines during hurricanes. The necessity for battery charging points to a key additional opportunity for renewable energy use whereby such battery devices could be charged by suitable renewable energy technology, especially in this case of an obvious life-long need for such charging capability. Potentially this is an area whereby government relief or subsidy could be additionally extended in order to make the payback of such renewable energy infrastructure more affordable, especially for those residents whose disabilities has detracted from their economic ability to earn.

3.2.6 Interior Energy Geography – Business Arena

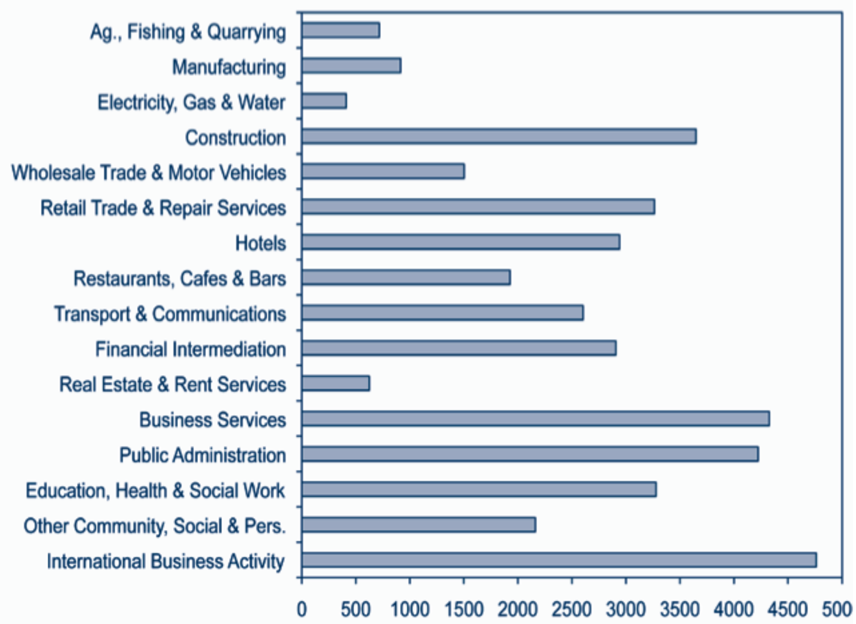
A similar trend in regards to a lack of diversity in terms of energy use patterns may be seen in the business arena (See Table 16). The disparity of diversity between businesses of different sizes[48] points to the potential for socio-economic factors associated with wealth and privilege to be significant in terms of influencing energy needs, which in turn influence demand and reinforce supply lock-in scenarios. For ‘urban and developed’ Small Island States like Bermuda, due to a lack of natural resources the well-developed economy is primarily orientated around energy-dependent service-based industries such as tourism and international business (See Figure 23), most of these being classified as ‘large businesses’. This also reinforces pressure on supply to stay with incumbent sources in order to sustain current local economic models. Energy (in)security clearly becomes associated with socio-economic class in this way, a trend which is discussed further in the section on economic accessibility (affordability) as a function of energy security.

Table 16: Energy Sources used in Business (Author 2011)

Large Business	Medium Business	Small Business
Electricity Diesel Petrol Natural Gas UPS Steam Heat Recovery Batteries Waste Incineration	Electricity UPS	Electricity Petrol UPS

[48] Under the Bermuda Small Business Development Corporation Act 1980, a “small business” is defined as: Bermudian-owned and managed, operating locally, having an annual gross payroll not exceeding five hundred thousand dollars ($500,000) and having annual sales revenues of less than one million dollars ($1,000,000). Under the Under the Bermuda Small Business Development Corporation Amendment Act 2011:28, “medium-sized business” means a Bermudian-owned enterprise with at least three of the following attributes - gross annual revenue of between $1,000,000 and $5,000,000; net assets of less than $2,500,000; an annual payroll of between $500,000 and $2,500,000; between a minimum of 11 and a maximum of 50 employees; and been in operation for a minimum of 10 years.”

Figure 23: Employment jobs by sector in Bermuda, 2008 (Bermuda Government Department of Statistics 2009b).



Many of the large businesses also cited that access to energy services such as electricity were critical for their operations and, as a result, many had independent generation capability available, mainly used to provide energy redundancy in the case of power outage. Additionally, some of these businesses with independent generation capability were also on a stand-by load-share program with the local utility that could be used in times where the utility's demand load was at peak. As an aside, most of the commercial stand-by independent generation facilities were diesel generators, which points to additional fossil fuel dependency, even in this case of independent generation.

However, more importantly in regards to energy diversity, the existence of such independent generation and the peak demand load-share program does give credence to the possible opportunity for distributed generation to play a larger role on 'urban and developed' islands like Bermuda. Such distributed generation programs could add to the diversity available in electrical generation facilities thereby reducing the load share of the sole utility and reducing the impact of monopoly in the industry, all aspects that would help in creating better energy security. These types of programs could be even more beneficial if combined with effective technical methods to measure and monitor energy usage by the individual businesses involved, as this would allow the employment of such independent generation to be used during times of either utility or individual company peak load, indicating the significance of technical accessibility to the energy security paradigm.

The potential of such a distributed generation programs could also lead to value-added opportunities for the use of combined heat and power (CHP) technology, of use in heating and cooling applications, which again would reduce demand from the sole utility in these areas. Currently there is limited use of heat recovery at places like the local hospital but there is currently major waste heat being generated at the local utility and the Tynes Bay EfW facility that could be used for such CHP programs or other industrial applications.

However spatial constraints associated with 'small islandness', discussed further on in later chapters, and the high costs of fuel make movement towards such distributed generation concepts difficult, adding further support to the integration of renewables in this regard. The need to also effect changes in the current operating licensing regulations for energy generation facilities, which is currently inadequate for these purposes, also serves as a potential political barrier to increasing energy security from such initiatives, such political barriers again discussed further on in subsequent chapters.

3.2.7 Energy Redundancy

From a domestic level, the issue of redundancy also seemed to be of importance in terms of providing greater energy security. This aspect was already spoken about in regards to energy use choices in the home. The view is also reinforced from the perspective of homeowners with installed renewable energy systems, many who saw energy redundancy in times of power outage as a chief benefit to having such systems (See Quote 3.3.2). With Small Island States like Bermuda being especially susceptible to extreme weather events such as hurricanes, a risk that is predicted to increase due to global climate change, the significance of such redundancy concerns becomes even more valid.

Interviewer: The propane generator is a new one from the one you mentioned before?
"Initially we are not going to have a generator. This is a new one, a Sieman's. We got it because we decided that if we did lose power for three weeks, and suppose anything else happened, we would not be sustainable then and would have to cut down the house and live in one room, so then we got the back-up propane generator as well. So this is why we figured we should use our own batteries at night because we do not actually have to rely on them totally because we have the propane generator as well now. It was a Bermuda company that made the connections for us" (Quote 3.3.2 - Extract from an interview with a resident with renewable energy system installed [RESI 2], 23/12/09).

Such issues related to technical accessibility interrelate to the energy security component of 'economic accessibility' (i.e. affordability) (See Section 3.4) as any energy infrastructure that can be utilised to create redundancy may also potentially be used as a vehicle towards achieving savings though the creation of the ability to use self-generated energy during times of peak cost. In the case of renewable energy, this potentially may mean the storage of generated energy that can be released for use during these peak times. Additionally, such dynamic use of energy across times of changing supply and demand needs would have to be accommodated by an efficient and effective regulatory regime capable of dealing with differentiated tariffs.

3.2.8 Enviro-Technical Barriers to Renewable Energy Integration

Whereas the integration of renewable energy technology may be useful in issues such as provision of redundancy and as an alternative to fossil fuel generated supply, issues of islandness and culture unique to Bermuda also impact technical accessibility. Renewable energy systems installed in Bermuda have to be 'Bermuda-proofed' outside of the standards normally approved for use in other jurisdictions (See Quote 3.3.4. – 3.3.5).

"Solar hot water heating was considered but the Bermuda Planning department was against it. Their reasons were that they were concerned about the potability of the roof water run-off and the need to have a separate system to accommodate drinking water" (Quote 3.3.4 - Extract from an interview with a resident with a building developer [16H], 23/12/09).

"If solar thermal or solar PV is something they are still interested in, we go up and look at the roof and see if it can support the units. We then look at the run to the water heater. The condition of the existing water heater. We are very careful to use passive materials. Sometimes certain roofs will need pitch sealing. Also, Bermuda's roofs are different in makeup – limestone slate, SKB, cement board – and so you have to use material that is compatible with each" (Quote 3.3.5 -Extract from an interview with a solar installation company installed [SI 2], 23/12/09).

These types of considerations may act as barriers to the integration of renewable energy technology due to compounding of issues such as affordability and ease of installation (See Quote 3.3.6).

> *The landlord felt it was due to a politics in planning as well as due to a lack of understanding of the technology. As the building project was limited in funds, the landlord felt it was not worth the risk and also offered too many complications. There was also no duty relief offered at the time.* (Quote 3.3.6 - Extract from researcher's notes during an interview with a building developer [16H], 23/12/09).

Weather concerns in islands are a particular issue and may act as a further barrier to renewable energy integration (See Quote 3.3.7). Bermuda with its extremely isolated and exposed mid-Atlantic position is particularly prone to these types of weather factors impacting technical accessibility.

> *Interviewer: How has Bermuda's weather conditions affected installations?*
> *"This was one of our major concerns. These systems are tested underwater in 90 degrees Celsius! However, the corrosive environment due to salt is the real challenge especially with different materials being in contact such as aluminium and steel, where we have to use a nylon washer. The exposed inverters have not given us any problems"* (Quote 3.3.7 - Extract from an interview with a solar installation business [SI 2], 23/12/09).

As early adopters of renewable energy in geographical locations where the use of renewable energy technologies is still uncertain, this need to make special accommodations for the island's unique environmental conditions may present an additional barrier to the widespread integration of technology as a function of cost (See Quote 3.3.8).

> *Interviewer: Has the Bermuda environment caused the company to have special accommodations for renewable energy installations?*
> *"We had to come up with a standard design for what is acceptable to attach to either an SKB or slate roof and/or rafter. We had to do it because we were the early bird and we had to prove that our attachment mechanisms were going to be sustainable in the long term"* (Quote 3.3.8 - Extract from an interview with a solar installation company [SI 3], 23/12/09).

One particular resident, who was quite elderly, a self-taught electrical engineer and who had installed his own solar PV system despite being on a low income found innovative and economical ways to help protect against the weather effects on his solar photovoltaic array (See Quote 3.3.9):

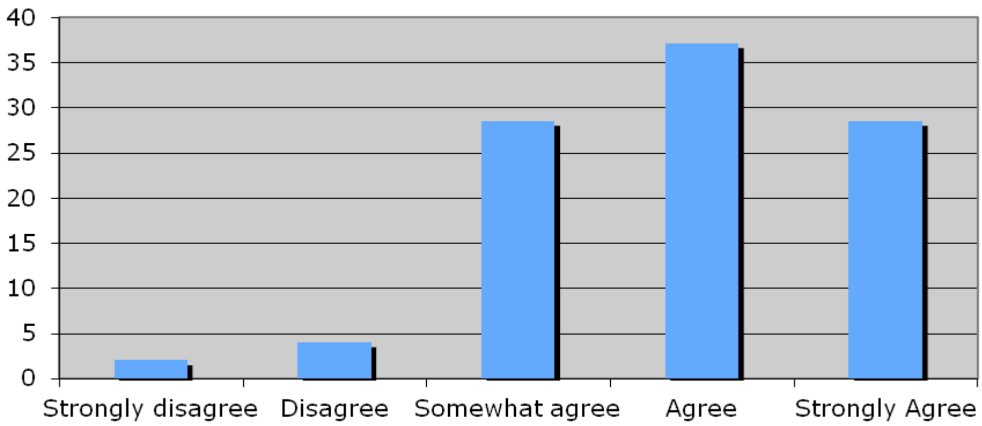
> Interviewer Notes: He uses Vaseline to protect the exterior metal components of his system against electrolysis and rust (Quote 3.3.9 - Extract from researcher's notes during an interview with a resident with a renewable energy system installed [RESI 1], 23/12/09).

3.2.9 Socio-Technical Accessibility – Inability to Understand as Energy Insecurity

Despite the provision of energy services, it is the ability to understand and effectively utilise these services that allows energy users to take full advantage. Having a lack of understanding towards technical aspects involved in the use of energy services can affect this ability and may act as a form of energy insecurity. This aspect of energy security is given the term here as the 'socio-technical accessibility' of users to energy services.

While the majority of residents that were surveyed claimed to know where their home electricity meter was located (~90% said "yes") and how electricity was delivered to their home (See Figure 24), barriers to socio-technical accessibility might start at a deeper rooted level than understanding of external technical aspects of the energy services infrastructure.

Figure 24: % of surveyed residents that claim to understand how electricity is delivered to their home (Author 2011).



This socio-technical understanding can begin at the very root of energy users' understanding of the term "energy" itself. Residents were found to have various different perspectives on what is meant by the term "energy" (See Quote 3.3.10 – 3.3.11):

> *She saw energy as what is provided by BELCO (Quote 3.3.10 - Extract from researcher's notes during an interview with a resident* [10H], 23/12/09).
>
> *Respondent stated that when she thinks of the word energy she tends to think of "electricity". She said she also thinks about "spiritual energy" (Quote 3.3.11 - Extract from researcher's notes during an interview with a resident* [11H], 23/12/09).
>
> *"I tend to think about my own personal energy. I never think about 'lectrics' (electrics). I think about my own energy – how am I feeling today, etc." (Quote 3.3.12 - Extract from an interview with an elderly expat long-term resident* [12H], 23/12/09).

This disparity in understanding of the term “energy” may cause potential conflicts in providing energy security across persons of different socio-economic backgrounds, including education and wealth. This may be a particularly challenging issue when it comes to moving towards the type of energy reform associated with the integration of renewable energy. This challenge was spoken about by a representative at the Bermuda Government Department of Energy, reflecting on the reception by the public on the announcing of the government’s intent to publish an Energy Green[49] Paper (See Quote 3.3.12):

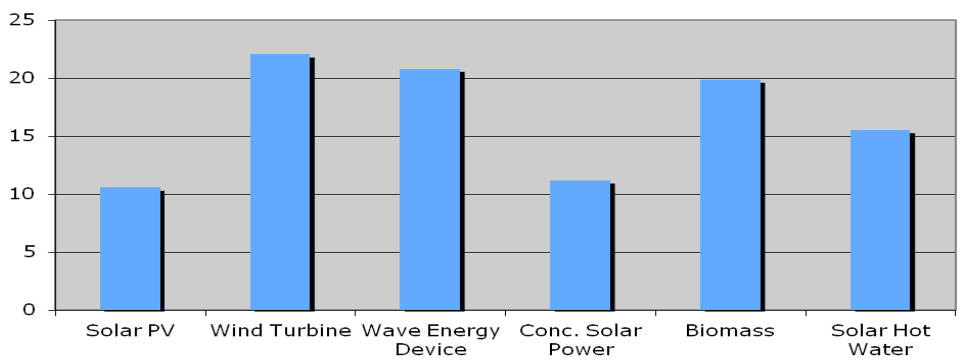
> *“I think there are certain things, for example, people associated the word “green” with the environment rather than with the nature of it being a consultative document. So everyone was talking about green energy and there was a degree of misunderstanding there”* (Quote 3.3.12 - Extract from an interview with the Director at the Bermuda Government Sustainable Development Unit, 23/12/09).

Other stakeholders such as the local utility also reflected on the importance of understanding and education in regards to technical innovation and change in energy reform, all relevant to the successful uptake of renewable energy technology (See Quote 3.3.13).

> *“Our challenge as a company and my challenge particularly in engineering is to how do we educate people that these are the choices that lay on the table. The other technology of storage integration and smart grids, all the things that people pick up as buzz words, I think leads to confusion”* (Quote 3.3.13 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

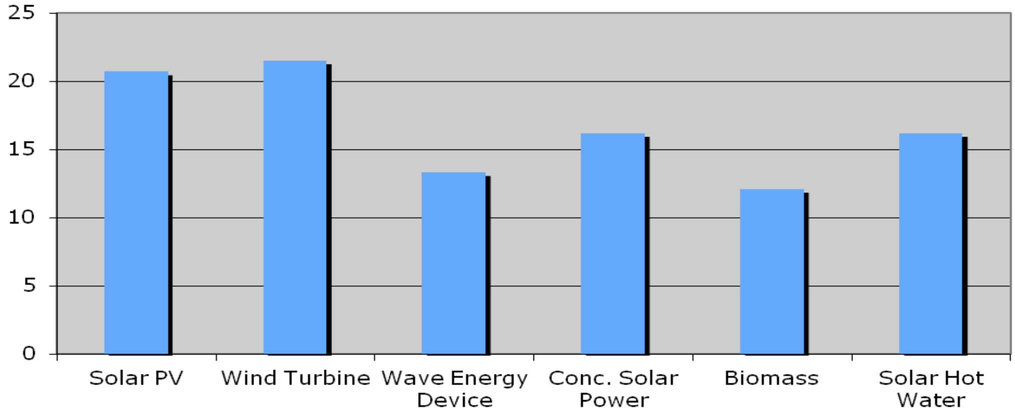
These concerns may hold some weight as a sample of residents surveyed on their ability to successfully recognise images of different renewable energy devices as well as state which ones they were most familiar with both returned rather low rates of success (See Figure 25 & Figure 26).

Figure 25: % of residents surveyed who successfully identified images of renewable energy devices (Author 2011).



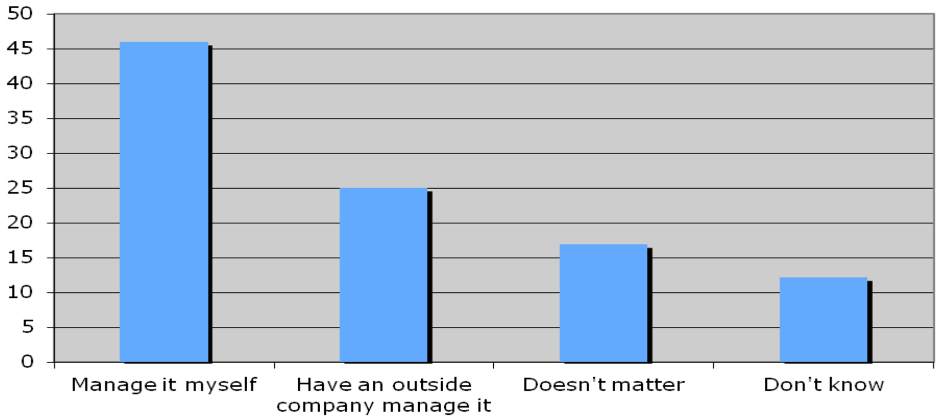
[49] “Proposals for new laws may be outlined in government White Papers. These may be preceded by consultation papers, sometimes called Green Papers, which seek comments from the public.” (See http://www.direct.gov.uk/, [Accessed August 17, 2011])

Figure 26: % according to familiarity with the renewable energy technology (Author 2011).



Nevertheless, despite these concerns in terms of socio-technical understanding of language associated with energy as well as current knowledge in regards to renewable energy devices, the majority of residents who were asked whether the term renewable energy was familiar to them agreed (~70%) that it was so and that if they did have a renewable energy device in their home that they would prefer to manage it themselves (See Figure 27).

Figure 27: % of residents from a survey asking "How would they like a home-installed renewable energy system to be managed?" (Author 2011).



Energy reform, in particular those directed at modernising energy services, will demand specific technical skill sets and an increased level of technical literacy in the labour market. This was demonstrated by business entities with innovative energy technologies having to outsource maintenance of these units (See Quote 3.3.14):

> *Interviewer: Do you have to have special maintenance staff for your energy infrastructure?*
> *"We have a service contract with Air Care for this building and we have a service contract with BAC for the new building. That is for the air conditioning and the well pumps, etc. That includes the ice system. Everything else we handle ourselves"*
> (Quote 3.3.14 - Extract from an interview with a large business [LB 8], 23/12/09).

Although, a barrier to energy reform in some ways, the moves toward energy reforms demanding more efficient and sophisticated energy technologies, including renewable energy, may also result in an increasing demand for suitably qualified human resources locally able to manage such technologies, adding to opportunities that increase the local technical labour market. There was also a perception that in order for energy reform directed at more sustainable energy use to be successful, there would have to be a learning and educational period for both the skilled workforce and energy users (See Quote 3.3.15 – 3.3.16).

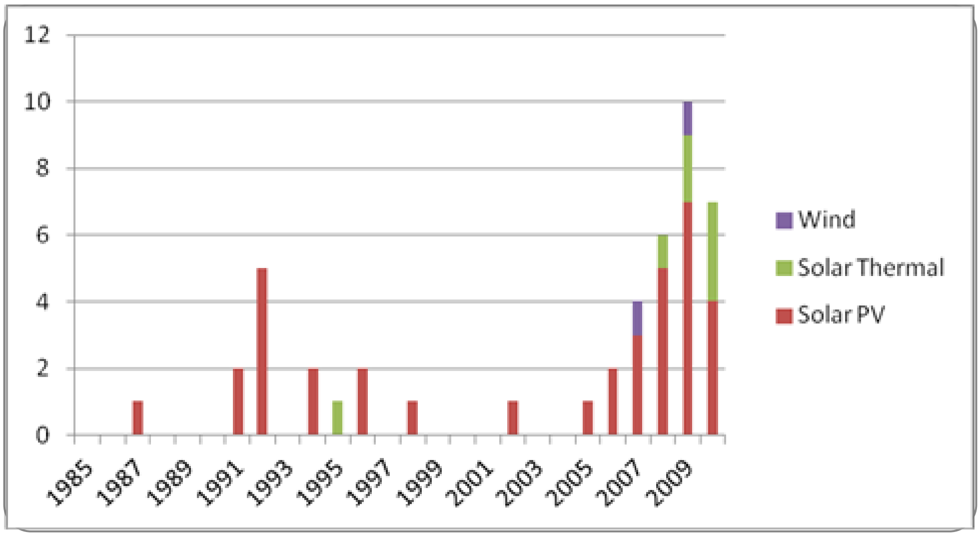
> *"All the staff will use computers and printers. Everybody is trying to go paper-less. If I could get my IT department to go a million sheets of paper less per year, which is quite an achievable target, but we really do have to up-skill the workforce to be literate to the level we need"* (Quote 3.3.15 - Extract from an interview with an executives at the island's sole hospital, King Edward Memorial, 23/12/09).
>
> *The respondent found the contractors that were used to install the dehumidification unit to be familiar with the concept on an industrial setting but not on a domestic setting. The contractors even questioned him on the need to carry out the installation* (Quote 3.3.16 - Extract from researcher's notes during an interview with a local resident [7H], 23/12/09).

This lack of technical understanding has already seemed to create some barriers in the integration of renewable energy technology (See Quote 3.3.17 – 3.3.19).

> *Interviewer: What has been the experience with the Bermuda planning department?*
> *"Lack of knowledge/experience with renewable power sources and their requirements"* (Quote 3.3.17 - Extract from an interview with a solar installation company [SI 4], 23/12/09).
>
> *He feels the current human resources in the construction industry can adapt to it and technically understand it but need more exposure to it (*Quote 3.3.18 - *Extract from researcher's notes during an interview with a large business* [LB 5], 23/12/09).
>
> *Interviewer: Has your own staff had to be trained in how to mount and use these solar devices or do you use an outside company?*
> *"We outsource an electrical company – we use First Class Electrics. They are well versed in all sorts of electrical devices. They did not have to study on it; we just gave them our product. But they have installed solar island-wide. They have never experienced the problems that they are having"* (Quote 3.3.19 - Extract from an interview with a medium size business [MB 1], 23/12/09).

Although local human resources that are able to undertake technical work involving a wide range of renewable energy integration obviously must already exist judging by the installations made to date (See Figure 28 and Figure 39), tradesmen working in this field should also have specific training considerate of Bermuda's unique island-related idiosyncrasies associated with renewable energy technology, a lesson that may extend to other Small Island States to often keen to blanket adopt technologies and innovations imported from offshore.

Figure 28: Renewable energy installations by device type (Data obtained from Bermuda Government Planning Department 2011).



3.2.10 Electric Vehicles – Opinions and Understandings

Understanding the role of electric vehicles is important when considering energy security and sustainable development in regards to any transition towards a non-fossil fuel based energy economy (Andersen et al. 2009). Section 1 highlighted how the import of fuels, for both electrical production and transportation use, were chiefly responsible for Bermuda's fossil fuel import dependency. Electric vehicles offer opportunities to utilise electrical energy generated from renewable energy sources and thus move away from fossil fuels. However, it is crucial to understand how stakeholders, particularly residents, feel about electric vehicles as well as objectify their understandings on the technology in relation to its use.

When a sample of residents where asked the question "What is energy most important to their home for?" (See Figure 29), transportation was not high on their list. However, when this question was asked in the national context, i.e. "What is energy most important to Bermuda for?" (See Figure 30), the relationship between energy and transportation was deemed much more important.

Figure 29: Residents responses to the survey question "Energy is most important to your home for ___?" S – lighting, G – cooking, K – TV/internet and entertainment, V – refrigeration and Y – water, transportation – X (Author 2011).

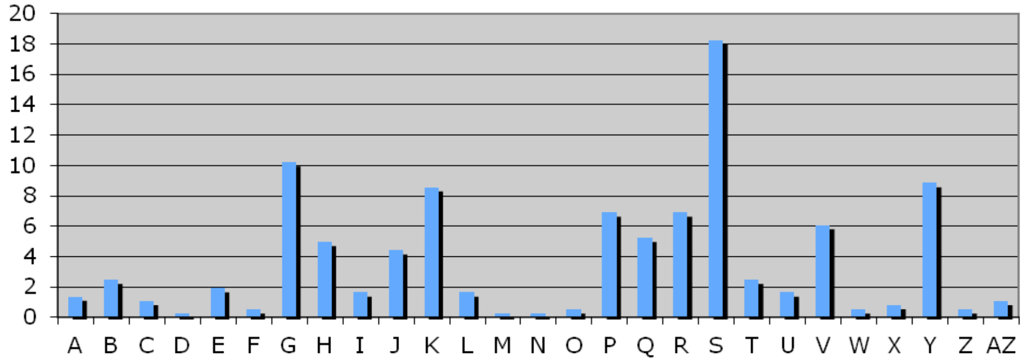
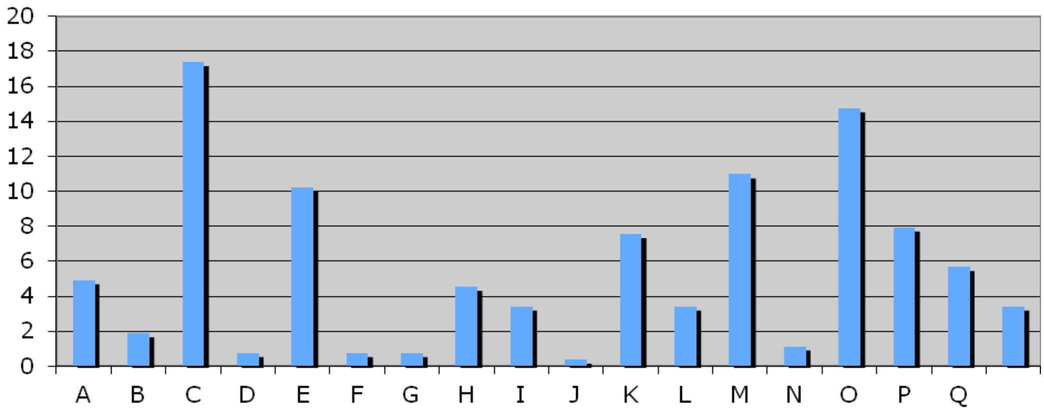


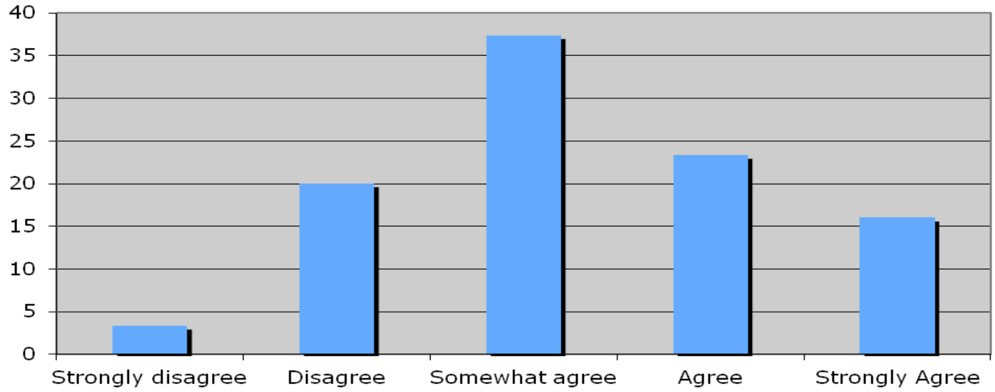
Figure 30: Residents responses to the survey question "Energy is most important to Bermuda for ___?" C - economy and business, E – Electricity, K – Appliances and General Utility, M - lighting, O – Comfort, Safety and Quality of Life and P – Transportation (Author 2011).



This suggests a disconnection in the minds of residents between the role of energy as it relates to their own personal home use and that on a national scale. With transportation, most of it residential based, accounting for large proportions of the imported fossil fuel utilised on-island, establishing a more sustainable methods of transport is extremely import for the long term energy security of the island. Unfortunately, transportation is one sector where renewable energy technology has not made as large a stride as it has in terms of production of electricity. While the use of biofuels has its pros and cons, Bermuda's island nature, specifically its isolation and small size, make the import of such commodities almost as unsustainable as the use of fossil fuels. Perhaps the most sustainable transportation option may be the uptake of residents of electric vehicles powered through the further integration of renewable energy technology as a chief source of energy production by the local utility, whether it be through centralised generation or through the incorporation of a distributed generation program inclusive of residential renewable energy devices all tied into the national grid, as suggested by

Worboys (2009). Indeed, a majority portion of residents agreed that they would consider buying an electric vehicle when surveyed (See Figure 31).

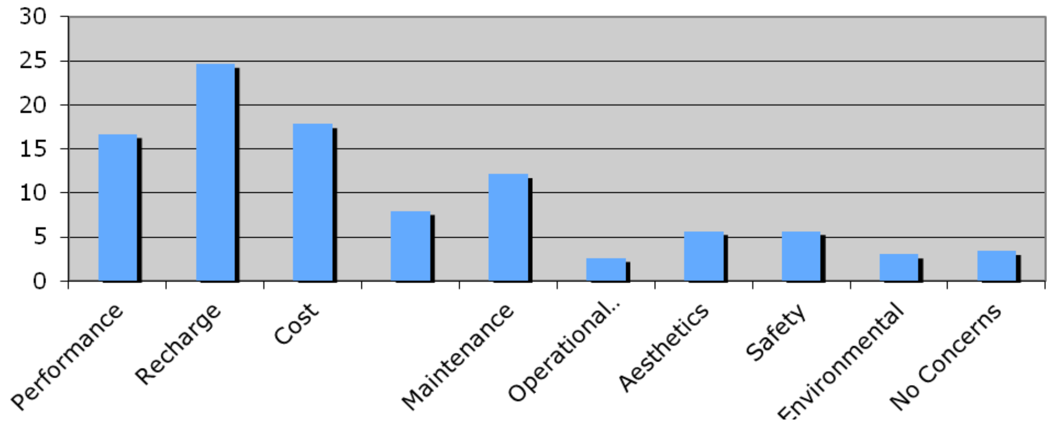
Figure 31: % of residents' responses on questioned "Would they consider buying an electric vehicle?" (Author 2011).



However, there were some concerns with this idea, with the need to recharge, the performance of such vehicles and their cost being the main concerning factors (See Figure 32). For the electric utility, a large scale uptake of electric vehicles would represent both an opportunity and a challenge (See Quote 3.3.20). Bermuda's small size and well-developed grid network mean that phasing in the necessary infrastructure to accommodate such vehicles wwould not be as challenging in other larger jursidictions, as vehicles would not have travel far, thus making charging at home more of an effective option.

> *"One of the general movements we are watching very, very carefully is the electric vehicle. Bermuda is well positioned – we are small and being small leads to different opportunities. Electric vehicles are a perfect example of that. We are small enough where EV or even hybrid vehicles will be a no-brainer step"* (Quote 3.3.20 - Extract from an interview with an executive at the sole electrical utility BELCO,

Figure 32: Concerns in regards to potential use of an electric vehicle (Author 2011).



However, faced with current space constraints on adding to further generation plant capability, rapid uptake of electric vehicles on-island would severly challenge the utillity already strained capabilitiy to meet the electrical needs of this additonal demand (See Quote 3.3.21).

> *"One, it is a threat from the perspective of you are putting a large demand on the grid because most vehicles will be charged at peak times…"* (Quote 3.3.21 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

While presenting such challenges, electric vehicles also present an opportunity for the island in regards to a more sustainable solution towards energy storage and thus provide a possible effective mechanism that ultimately could allow the increased integration of renewable energy on a large scale (See Quote - 3.3.22).

> *"…but one shouldn't lose sight of the fact that it is not only a demand consumption load, it is also a generator as a storage device. And storage is the holy grail of any grid. If we could solve the storage problem efficiently and effectively, then you basically can make the most optimum generation system you can make. In Bermuda we have no hydro and compressed air is limited. Batteries are the only thing and electric vehicles in every household and 35000 metered connection could lead to the optimum balance of storage. The concern is what is the relative probability of implementation and how do you build the grid."* (Quote 3.3.22 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

The potential of such a large scale uptake of vehicles dependent on charging as well as the opportunity for their use as a storage mechanism that works on behalf of the utility would necessitate an energy services infrastructure that was made much more intelligent than is currently available or expected even in the developed technical grid environment of Bermuda. Smart meters and smart grids would be vital to making such bold steps (See Quote 3.3.23).

> *"Which goes back to the new energy equation and within this new energy equation there is a smart grid and part of the smart grid is the infrastructure required to communicate with all of this stuff. Do the telecommunications sector realise where the utility needs are going to be in 10 years from now or why does it have to be a utility. What if GM or HWP wants to manage the fleet of vehicles they sold to customers and they want to communicate to every electric vehicle out there? The number one factor limiting smart integration is communication. If we believe that is a real need, and we look at other parts of the world that are advancing smart grid applications to the highest level, they are putting in trunks of fibre optics. They have positioned themselves for the future and using the core infrastructure in place."* (Quote 3.3.23 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

3.2.11 Conclusion

Both Bermuda's inherent commonalities with other Small Island States and its uniqueness as a result of its 'urban and developed' nature have both affected the technical accessibility of energy services locally and in turn influence the role of renewable energy as a local sustainable development energy solution. The 'urban and developed' nature of the island may act as a barrier to the technical infrastructure changes necessary for the integration of renewable energy as part of an energy reform motivated by sustainable development. In contrast, the increased use of renewable energy technology can provide an added layer of energy security associated with less reliance on imported fossil fuels and the limitations of on-island fuel infrastructure including transportation and storage. The integration of renewable energy for such entities could bode well in this respect as an additional form of energy security and energy redundancy.

The space constraints placed by both the inherent island trait of 'smallness' as well as exacerbated by the pressure placed on the local utility to expand to meet growing energy demand needs may also be assisted through further widespread integration of renewable energy technologies. However, Bermuda's unique climatic attributes can act as a challenge to the technical operational effectiveness of renewable energy devices, even more so than normally expected for other island locales due to its extremely isolated mid-Atlantic geographic location. Furthermore, socio-technical issues related to understanding of renewable energy technology, both by the general public and by those human resources needed to facilitate the technical integration of renewable energy devices on-island also play a key role in its further uptake. Ideally, the expansion of this industry through initiatives that increase both resident knowledge of renewable energy technology and facilitate the training and development of working professionals suitable for the renewable energy industry presents a key opportunity for adding further diversity to the local economy.

3.3 Economic Accessibility (Affordability) as a Function of Energy Security

The economic accessibility of energy and energy services plays an obviously significant role in the ability of stakeholders at all levels to access energy services. The term "affordability" has been used as a general umbrella terminology when referring to issues involving such economic accessibility in relation to notions of energy security (APERC 2007). At all levels along the energy services chain, greater affordability of energy resources can bring about greater abilities to access and diversify the types of energy resources used, which in turn may lead to greater levels of energy security. A lack of economic accessibility to energy services may act as a strong source of frustration for energy users and thus work to create pressure for energy reform, such as renewable energy integration.

In terms of general energy affordability, energy services are generally more expensive in Small Island States than those seen in other continental or less isolated jurisdictions with larger economies of scale. The high cost of energy services in Small Island States has led to many suggesting that renewable energy integration may be able to play a role in the provision of sustainable energy services over the long term in these areas, despite the elevated cost of renewable energy technologies when compared to fossil fuel-based energy. Due to a combination of depressed economies alongside high energy costs, the potential accorded to renewable energy integration is considered to be particularly beneficial for Small Island Developing States, especially those which are very isolated. However, the validity of such assumptions needs to be examined in the unique case of 'urban and developed' Small Island States like Bermuda, whose economic demographics may present special considerations that change the dynamics of economic accessibility in relation to energy security, and in turn, change the relevancy of the role that renewable energy may be able to play in improving energy security.

As with other aspects of energy security, impacts relating to the economic accessibility of energy and energy services can involve issues occurring at either the international, national or local scale. From a national perspective, a primary issue to be examined in terms of economic accessibility for an 'urban and developed' Small Island State like Bermuda concerns the impact of a total reliance on energy imports on national fiscal economic sustainability. For Small Island States, with their already vulnerable economies, the reliance on fuel imports serves as a substantial fiscal drain to the retention of vital foreign exchange. Considering the financial outlay of fuel importing countries to import fossil fuels as a proportion of GDP has been used as 'vulnerability' indicator[50](Bhattacharyya 2009:2414) and such an indicator provides a perspective to the cost of an economy of being over reliant on such imports. For Bermuda, from a national standpoint, over $90 million was spent in both 2007 and 2008 to import fuels for the production of electricity and for use in transportation (Bermuda Government Department of Statistics 2009a), representing some 1.5% of national GDP and an astounding 7.8% of total national import costs (Bermuda Government Department of Statistics 2009b).

From this national perspective, integration of renewable energy technologies may help to remediate the economic impact of relying totally on energy imports by offsetting the amount of energy imports needed through on-island production of energy where possible, particularly in terms of electricity generation. Increases in the proportion of energy obtained from local generation, especially that of local independent generators, would serve to act as a significant boost to overall national fiscal sustainability when compared to current energy import purchase trends. Such economic savings potentially could be diverted to other measures aimed at promoting sustainable development. From the perspective of national government, there is a suggestion that financial savings achieved through the long-term use of renewable energy systems could mean the availability of more money able to be directed to national sustainable development programs (See Quote 3.4.1 – 3.4.2).

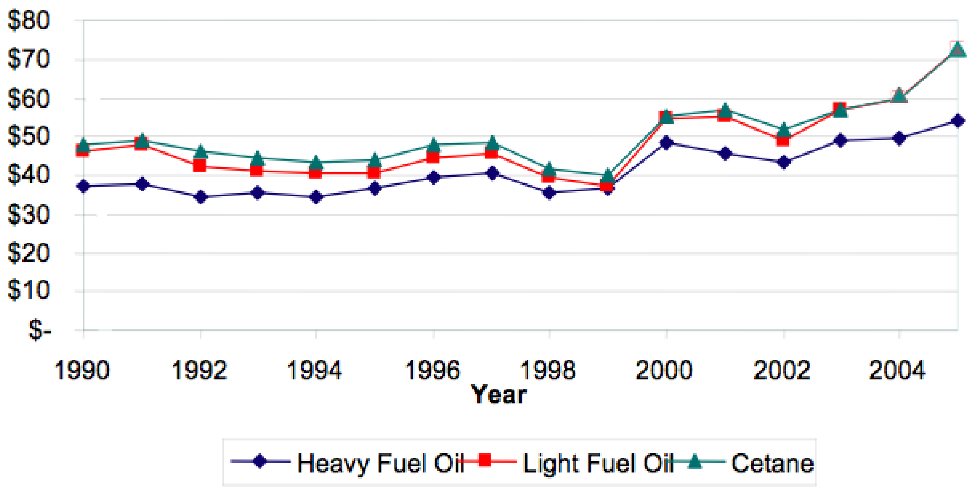
> *Interviewer: Is the conversation amongst government more in line with the ideas of cost reduction or environmental concerns?*
> *"It is both. The leader is on environmental considerations because they do not see it as their money. The $18 million the government spends on energy – the population does not see it as their money. Some people see it as "maybe if we can peel off $1 million from burning the lights at the stadium, maybe we can put that into four tours for the U-13's". People do not make that connection but that's this office's responsibility. Those are the connections we hope to make. Right now it is a little bit difficult"* (Quote 3.4.1 - Extract from an interview with the director of the Bermuda Government Sustainable Development Unit, 23/12/09).

[50] Vulnerability = Fuel bill for power generation / Gross Domestic Product

"For example we could have a cable just going somewhere and presumably we wouldn't be oil powered, we could use other fuels and so the price of electricity instead of bouncing between $0.30 - $0.40 /kW/hr, we could be running on like $0.10 a kW/hr, and so electricity would become cheap" (Quote 3.4.2 - Extract from an interview with a representative at the Bermuda Government Department of Energy, 23/12/09).

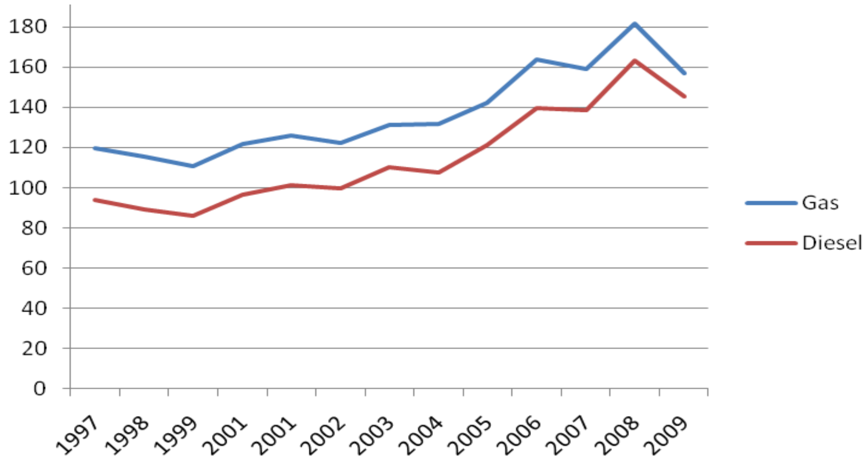
Considering local aspects of economic accessibility to energy and energy services and the impact of energy affordability on local users is perhaps an even more significant consideration in the context of energy security towards sustainable development in 'urban and developed' Small Island States like Bermuda. The 2009 Bermuda Energy Green Paper states that Bermuda has "one of the highest costs for electricity in the world" (Department of Energy 2009:24) with "the total rate charged per kilowatt hour in November 2008 at 42.5¢[51] per kilowatt hour, consisting of a 22¢ per kilowatt hour base charge and a fuel adjustment cost of 20.5¢ per kilowatt hour (ibid)." At that rate, fuel adjustment costs represent 48% of the total cost of electricity. Empirical data such as the price of primary fuel products needed for transportation and the production of electricity also give testament to the rising cost of energy services in Bermuda, both having historically increased over time (See Figure 33 & Figure 34). The impact of Bermuda's isolated nature on the cost of energy was made clear in an interview with a representative of the Bermuda Government Department of Energy.

Figure 33: Historical imported fuel prices over time, Bermuda ($/Barrel) (BELCO 2006).



[51] By comparison, the average price of domestic electricity in the UK for 2008 was $0.20 per kilowatt hour (DECC n.d.).

Figure 34: Retail gasoline pump price (cents per litre) (Department of Statistics 2009a).



The high costs of energy services may also be compounded through other aforementioned factors associated with vulnerabilities inherent in many Small Island States, such as small economies of scale, often resulting in a lack of commercial diversity and competition, particularly in energy services industry like the generation of electricity. For example, the island's small economies of scale make the purchase of generation equipment expensive for the electrical utility due to the relatively small amounts that need to be ordered (See Quote 3.4.3).

> *"What we are seeing now is that the lead times on equipment are becoming lot more extensive than in historical years and the cost is becoming more expensive. The last project we did we were up 40% from the last build out and the lead time increased by two fold. That's quite concerning because you normally work in 2-3 year development timelines and that is being pushed to four to five years. We are too small to influence the demand of what technology we can choose from overseas manufacturers such as custom built engines. Our equipment demand is not great enough to warrant priority of manufacturers to put us first"* (Quote 3.4.3 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

Aspects of Bermuda's 'urban and developed' nature also contribute to higher energy costs. Due to space constraints on further expansion of generation plant, any additional demand pressure on the island's sole electrical utility during peak times has to be largely fulfilled by the use of smaller gas turbine generation plant, which are more expensive to run, more polluting and much less efficient.

The affordability of energy was also given as an important source of local energy insecurity when examined from qualitative perspectives (See Quote 3.4.5 – 3.4.8). The existence of a significant surcharge on fuel was a particular point of contention by many residents when speaking about their current energy use. When speaking about the fuel surcharge, a representative from the Bermuda Government Department of Energy suggested that in 1998 the consumer was paying roughly 17% of the fuel costs and by 2009 they were paying 76%.

> *"The cost of electricity in Bermuda. No matter how we tried to cut back, the bills were not coming down. With the surcharge they add to your bill you have no control of that or the price of oil. We are coming up to retirement and on fixed income. It was a no-brainer. We wanted to forward plan"* Quote 3.4.5 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).

> *"Then we have grown into it since then and we would really like to cut down our power reliance on BELCO and therefore our bill. This surcharge that they are putting on now is almost 50% of the bill"* (Quote 3.4.6 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).

> *Interviewer: A lot of people do not even think about the surcharge. What made you aware of the fact that the surcharge was in the bill?*
> *"You see it. It is right there. It doubles your bill. I am very conscious of what I am spending on power. Also, I am definitely thinking about retirement and what our budget has to go to for retirement. The BELCO bill is something that we had no control of whatever. You can keep cutting back and cutting back but you still need power"* (Quote 3.4.7 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).

> *"Having worked and doing land surveying in BELCO, that is not really a resource anymore. It is old and antiquated. We are seeing that with the rolling brown outs that have been happening with BELCO. It annoys me that everyone is complaining about recession but the fuel surcharge is ridiculous. Can the BELCO just do whatever they want! It seems if they have a monopoly on things"* (Quote 3.4.8 - Extract from an interview with a resident [15H], 23/12/09).

The impact of the high cost of energy was also reflected in the attempt by many residents to introduce measures towards increased energy efficiency in the home in order to reduce energy costs. This was evidenced in the responses of residents when surveyed on whether they make an attempt to conserve energy in their homes and whether the purchasing of energy efficient devices was important to them (See Figure 35 & Figure 36).

Figure 35: Resident responses (%) to the question of "Whether they make an attempt to conserve energy at home?" (Author 2011).

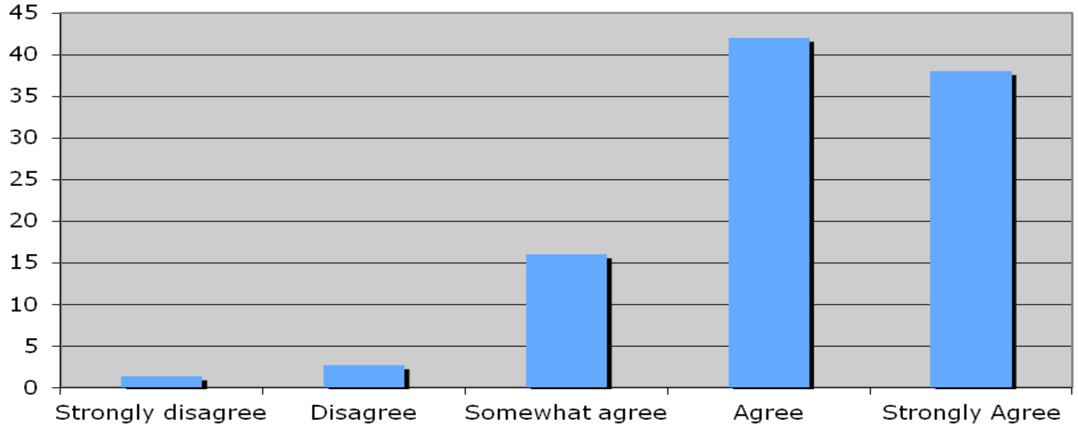
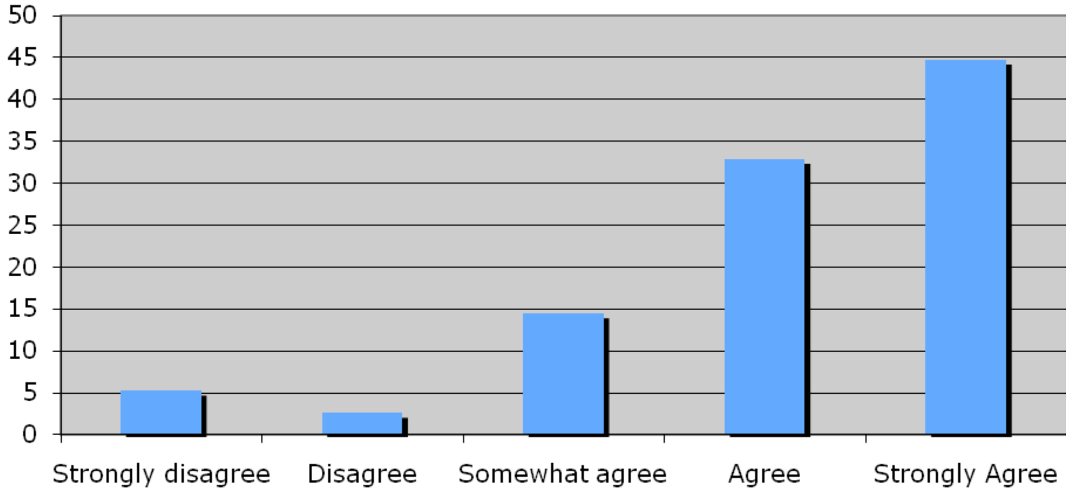


Figure 36: Resident responses (%) to the question of "When purchasing home appliances, is buying those that are energy efficient important to you?" (Author 2011).



3.3.1 Economic Accessibility and Uptake of Renewable Energy by the Utility

Although the high cost of energy may act as an incentive to increasing momentum towards the consideration of renewable energy uptake, economic issues may also act as barriers to this type of low carbon transition. For ‘urban and developed’ Small Island States like Bermuda, the energy services infrastructure is heavily influenced by a monopoly utility and wide-spread integration of renewable energy at the local level necessitates the embracing of such initiatives by the electrical utility, especially in regards to the technical impact on the local electrical grid infrastructure and the effective administration of financial incentive programs such as net metering (See 3.4.9).

> *"If we move to for example and as we believe in our new energy equation, as we move to a more diversified model that has diesel plant as well as large scale renewable as well as energy efficiency and conservation program, all embodied in the future, we recognise that that is going to come with a cost. The cost of renewables will be more than the cost of base load plant because renewables will not sustain us.*
>
> *It is kind of ironic that innovation is not really embraced because innovation tends to be a risk and cost money. Those two words are not acceptable in the utility business, so it is very challenging to introduce innovation and introduce new technology to an environment that is very stable because the technology has been very stable over the past 150 years.*
>
> *You get incentives to drive that type of change but no organisation that is working in a regulatory environment that has to answer to cost, price and liabilities and safety is going to take on a large degree of risk if there is not a quantifiable return. A price in base cost, price in reliability, price in aesthetics"* (Quote 3.4.9 - Extract from an interview an executive at the sole electrical utility BELCO, 23/12/09).

Increasing constraints on the utility's ability to meet electrical demand using its incumbent fossil fuel model, as well as national efforts to promote sustainable development in the island, have placed the utility under pressure to make transitions towards greater use of low carbon energy sources. Movement towards such renewable energy integration would place additional financial pressures on the utility as renewable energy integration, either centralised or distributed, would mean considerable investment towards initiatives of which many may be considered high risk, both financially and technologically.

As may be expected for a business based on shareholder profits, there is also a perception that there is internal resistance within the utility to incorporating energy monitoring initiatives such as net metering as they may lower shareholder value as a result of increased consumer knowledge and increased control over energy use consumption and costs. As a shareholder-owned entity, the utility is not welcoming of all of these types of financial risks or factors of added operational costs, adding to pressure for the continued embedding of incumbent fossil fuel technologies and an example of technological lock in spoken of previously (See Quote 3.4.10 – 3.4.12). Any hesitance such as these stemming from profit-driven rationales by the utility can serve to act as real disincentives to creating momentum towards renewable energy integration at the utility scale.

"Historically, financing of the cost of these growth initiatives have not been a significant issue. Financing in the BELCO model is quite unique in that we do not borrow a lot of money here. We finance our capital through our shareholders. Shareholders are expecting more nowadays. BELCO's model as a regulated utility is that for example in the US or Europe the shareholder gets a lot more of a return than we offer, as our return is quite nominal, because we use the shareholder value to finance our capital projects" (Quote 3.4.10 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

"The cost will be about $32,000. However, she has had difficulties with BELCO who will not put on a net meter for her" (Quote 3.4.11 - Extract from an interview with a resident wanting to have a home solar PV array installed [1], 23/12/09).

"We are trying not to move capital from the large utility to put other companies out of business but rather trying to empower these small businesses by training their staff to be able to install and maintain the equipment. Although we are often looked at as the big bad wolf by some, the originating company BELCO was trying to birth small companies under a sound structure that was going to be here in the long run" (Quote 3.4.12 - Extract from an interview with a solar installation company [SI 3], 23/12/09).

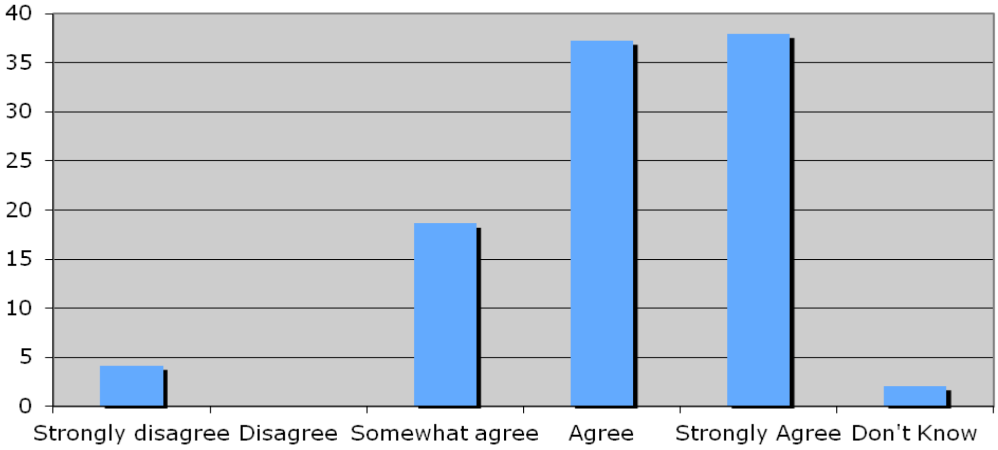
In the pursuit of renewable integration as a low carbon and more sustainable generation initiative for small island utilities, the local utility has developed a sister renewable energy installation company. However, with the utility's market share capture and vast unchallenged financial position in the electricity delivery industry, there is a potential that such moves may lead to parallel monopolies in local renewable energy industry, something recognised by the utility's renewable energy installation off-shoot. The transfer of monopoly power to renewable energy companies from incumbent utility companies may potentially lead to further monopolies in the renewable energy business sector, whereby the legacy wealth of the monopoly unless regulated internally or externally can easily create a monopoly in a developing renewable energy industry.

3.3.2 Economic Accessibility and Residential Uptake of Renewable Energy

With the backdrop of such high energy prices, the integration of renewable energy indeed may seem to be very attractive for local consumers (See Quote 3.4.13), acting as a key driver to its uptake by locals if economic 'payback to investment' ratios are favourable for such systems. When surveyed, a majority of residents indicated that there were favourable towards the idea of installing renewable energy devices in the home (See Figure 37). Interview responses from residents also seemed to confirm this willingness.

He was aware of the plans to put up a major solar power station and recommends this move. He feels Bermudians should get into solar energy. He definitely sees the price of fuel going up (Quote 3.4.13 - Extract from researcher's notes during an interview with a resident with a renewable energy system installed, 23/12/09).

Figure 37: Resident responses (%) to survey questioning, "Would you consider having your home energy provided for by renewable energy devices?" (Author 2011).



Residents that have had systems installed have seen reductions in the electrical demand needed from the utility-supplied grid and thus also achieved reductions in their overall electricity costs. The use of net metering devices (See Plate 6) in these cases were crucial as they allowed consumers to see how much energy they were generating and in turn how much they should be credited by the utility.

Plate 6: Net meter installed in a resident's home with renewable energy devices (Author 2011).

From the perspective of enhancing economic accessibility as a function of energy security, the use of such devices in the accompaniment of other energy consumption monitoring systems often associated with the use of renewable energy technology is also important as it allows consumers to more effectively change energy consumption behaviour as a direct result of increased consumer knowledge (See Quote 3.4.14).

> *Interviewer: How is the installation connected to the BELCO mains - net meter, microprocessor, etc.?*
> *"We had a duel meter installed, but have recently learned that this will be set for net metering. Which is of course excellent for us ... it means that the utility really is just a big battery backup ... sourcing or sinking load as needed, without cost impact to us. In terms of our behaviour the single most important change was triggered by the monitoring. My wife constantly watches our electricity production, and times running certain appliances accordingly. So dishwashers and washing machines have timers to come on later in the day when the sun is shining. (However, now that we have net metering this is really not necessary --- another key reason why net metering is paramount)"* (Quote 3.4.14 - Extract from an interview a resident with renewable energy system installed [RESI 3], 23/12/09).

Through the use of such net metering programs, installation of renewable energy devices on the homes of residents could actuate new sources of revenue for many, especially considering the supply and demand pressures that the electric utility is currently faced with. Such additional revenue sources can potentially serve as a conduit for wealth transfer, allowing residents of varying socio-economic class to economically gain from currently disconnected revenue sources, significantly as a conduit for foreign exchange transfer in the context of helping the utility to meet the considerable energy demand generated by the international business and tourism industries. These types of wealth transfer between socio-economic classes embrace notions of equity that are important in achieving holistic sustainable development.

However, although many residents stated that they would like to invest in renewable energy, the level of investment needed towards renewable energy integration for domestic homeowners may present an economic barrier in this regard, particularly to those of lower incomes. Residents who had renewable energy systems installed revealed that installation carried considerable costs associated with the need for supporting equipment (i.e. batteries (See Plate 7), inverters, monitoring systems, etc.) and even at times, additional structural construction (See Quote 3.4.15 – 3.4.19).

> *Interviewer: What behaviours towards energy conservation and energy efficiency are made in the home?*
> *"We have not made any changes yet, we would be open to using Renewable Energy for everything. It's just that installing cost are high I think installing Solar Panels is a great way to conserve energy"* (Quote 3.4.15 - Extract from an interview with a resident [13H], 23/12/09).

> *Interviewer: Would you be willing to use renewable energy to power your home? Why?*
> *"Yes I would say we would be willing to use Renewable energy for everything if it was not so expensive hopefully this will change soon because I believe conservation is a way that people can be more responsible for helping the planet to heal"* (Quote 3.4.16 - Extract from an interview with a resident [13H], 23/12/09).

> *"The battery racks were also bought from the same company. 175 W/24 V at $865 each"* (Quote 3.4.17 - Extract from an interview with a resident with renewable energy system installed [RESI 1], 23/12/09).

> *"The system has a life expectancy of 20-25 years. The batteries are the first thing that goes"* (Quote 3.4.18 - Extract from an interview with a resident with renewable energy system installed [RESI 2], 23/12/09).

> *"We have a dedicated out-building housing all the inverters and batteries and monitors and utility electrical distribution panels"* (Quote 3.4.19 - Extract from an interview with a resident with renewable energy system installed [RESI 3], 23/12/09).

Plate 7: Bank of 16 batteries used for storage in a resident's home [RESI 1] with renewable energy devices installed (Author 2011).

Installation also carried potential costs due to the planning application process which could substantially increase if the expertise of an architect is needed (See Quote 3.4.20).

> *"We then ask for plans and if they do not have any plans there to create additional plans then that would be a significant cost. This application has to go to Environmental Control and Conservation Services, with $150 for each application ($300), and then it has to go into the newspaper for two weeks for objections to be lodged"* (Quote 3.4.20 - Extract from an interview with a solar installation company [SI 2], 23/12/09).

The payback of renewable energy systems tended to be measured in years which may not be attractive to those with only small amounts of disposable income and could potentially act as a disincentive towards making any considerable investment in such systems (See Quote 3.4.21 – 3.4.23).

> *The cost will be about $32,000. However, she has had difficulties with BELCO who will not put on a net meter for her. She has made a choice between putting her child in private school and getting solar PV and chose solar PV. She feels fortunate to be in an area known for good schooling so that she can use public schools. She feels that a lot of people are interested but will not participate because of the lack of a 'payback deal'* (Quote 3.4.21 - Extract from researcher's notes during an interview with a resident who has a solar system installed [NGO 1], 23/12/09).
>
> *Interviewer: What was your trade off between deciding to cut back on your energy use and instead going to get a system to generate your own energy?*
> *"We worked it out that we would start seeing a return after 10 years. That is not too bad with our life expectancy and what we are going to pay for it"* (Quote 3.4.22 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).
>
> *Interviewer: What was your rationale for installing the system - cost savings, environmental considerations, etc.?*
> *"Well it certainly makes NO financial sense to do this. In a few years time, given the near exponential price / performance curve of PV, it will make a lot more sense. Purenergy, like all such companies, gave us various models and projections on how we'd save money. That at worst the system would pay for itself in 15 years. This is BS though, as 1) they idealize the amount of power you generate. 2/3 of the day there is no useful sunlight, even in summer! They also forget about the cost of money ... a lump sum given to them today has a time-value growth of at least 5%, which they typically discount completely. The cost of our system was in the region of 250K, more than most because of our desire to make it aesthetically pleasing "* (Quote 3.4.23 - Extract from an interview with a resident with a renewable energy system installed, [RESI 3], 23/12/09).

Considering the island climate of Bermuda, insuring renewable energy systems against weather related damage was also advisable, another aspect of cost that would not be easily affordable by many residents of lesser economic ability (See Quote 3.4.24).

> *Interviewer: What happens during storms?*
> *"They can actually take it down. The panels are left up there. The ones on the roof are rated for storms. We have house insurance that includes the panels and devices. I am saying we are insured but we are not totally yet. They have to complete that. Purenergy as well comes down to have a look and monitor in times of storms"*
> (Quote 3.4.24 - Extract from an interview with a resident with a renewable energy system installed, [RESI 2], 23/12/09).

There was also a need to understand the economic commitment associated with different types of renewable energy systems so that potential investors can choose systems most aligned with their financial ability and specific energy needs. There was evidence that solar thermal energy systems used to heat hot water would have a faster payback than solar photovoltaic systems due to the lower equipment costs. Renewable energy systems also have specific life expectancies, again adding an additional long-term cost due to the need to replace equipment, and which differs according to system type. These various factors affecting the overall cost and economic considerations of installing specific systems will invariably impact on the economic accessibility to renewable energy integration depending on socio-economic factors.

Residents of high wealth were able to make larger investments in renewable energy systems and thus able to achieve higher paybacks over time. These residents invariably had larger homes with larger roof or yard areas conducive to larger renewable energy systems (See Plate 8 & Plate 9), connecting issues of energy generation, wealth generation and socio-economic class as a factor of achievable system size.

Plate 8: A bank of solar thermal panels on the roof of a wealthy resident (Author 2011).

Plate 9: A ground-mounted bank of solar photovoltaic panels in the yard of a wealthy resident (Author 2011).

However, wealthy residents with larger systems also had to invest more not only due to size considerations but also due to factors such as their desire to make them more aesthetically pleasing so as to not to compromise existing property décor (See Quote 3.4.25).

> *"A central driving theme for us was aesthetics. Black panels on white roofs are ugly, to say the least. So our main bank of panels seated on the veranda roof are completely hidden. We built a small stepped wall (about a foot) on the roof that just looks like a normal Bermuda roof, but hides the edges of the panels. They can only be seen from the sea. We built the pergolas in cedar to tie in architecturally with the house --- the Sanyo panels we choose as they are translucent, giving nice shade but not cutting too much light. So these look quite high tech and cool but we feel integrate nicely into the property. We have a dedicated out-building housing all the inverters and batteries and monitors and utility electrical distribution panels"* (Quote 3.4.25 - Extract from an interview with a wealthy resident with renewable energy system installed [RESI 3], 23/12/09).

Longer system life expectancy also becomes important in relation to the potential for financial gain as the longer a system can run with less mechanical breakdown, the greater the potential for both energy and wealth generation (See Quote 3.4.26).

> *Interviewer: What was your trade-off between deciding to cut back on your energy use and instead going to get a system to generate your own energy?*
> *"We worked it out that we would start seeing a return after 10 years. That is not too bad with our life expectancy and what we are going to pay for it"* (Quote 3.4.26 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).

Invariably again, wealthy home-owners could potentially purchase more robust equipment considered to be the most reliable in Bermuda's challenging island environment. As a result of all the cost implications associated with the installation of renewable energy and its economic viability over the long term, invariably those of a wealthy disposition have become first adopters (See Quote 3.4.27 – 3.4.28).

Interviewer: What is the economic strata that you find your customers arising in?
"I would say that the high net worth customers will always be first in a market without policy and regulatory intervention. Whether they be large residential home owners or commercial owners" (Quote 3.4.27 - Extract from an interview with a resident with a solar installation company [SI 3], 23/12/09).

Interviewer: Are you customers mostly home owners or businesses? Do Solar Bermuda Ltd.'s customers tend to come from a certain economic strata? How are these costs financed by the clients?
"Primarily residential at the moment. Notable commercial interest. Two types: Tend to be either very "green" minded (younger typically) or Upper middle-class looking to reduce utility costs. Most clients to date have been Upper Middle Class " (Quote 3.4.28 - Extract from an interview with a resident with a solar installation company [SI 3], 23/12/09).

The disparity in the affordability of renewable energy systems was demonstrated clearly in the case of two separate homeowners, both having renewable energy systems installed. While the wealthy homeowner used insurance as protection against storm damage, the older, retired resident used a manual 'movement by hand' method to protect his system (See Plate 10) during times of high wind as well as to optimise the solar irradiance angle of his panels during the day. In fact the latter resident felt that this manual method of adjustment and ease of access allowed him to manoeuvre his system easier so as to harvest sunlight more effectively. However, his retired status allowed the flexibility to be present over the period of the day to afford him this ability. For those of less economic ability, such financial investment necessary may to be committed to any renewable energy system significant enough to impact energy costs may potentially be better spent making the consumer homes more energy efficient.

Plate 10: An array of ground mounted solar panels in the yard of a retired elderly resident (Author 2011).

As such, some installers were exploring initiatives where energy savings larger than system investments could be achieved so as to make systems available to less wealthy residents. However, one installer questioned the financial motivation behind many locals who were expressing initial interest in having renewable energy devices installed at their homes, feeling that consumers should consider the value of investing in such systems as being able to achieve a "long-term savings legacy rather than a short term value proposition." The installer felt that there was a trade-off between companies that offer customers short term ready-made renewable energy installations which may free up disposable income in the short term compared to long-term renewable energy installations, which ultimately yield a long term legacy of financial savings. The installer also expressed how the use of energy generation monitoring system was essential to achieve the long-term value proposition. Such monitoring systems seem vital to allow the renewable energy systems to be used as a vehicle towards achieving peak shavings by having the ability to generate and store energy and released during times of peak demand, thus achieving a better power purchase rate from the utility (See Quote 3.4.29). However such relatively advanced initiatives have to be accommodated by a regulatory regime that includes a differentiated tariff system.

> *"You have several ways of providing redundancy but also make sure you are peak shaving in terms of your use of BELCO's supply such that whatever you generate becomes an avoided cost from the BELCO generation"* (Quote 3.4.29 - Extract from an interview with a resident with a solar installation company [SI 3], 23/12/09).

Interestingly, the researcher's experience gained from a participant observation research exercise in the UK at a solar installation company found that many of the company's clientele were former professional, now elderly retired residents, whose main motivation for installing a renewable energy system was that they saw the greater economic benefit in the savings that they would gain from the generation of their own electricity when compared to investing the same amount of money into an interest earning account at local banks. For them, it afforded them the same financial incentives as a pension would in the long term, guaranteeing them a source of income once the payback of the initial investment had been accomplished, especially with the added incentives of the UK government's feed-in tariff system and solar grant scheme at the time.

Returning to the Bermuda case study, some local Bermuda installers stressed the importance of not going for "unbudgeted money" towards energy but focused instead on the resident making a savings and rationalising payment for their services from that savings potential. This is where the importance of energy audits seems critical.

Installers expressed that making properties as energy efficient as possible was essential in being able to optimize any savings or potential earnings from independent generation systems (See Quote 3.4.31 – 3.4.32).

> *In the interior of homes, the Respondent recommended installing LED bulbs, as that way you can reduce the electrical consumption, meaning less energy is needed from the renewable energy units* (Quote 3.4.31 - Extract from researcher's notes during an interview with a resident with a solar installation company [SI 2], 23/12/09).

> *Interviewer: What are the main solutions that your company is pushing?*
> *"The first thing is conservation and efficiency. For example, a customer called about solar PV, but I have a feeling I am going to go there and help them understand energy efficiency and conservation. We believe in doing the ethical thing and the economical thing. Our philosophy is to get the facility as energy efficient as possible before incorporating any renewable energy devices. I have a feeling that I will be talking about solar hot water which should come first. We provide the whole gamut – energy assessment, energy audits, solar thermal, PV"* (Quote 3.4.32 - Extract from an interview with a resident with a solar installation company [SI 2], 23/12/09).

This continued emphasis on energy conservation and efficiency as a precursor to any installation of renewable energy devices suggests that much more could be done towards sustainable use of energy through conservation and efficiency approaches before moving to renewable energy platforms as a first approach towards issues of energy security associated with energy affordability. Such energy efficiency measures also have the potential to introduce other synergies in relation to energy security, such as cooler homes due to less heat-producing lights and appliances, and thus less demand on the overall energy supply from the utility.

A clear dearth in vision and direction towards financing mechanisms that would spread the potential to adopt renewables with less risk can be seen as a clear gap in the local renewable energy integration picture. Installers have attempted to make the installation of systems more affordable by partnering with financial institutions to offer loans with a reduced rate to accommodate savings (See Quote 3.4.33 – 3.4.36).

Interviewer: What financing mechanisms would B.E.S.T. support in terms of encouraging renewable energy uptake?
"We don't know enough about the range of mechanisms" (Quote 3.4.33 - Extract from an interview with a NGO [3], 23/12/09).

He also feels that the PV systems currently available are easily adapted to Bermuda but need innovative financial mechanisms to encourage their uptake. As an electrician, he does not go for unbudgeted money, but looks at cleaning up electrical use in the home, which creates a saving which he can obtain from the customer (Quote 3.4.34 - Extract from researcher's notes during an interview with a resident with a solar installation company [SI 1], 23/12/09).

"We are exploring ways we can help to finance projects for people without financing up front. Ideally, the monthly savings would be more than the loan costs. Costs are definitely a hurdle" (Quote 3.4.35 - Extract from an interview with a resident with a solar installation company [SI 2], 23/12/09).

"If I can get a purchase-power agreement that allows me to sell back at a retail rate in a net metering arrangement that enables me to make money at the retail rate than I going to add value. We partner with the banks to establish a financing program. We are the only company on the island that has financing with the bank of Bermuda whereby we can offer a rate below prime where the debt service will be paid out of the savings that you get out of the solution thus you have no upfront cost. Many people in Bermuda do not want to borrow money" (Quote 3.4.36 - Extract from an interview with a resident with a solar installation company [SI 3], 23/12/09).

However the effect of such innovations may be limited for owners of small size system as they would not have the power generation to effect large paybacks, again allowing the wealthy to have a financial advantage over those less wealthy (See Quote 3.4.38 – 3.4.40). Also, it is better for investments to be made from as early an age as possible so that they have a longer return time. As many of the first adopters are those of higher wealth status, this may reflect a connection between education, earning potential and the understanding of the value in long-term investments concepts.

> *"Most people think at first that they do not want to spend that type of money. Our system is more robust than the average homeowner would want. The reason why we do it is we question homeowners to ask them are they trying to minimise their upfront capital costs, are you trying to optimise your short term savings or are you trying to ensure that what you invest today is going to lower your overall cost and you will have the ability to measure the value so if you need to change behaviour you can do so"* (Quote 3.4.38 - from an interview with a resident with a solar installation company [SI 3], 23/12/09).
>
> *Interviewer: What is the economic strata that you find your customers arising in?*
> *"I would say that the high net worth customers will always be first in a market without policy and regulatory intervention. Whether they be large residential home owners or commercial owners"* (Quote 3.4.39 - Extract from an interview with a resident with a solar installation company [SI 3], 23/12/09).
>
> *Interviewer: What has been their motivation?*
> *"I would say energy independence to drive cost savings and subsequently a lack of reliance in petroleum based fuels. They get the whole idea that this can be a greater return on investment, especially if I can capture the incentive coming from government or from the utility. If I can get a purchase-power agreement that allows me to sell back at a retail rate in a net metering arrangement that enables me to make money at the retail rate than I going to add value"* (Quote 3.4.40 - Extract from an interview with a resident with a solar installation company [SI 3], 23/12/09).

As an aid to making such investments more attractive, the Bermuda Government has begun to offer financial support in the form of rebates for renewable energy equipment. There is a duty free arrangement being offered on renewable energy equipment but many necessary components that are not covered under this arrangement often are the most costly (See Quote 3.4.41).

> *"The renewable devices are duty free for most things. For example, for solar thermal, the panel will be duty free but the other devices and equipment is not duty free. I think it has supposed to change but the communication between suppliers, shippers and Customs is not always effective. Since you have to buy copper, valves, etc. from different suppliers, you can run into serious problems with having a lot of duty"* (Quote 3.4.41 - Extract from an interview with a solar installation [SI 2], 23/12/09).

Until recently the electrical utility did not have an energy buy-back program although this has recently changed. However, the utility has placed a significant limit on the number of homes and size of systems eligible for their current program, underscoring their resistance to competition and any devaluation of shareholder value as described earlier. Issues relating to socio-economic class also seem to play a role in attitudes towards how such buy-back programs should and could work. Older residents were not favourable towards energy buy-back programs involving aspects of credited rebates and preferring instead direct discounts on their electricity bills based on energy produced (See Quote 3.4.42).

> *As she is retiring soon, cost of expenses is a factor and so she would only invest in renewable energy if the cost weighed up and she could recoup the amount of investment spent* (Quote 3.4.42 - Extract from researcher's notes during an interview with a resident [10H], 23/12/09).

Many residents also described how they did not want external parties determining how much they should earn but would rather achieve a ‘kilowatt for kilowatt’ exchange on renewable energy produced.

The qualitative research revealed that other issues relating to the socio-economic class of residents could potentially affect the impact of notions of affordability relating to energy security. The type of residential accommodation occupied by residents was determined by the economic class of residents, with more economically stable residents being able to live in homes of greater energy efficiency, such residents having more control over their overall energy use and thus energy costs. The homes of poorer families visited were clearly less energy efficient, which made such residents more dependent on the use of less efficient, ‘energy-expensive’ equipment like air conditioners and space heaters to maintain a comfortable living environment.

One young couple who resided in a somewhat depressed multi-apartment complex had no access to their utility meter, as the cost of electricity was included in the overall rent. This lack of access meant that there was somewhat of a disconnect from their energy use and the direct impact of energy costs. Such disconnects can potentially result in a lack of momentum towards individual energy reform as a result of issues relating to energy affordability, i.e. making energy efficiency improvements to the home, lessening the use of energy-expensive appliances for comfort or considering renewable energy devices. Residents of lower income also tended to have more persons living in the home per space available, placing additional pressure on energy demands and overall energy costs. However, such residents often rented accommodations rather than being homeowners, which place limits on the type of energy reform changes they could pursue (See Quote 3.4.43).

> *Interviewer: Have you ever thought on your own about doing anything with solar panels?*
> *“I have but I live in a condominium complex. At one of the AGM meetings, someone brought this up about in the future - people will be asking about if they can install solar panels on their roofs. It was not accepted because driving into a development seeing all of these black things on the roof so they kind of nipped in the bud there. It is the same with satellite dishes. You know you want to keep your property prices high. Once you start letting things go, your prices drop down. I am very careful with different things so I think we do our best with this energy crisis“*
> (Quote 3.4.43 - Extract from an interview with a resident [12H], 23/12/09).

Age again rose as a factor affecting approaches and impacts in regards to economic accessibility, as older residents spoke about a decrease in family members living in their homes over time, thus lowering their overall energy costs. In contrast, those of wealthy disposition reflected on the fact that even though less people lived at home, their energy use was high, resulting in high energy bills, due to the impact of increased use of household amenities for comfort (central air conditioning, large appliances like dishwashers) and entertainment (large appliances like plasma televisions). However, these persons usually owned their own homes or rented whole houses and thus their ability to make significant changes to their domestic energy use devices was greater.

3.3.2.1 Cost versus Comfort

Despite the high costs of energy in Bermuda and considerable discontent among both wealthy and poorer residents, the qualitative research revealed somewhat of a paradox in regards to the significance of local energy affordability. Many residents stated that personal comfort in their home was more important than was cost of energy to provide that comfort (electricity). This suggests that the cost of energy had not reached a suitable "tipping point" whereby it is too exorbitant so as to necessitate doing without amenities such as air conditioning and heating. This may point to issues of economic accessibility being not as great an incentive towards issues of energy insecurity in such 'urban and developed' Small Island States such as Bermuda and thus present a barrier to energy reform such as renewable energy at this time. This preference of 'comfort over cost' may be attached to the high material development of residents, who despite disparities in socio-economic class, are used to having material needs met with cost not being a particular barrier, a view reinforced by a representative of the local electrical utility (See Quote 3.4.44).

> *"We are our worst nightmare in that our service is very good and I think that leads to complacency. People only take on BELCO when it is a major issue such as fire, hurricane, etc. People do not really appreciate coming into a small island utility, as surprising as it may sound, that the utility and the infrastructure here has limitations. That we are very much an isolated community and very much we have grown and adapted to the needs of the country over time.*
>
> *My point is as a culture, this community I think lacks the understanding of a planning requirement and that has stemmed from the fact that we appreciate the need of infrastructure planning on a whole when it comes to sustaining our community"* (Quote 3.4.44 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

This lack of importance in regard to energy affordability is also reflected in the overall lack of investments that were generally reported by residents to have been made in the home towards energy efficiency. Where investments had been made, most mentioned were quick fixes such as light bulb changes.

3.3.2.2 Economic Accessibility as a Function of Socio-economic Class

There was good evidence to suggest that social access to energy can also equate to notions of socio-economic power, specifically as a function of class. If this is the case, then the integration of renewable energy and the role that it may play may also be influenced by class hierarchy or in turn, influence transitions within class hierarchy as a function of gaining power through energy empowerment. These notions of power in association with energy were reflected directly in the thoughts of residents (See Quote 3.4.45).

> *However, Respondent 1H felt that whoever was in charge of energy had use of power* (Quote 3.4.45 - Extract of researcher's notes from an interview with a resident [1H], 23/12/09).

Access to energy being associated with higher levels of socio-economic class has potentially evolved as a historical relationship. An older resident spoke about the disparities in the neighbourhood between homes that had access to energy-using appliances and those that did not (See Quote 3.4.46).

> *"Neighbourhoods were segregated racially. Some homes had televisions but others did not…An iceman would come by with ice that could be used for an icebox for those homes that had one"* (Quote 3.4.46 - Extract of researcher's notes from a historical recollection by a resident during an interview with resident [1H],

In present times, this relationship between access to energy and power as a function of socio-economics manifest in various ways. The interview extract below (See Quote 3.4.47 – 3.4.49) highlights such examples, in particular the experience of local residents from a lower economic class having to make the choice between access to adequate, sustainable energy conditions and their need for a stable home unit as well as examples of more economically able residents seeming to have the ability to influence energy decisions higher up the energy services chain to their ultimate benefit.

Their home is not adequately sealed so heat is lost during the winter. The condition of the apartment is not good. The windows are not sealed and the electrical socket on the stove is faulty. However, having a place to live is more important than making a fuss about home conditions. They are not sure if making an issue about the home conditions would affect the status of their renting (Quote 3.4.47 -Extract of researcher's notes *from an interview with a young couple with a baby* [8H], 23/12/09).

Interviewer: Do you think your origins (one Bermudian and one US) make a difference in your awareness?
"For him, I think it is career. For me (wife), I think of things like water because growing up as a child we had things like having to wash and turn the water off, then rinse, etc. I think because financially I am in a better position than my parents so I am not as – I used to be – sometimes I think about and sometimes I don't. I know growing up in Bermuda we had to turn the lights off constantly, etc. Some of it is growing up in Bermuda, aka not flushing on no.1. Now I do not tell my girls that. I think that because we are blessed and in a better financial position than it is not that big of deal" (Quote 3.4.48 - Extract from an interview with a wealthy couple [13H], 23/12/09).

"Our thought is that the more corporate citizens that put up these systems, then we are going to collectively have a lot of say on BELCO and if they do not start cutting deals or buying back electricity we will go to their AGM's and cause all sorts of shit. I have shares in BELCO so I could go and make a demonstration. I know Vince Ingham and I know Andrew Parsons, the head of the operations at BELCO. I just think that it is very topical and if they want to be obstinate, they are going to look very silly" (Quote 3.4.49 - Extract from an interview with a large business CEO [LB9], 23/12/09).

In contrast to the experience of residents more economically well-off, less economically-able residents as well as small and medium-sized businesses seemed to have very little relationship with the local utility, many of them expressing that there was very little information emanating from the utility in regards to energy matters (See Quote 3.450 – 3.4.51).

"There has been no information from BELCO" (Quote 3.4.50 - Extract from an interview with a resident [2H], 23/12/09).

Interviewer: What is the relationship like with BELCO?
"There is no relationship with BELCO" (Quote 3.4.51 - Extract from an interview with a medium-sized business [MB2], 23/12/09).

This hierarchy in relationship access was also reflected in the utility, with seemingly clear chains of communication open for large entities but not as much for smaller users (See Quote 3.4.52).

Interviewer: What is the relationship between BELCO and the business community?
"From the point of the large scale developers, they normally come to us and so it is very good relationships. We have worked with the Morgan's Point developer. We worked with Club Meds. It is a predominately after-thought relationship although some of them are getting better at coming to us earlier in the day although I would still say it is it is not in the appropriate point of their development timeline as it should be."

"As we get notification through various sources of development in the City of Hamilton whether it be the Front St area or the EEZ, we are always very practical to look at to engage the Corporation of Hamilton and say "are you are aware of this, can we support the improvement to that be it underground or growth." We try to be proactive. I do not think they are fully aware of some of the significance of some of the things they want to do and how they may affect the existing infrastructure or new infrastructure" (Quote 3.4.52 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

This relationship between socio-economic class and energy continued over to the realm of renewable energy integration also, with wealthier residents seeming to be able to benefit as first adopters to the transition to renewable energy technology (See Quote 3.4.53 – 3.4.54).

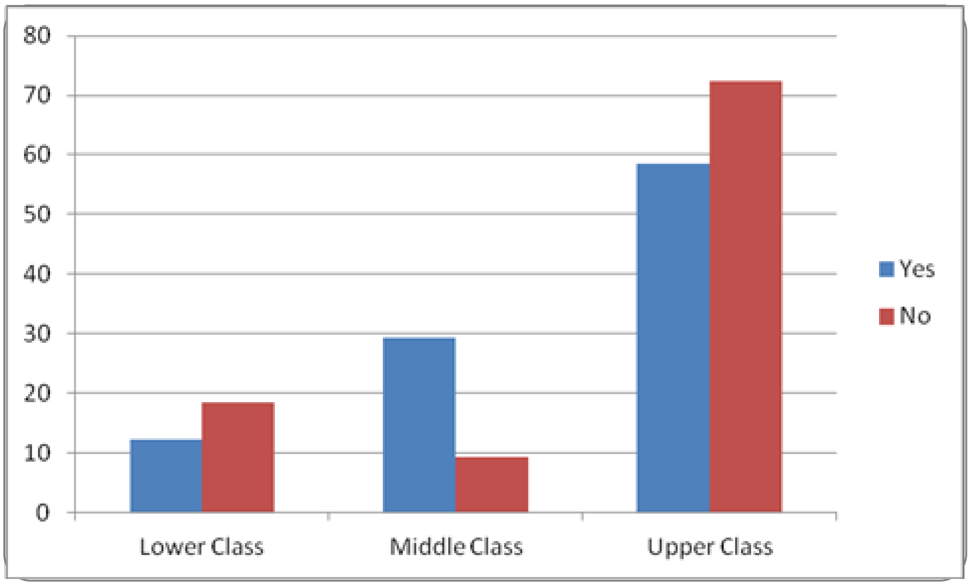
She mentioned that she knows that a government minister has a net meter (Quote 3.4.53 - Extract of researcher's notes from an interview with a resident expressing her frustration that she cannot get a net meter installed for her solar PV unit - NGO [1], 23/12/09).

Interviewer: What is the economic strata that you find your customers arising in?
"I would say that the high net worth customers will always be first in a market without policy and regulatory intervention. Whether they be large residential home owners or commercial owners" (Quote 3.4.54 - Extract from an interview with a solar installation company [SI3], 23/12/09).

Further evidence to this connection between socio-economic class and the installation and access to renewable energy technology is also demonstrated in the results of a survey questionnaire asking "Do you or anyone you know have any renewable energy installations at home?" Although the majority that responded said "No" (~70%) to the question of those that did say yes (~30%), the majority were of an upper class economic bracket based on income[52] (See Figure 38).

[52] Income categories: Lower class – $0 to $30,000; Middle class – $30,000 to $50,000; and Upper class – >$50,000.

Figure 38: Class breakdown of responses in percentage (%) saying yes or no to the question, ""Do you or anyone you know have any renewable energy installations at home?" (Author 2011)



The ability to access wealth also influences other lifestyle attributes such as ability to travel and access to educational opportunities and thus career choices. These in turn also seem to have implications on the ability of energy consumers to create change to energy use patterns in their home such as the use of renewables, which in many cases was directly impacted by this access to increased choices (See Quotes 3.4.55 – 3.4.58).

> *"The first time we were really interested was because we went to Israel many years ago (15) and there you cannot put up a structure without putting up solar panels. Then in Nova Scotia we know 1 or 2 people who are actually off the grid and they have turbine. In southern California there are big wind farms as well as parts of Spain"* (Quote 3.4.55 - Extract from an interview with a wealthy resident with a renewable energy system installed [RESI 2], 23/12/09).

> *Interviewer: Do you think that because you are well educated and travelled that has made a difference to your awareness of choice towards renewable energy?*
> *"No. First of all we do not tend to go to the same places, all the time. The only way to learn about the world is to go to different places. The size of the turbines are all enormous as you have seen in the UK compared to this thing but it wasn't the fact that one travels but you get an idea of what you can do. But I think if you travelled to Florida all the time for a holiday you are not going to see much of devices like this at all"* (Quote 3.4.56- Extract from an interview with a wealthy resident with a renewable energy system installed [RESI 2], 23/12/09).

> *The Respondent himself has travelled to Denmark, Germany and Canada to investigate renewable energy* (Quote 3.4.57 - Extract from researcher's notes during an interview with a CEO of a large business [LB 5], 23/12/09).

> *Interviewer: Is energy conservation important in the home?*
> *"Yes, it is. It becomes more important in terms of economics. Water as well. I (husband) equate the conservation to carbon emissions as well. BELCO emits carbon for the electricity we use and I see the big picture. I became aware of this big picture through my employment." (Wife)- "I do not think like that. Every day in the trade press I read I hear about topics like global warming, carbon limits, etc."* (Quote 3.4.58 - Extract from an interview with a wealthy resident employed in high level commodity trade [13H], 23/12/09).

However, having access to information may offer the ability to change such disparities, with the internet potentially playing a key role in this light (See Quote 3.4.59 - 3.4.60).

> *Interviewer: How did you educate yourself on the process of renewable energy?*
> *"We looked at it on the internet but also BELCO just started with Purenergy, so that's the way we went. I do not think there was anyone else that we knew about at that point. We figured that this was BELCO so there was a good tie in, plus they will buy back your excess so we will hopefully make something*" (Quote 3.4.59 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).
>
> *Interviewer: How did you obtain your equipment?*
> *He obtained his equipment from a catalogue. He uses the internet to keep current.* (Quote 3.4.60 - Extract from researcher's notes during an interview with an older resident with a renewable energy system self-purchased, self-installed and self-maintained [RESI 1], 23/12/09).

The relationship between energy and power may also cross over to influence public perception and thus public opinion. For example, along with the disconnect felt between residents and the utility, government interaction with people in terms of energy is also seen as low and increased interaction by either party may be negatively perceived if handled poorly (See Quote 3.4.61 – 3.4.63) . In turn this negative public opinion may play a role in how the local stakeholders respond to efforts to energy reform such renewable energy integration and potentially act as barriers to reform efforts directed at increasing renewable energy locally.

> *Interviewer: Do you receive any information in the home about energy use from the government or companies?*
> *"No, it's mostly from BELCO. I think it is just a case of them having to. They have to be seen as they are getting people to try and cut back on their energy usage. They keep sending out these pamphlets in the BELCO bill. I kindly look at them and think oh, yeah and then just chuck it in the trash. What gets me is that they still have their big profit sharing but they want everybody around them to cut back on their spending." (*Quote 3.4.61 - *Extract from an interview with a resident* [12H], 23/12/09).
>
> *Respondent 1H felt that those olden times provided good value for money in terms of electricity but felt that energy provision now was not fair* (Quote 3.4.62 - Extract from researcher's notes during an interview with a resident [1H], 23/12/09).
>
> *"Our challenge is that the general population doesn't believe us or sees BELCO as an eyesore. When we engage the residents, the people that live in this area do have issues with fall out and we do address their concerns but people don't want any more built at the Pembroke site. We are not going to solve this overnight but one of the things we have to solve is how do we get the buy in from the general population. I think that is what is lacking the most. The fact remains and it will be very interesting next year when the plant is being pushed over the next five years to get through the next phase and the gas turbine people see as a new plant, but it is actually only an emergency standby plant but in reality it isn't. We will submit phase two next year and it will be a medium speed diesel plant that won't be built on any of the footprints. I will be very curious what the reaction will be at that point in time. We can anticipate the reaction and we can speak to all the history of what we have done, but people only remember the last thing put in front of them and it is very unfortunate"* (Quote 3.4.63 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

3.3.3 Economic Accessibility and Business Uptake of Renewable Energy

The high cost of energy also impacted businesses and their operations as well. On a national scale, the high cost of energy acts as a potential threat to the wider economy as some larger businesses recorded having to operate aspects of their operations outside of Bermuda in order to protect their company. Socio-economic distinctions also seemed to play a role in affecting economic accessibility as a function of energy security in regards to local businesses. Research interviews suggested that paradoxically neither the size of business nor the role that energy plays in operations influenced the priority attached to energy costs as much as did the high cost of labour or cost of imported product (See Table 17), factors both impacted on by Bermuda's small islandness combined with its economically developed status.

Table 17: Priority of business cost across a range of different sized businesses (Author 2011).

Business Size	Business Type	Priority		
		High	Middle	Low
Large #1	Telecommunications - Landline	Staff	Equipment maintenance	Electricity
Large #2	Telecommunications - Mobile	Equipment	Electricity	Staff
Large #3	Construction	Staff	-	Electricity and Fuel
Large #4	Retail Grocer	Staff	Product cost	Electricity
Large #5	Retail Hardware / Home Supplies	Product	Salary	Electricity
Large #6	Hospital	Staff	Supplies, repairs and maintenance, office expenses	Energy
Medium	Retail	Inventory	Payroll, taxes and mortgages	Electricity
Small	Land Surveyor	Salaries	Equipment, maintenance, office expenses	Fuel (Diesel)
Small	Taxi	Fuel	License and insurance	Equipment maintenance

The case of small businesses like taxis particularly highlights the limitations on the role that renewable energy integration can play towards enhancing energy security for stakeholders of differing socio-economic backgrounds. Taxi owners who own and drive their own vehicles rather than rent vehicles from other owners are particularly vulnerable to high energy costs and fluctuations in the fuel market both locally and internationally (See Quote 3.4.64).

> *"When you look at things like the taxi drivers, and when the oil price went up and the fuel price went up, at times those guys based on our estimates were probably spending $6000-$8000 a year on fuel. For them, their rates, they change infrequently, which is probably an understatement, whereas BELCO are allowed this fuel adjustment every single month…If someone deemed it to be politically very important that truckers, taxi drivers, other people using fuel and energy be factored into the whole energy regulation, it would be there in the Energy Act. I am not saying that that is not regarded as important but the focus at the moment in terms of regulation is more on the electricity side. The transportation may come in due course"* (Quote 3.4.64 - Extract from an interview with an executive at the Bermuda Government Department of Energy, 23/12/09).

Renewable energy devices such as those most commonly being integrated in islands such as solar PV, solar thermal and wind devices have little or no bearing on business-related energy costs for these types of businesses, unless of course the vehicles are electric. When asked if they would consider driving an electric vehicle, a development that the electric utility welcomes but is optimistically cautious about, the taxi drivers interviewed responded "yes", so this is potentially an area that could be developed (See Quote 3.4.65).

> *Interviewer: Would you drive an electric vehicle?*
> *Taxi Business #2: "IF it helps to save fuel cost. "*
> *Taxi Business #3: "Yes. "*
> (Quote 3.4.65 - Extract from an interview with taxi driver [TB 1 & TB 2]).

However, the key incentive for any change in energy use for those in this small business, whether it be electric vehicles or use of a bio-derived fuel, was clearly costs and chiefly, that is, the cost of fuel (See Quote 3.4.66).

> *Interviewer: Would you feel comfortable using a fuel derived from plant sources (bio-fuel) in your taxi?*
> *Taxi Business #2: "I am willing to try anything new that would assist in saving money on fuel. "*
> *Taxi Business #3: "Yes. "*
> (Quote 3.4.66 - Extract from an interview with taxi driver [TB 1, TB 2 & TB 3]).
> Government Department of Energy, 23/12/09).

Unlike the electrical utility with their unpopular 'fuel surcharge', the local taxi drivers do not have a recourse to adjust their pricing structure as fuel costs rise and fall as a response to international market value. And unlike local residents who rely on transportation to go to and from work, taxi drivers cannot afford to adjust their modes and durations of transport as the accumulation of mileage is directly proportional to their profits. Unfortunately, it is the electricity generating industry and the use of electricity at home and at work that is garnering most of the attention in regards to potential energy reform on-island, especially in regards to the further integration of renewable energy devices. For renewable energy integration to be truly holistically a part of sustainable development efforts for Small Island States, the measures have to find ways by which these energy users who are often on the fringe can also obtain benefit from this type of energy reform.

It is clear that the priority attached to energy depends heavily on the commercial area that each particular business engaged in. However, although larger businesses invariably used more energy and thus had larger energy costs, businesses that were more vulnerable were potentially small businesses such as sole-owned taxis, as a function of their size, reliance on fuel for commerce and little adaptability in regards to energy reform changes such as renewable energy integration. These factors suggest that energy insecurity as a function of economic accessibility differs according to business size and/or type and thus, momentum towards renewable energy may not be as attractive to some businesses in the same regard. Other social-economic factors such as building ownership also affected issues with energy cost. While larger businesses tended to own their own facilities, small and medium size businesses tended to rent. Many of the small business owners did not even receive an electricity bill as it was included in the rent. This suggests that a drive towards the installation of renewable energy devices would probably not have as great of an impact on small business owner directly (See Quote 3.4.66 – 3.4.68) and would be more effective if targeted at businesses that owned their own facilities or at landlords directly.

> *The business owner has considered solar for home but not for* business (Quote 3.4.67 - Extract from researcher's notes during an interview with a small business [SB 1], 23/12/09).
>
> *Interviewer: Have you ever considered incorporating renewable energy aspects into your operations?*
> *"Yeah. Solar. I have considered solar power to replace the recharging aspect for the batteries. I haven't looked much lately so it hasn't progressed much. We do not have any demand for hot water, etc. so that is about it. At base, I haven't thought of anything else here either"* (Quote 3.4.68 - Extract from an interview with a small business [SB 4], 23/12/09).

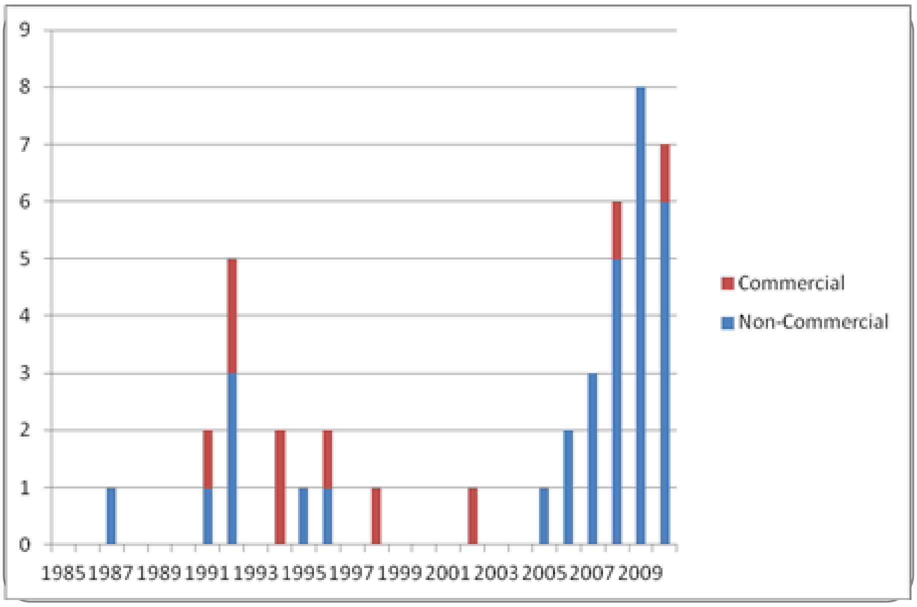
Although not necessarily as high a priority as other business costs, for those businesses with high energy costs, renewable energy may be able to play a role. However, although many businesses had considered the option, most found the purchase and installation costs to be prohibitive, citing not just material purchase as unattractive but also labour. This hesitance to installation of such devices can clearly be seen in a comparison between installations by commercial entities versus non-commercial entities (See Figure 39).

Companies reported that the current recessionary climate had affected their ability to invest in non-essential investments such as these types of energy initiatives. Renewable energy installations were particularly unattractive, as this would mean directing financial resources towards projects that were seen as potentially risky (See Quote 3.4.69 – 3.4.70). Businesses did not want to be first adopters nor even early adopters as there was too much uncertainty. This hesitance extended to the business services offered by some businesses as one insurance company interviewed stated that unknowns associated with the installation of renewable energy devices on Bermuda's buildings such as potential damage to roofs from hurricanes, non-standardization in the regulation and licensing of installers and the possibility of toxicity of the devices on potable water have led to them having to re-examine their insurance coverage of businesses with such devices.

> *The government has offered a temporary (3 year) rebate on the purchase of new equipment for certain areas as well as duty free for some areas. They have looked at solar PV but the cost is prohibitive ($100,000 investment), with the labour for installation being high as well the import of equipment needed for installation and a potential lack of reliability also being cited as barriers. There would be a 17 year payback and not enough is known about the technology to justify the cost to shareholders. There is also still not enough regulatory support for renewable energy systems use. It needs to be more financially viable. In the short term they are investing in energy efficiency rather than in renewable energy systems as a better investment due to the economy* (Quote 3.4.69 - Extract from researcher's notes during an interview with a large business [LB7], 23/12/09).

> *Interviewer: Has the use of renewable energy been a possible initiative on the radar at all?*
> *"We have talked about it. We do recognise that that would be a major retrofit and that would be very expensive. I am not exactly sure how much it would take to actually save us and get a payback"* (Quote 3.4.70 - Extract from an interview with a large business [LB7], 23/12/09).

Figure 39: Commercial versus non-commercial renewable energy installations over time (Data obtained from Bermuda Government Planning Department 2011).



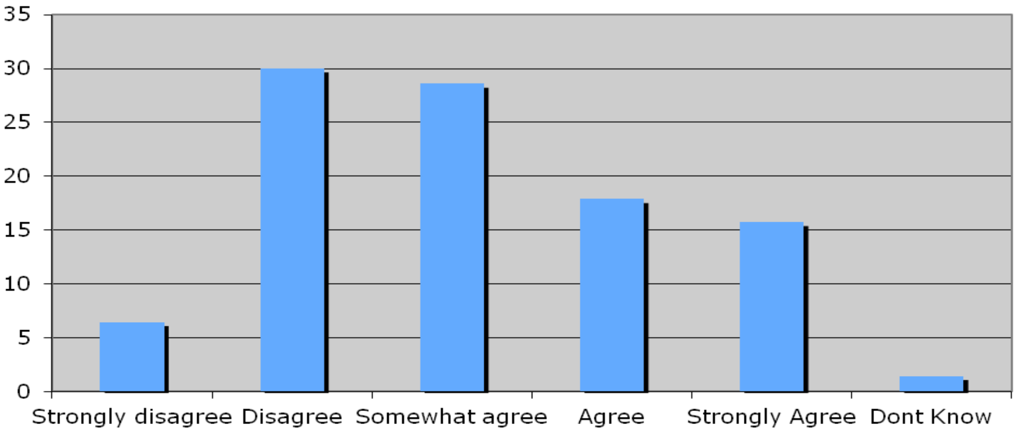
In many businesses were high energy costs was an issue, such cost still did not seem to act as a barrier to their ultimate affordability as they were managing to fund these costs. Instead, for those large businesses that had energy as a major cost concern, energy efficiency and conservation measures were actively being sought and put in place as an attempt to bring down energy costs (See Quote 3.4.71). However, the extent of energy investments was mostly to minor energy efficiency measures such as lighting changes (See Plate 11) and environmental control not directly related to alternative energy sources.

> *Major renewable energy devices such as solar PV arrays and solar hot water heating may be more difficult but things like LED lighting can be done* (Quote 3.4.71 - Extract from researcher's notes during an interview with a large business [LB 3], 23/12/09).

This again as in the case of residents, despite the high cost of energy on-island, suggests that the tipping point has not been reached for businesses whereby energy affordability becomes an issue of energy insecurity and results in movements towards increased renewable energy installation, an assertion supported by the low proportion of residents that indicated that their work place actively encouraged energy conservation (See Figure 40). It may also indicate that this tipping point of momentum towards increased renewable energy integration is potentially higher in 'urban and developed' Small Island States like Bermuda, for both the residential and commercial sectors.

Plate 11: New 'fluorescent tube style' LED lighting about to be installed in an office building (Author 2011).

Figure 40: Resident responses on the question of "Whether their work place encourages conservation?" building (Author 2011).



For these large companies, there was also evidence of decoupling of the links between the management of energy use, physical energy infrastructure and the cost of energy within the overall budgetary line of companies. As a result of the existence of multiple departments handling different aspects of operations, energy costs were in many cases were handled as a separate micro-budgetary line within a larger budget of a larger department such as Facilities and Maintenance rather than directly by departments or staff directly dealing with operational costs such as the Financial Director. This decoupled link between the costs of energy and the fiscal management of large companies may also act as a potential barrier to energy reform towards low carbon initiatives such as renewable energy integration as the impacts of energy use patterns are not directly tended to by those responsible for directing budgetary resources.

While many large businesses had energy redundancy infrastructure on-site, all such devices were dependent on fossil fuels. Renewable energy devices could play a further role in providing critical energy redundancy during times of need but also could play a role in reducing energy costs by similar energy buy-back schemes as has been mentioned in the case of residential properties. This would be specifically useful for the utility in times of peak demand but also could be used by businesses to achieve maximum savings by using either stored renewable energy or purchasing energy from the utility based around times of peak costs. Having power-purchase agreements that allow sale of power generated from renewables for higher costs will add value if such programs are introduced (See Quote 3.4.72). However, this has to be accommodated by a

> Interviewer: *Are you part of BELCO's standby program?*
> *"Not really. The way that the building was designed, all of the infrastructure was there for Phase 1 and Phase 2. Everything from this level and down was for Phase 1 and Phase 2 but they only built the actual phase 1 building. So all of the anchor bolts for phase 2 and including all of the infrastructure. So the generator was sized for powering the emergency services in both buildings. Consequently when BELCO goes out, the generator supplies the emergency services for this building which is only about 300-400 kW so it is supplying the life safety (emergency lighting), then the UPS, then the emergency MCC (motor control centre – which runs a small chiller which keeps the computer rooms cool), so its big enough to run the whole building but the way the building has been wired it would cost about $500,000 to supply the whole building but if we never build phase 2, it may be a consideration, because BELCO have their co-op program when they are hitting peak loads...and I worked at BELCO for 8 ½ years as an engineer so I know the systems"* (Quote 3.4.72 - Extract from an interview with a large business [LB4], 23/12/09).

regulatory regime that sets up these types of differentiated tariffs.

3.3.4 Conclusion

Potentially, there may be benefit for energy-dependent businesses of all sizes to find some method so as to enable the spreading of energy costs over the long-term, perhaps by purchasing future fuel and energy in advance, as a means to ensure stability. Similarly this also may be of benefit for the utility to achieve lower energy costs as well. For large scale building projects, there could be lessons learned from a recent example of a public-private partnership used to finance the building of a new local hospital (See Quote 3.4.73). Within such public-private partnerships that could be used to facilitate future large construction projects such as hotels, etc., energy innovations could be made one of the requirements requested from tender bids and thus the onus placed on developers to find cost effective ways to integrate renewable energy devices within these projects.

> *"In terms of tangible actions, we are not in a situation where we design and we build it. We are doing it PPP (public-private partnerships). We say that these are the functions and these are the standards we want and the firm comes in and says these are our designs. In there we have set down certain standards on energy. We do not know how they are doing it but when they come, we than measure them to the standards we set and choose the best model. There is then an incentive for them to be innovative to choose the best energy models"* (Quote 3.4.73 - Extract from an interview with an executive at the sole hospital, King Edward Memorial, 23/12/09).

Another key consideration here is the real evidence presented in this section that any successful regulatory environment or private-public initiatives that facilitate the increased integration of renewables, particularly amongst those less economically-able, can serve as to significantly level the economic playing field regarding not only energy but wealth in general. This can only be facilitated by the willingness of the utility to allow entry into the electrical market by a distributed network featuring residents interconnected to the grid and who are offered reasonable rates for any energy sold. As stated, care must be taken to not only not allow such schemes to become dominated by those who need them least but also to have initiatives in place to facilitate participation by those who may not have the initial capital to do so (See Quote3.4.74 and 3.4.75). Equity such as this is a key factor in the sustainable development paradigm.

> *The Respondent felt that residents are aware on the amount of electricity they use but they see the initial investment in renewables as a challenge. He uses a cost-savings over time energy report to rationalise to customers the savings they will make over time. He saw the investment in solar PV as a good source of income for seniors and an investment in their own home* (Quote 3.4.74 Extract from researcher's notes during an interview with a resident with a solar installation company [SI 1], 23/12/09).

> *"For example, let's use Haiti for a market. A person does not have electricity and so what happens in Haiti is that they do not have to use a charging station and so literally you will see a guy on a bike and on the end of the bike you will have a wheel and he will have this thing going around and all these plugs so that Joe Average will have the cell phone and charge it. Because the average person does not have electricity. Even in Jamaica, that becomes a huge part of the business – charging the mobile phone"* (Quote 3.4.75 Extract from an interview with a large business [LB 2], 23/12/09).

3.4 Environmental Accessibility (Acceptability) as a Function of Energy Security

As environmental implications associated with the global energy problem have become more apparent, considering how energy security is influenced by environmental concerns has also become important. As this consideration of environmental concerns has mainly to do with how acceptable society's energy choices are in regards to their impact on the environment, this particular area of energy security has been termed by some under the broad heading of 'acceptability' (APERC 2007; Kruyt et al. 2009). As with all the different components of energy security, this component can be considered from varying perspectives of scale, including the global, national and local.

On all these differing scales, renewable energy integration is thought to be able to play a key role in increasing the environmental accessibility of energy generation specifically as an alternative to traditionally used fossil fuel generation methods. For Small Island Developing States looking to improve their provision of energy generation towards sustainable development, generation of energy from renewable energy presents an attractive alternative to developing an energy services infrastructure founded on a more environmentally sustainable platform than those traditionally used by developed jurisdictions.

However, it needs to be understood further how this same assumption holds for Small Island States that are 'urban and developed' like Bermuda and how their unique characteristics impact on environmentally-related aspects of national and local energy security concerns.

3.4.1 Fossil-fuel Use

From the national/local perspective of environmental acceptability, the high demand for energy-dependent services in Bermuda such as electricity and transportation due to its 'urban and developed' nature already challenge notions of environmental acceptability due to the island's dependency on non-renewable fossil fuels to meet these energy needs. Additionally, the use of these fossil fuels has specific local environmental impacts such as the production of harmful atmospheric emissions (Peters 2004) as well as potentially contributing to both groundwater and aquatic pollution (Bacon et al.

2003) which can impact small islands more significantly due to these locales having uniquely sensitive ecosystems. An example of this relationship between small islandness, environmental acceptability and characteristics inherent in Bermuda's 'urban and developed' nature is the necessity for the electric utility to engage the use of less efficient and higher polluting gas turbine generation units when they are unable to cope with higher electrical demand than normal during peak times (See Quote 3.5.1).

> *"Last year, we were forced to submit a particular phase, which we refer to as the emergency option which was the gas turbine complex. So the large scale development of the site has been put on hold and we ultimately submitted and got approval for the gas turbine expansion project, which will only get us another 2-3 more years beyond the 2011 timeline"* (Quote 3.5.1 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

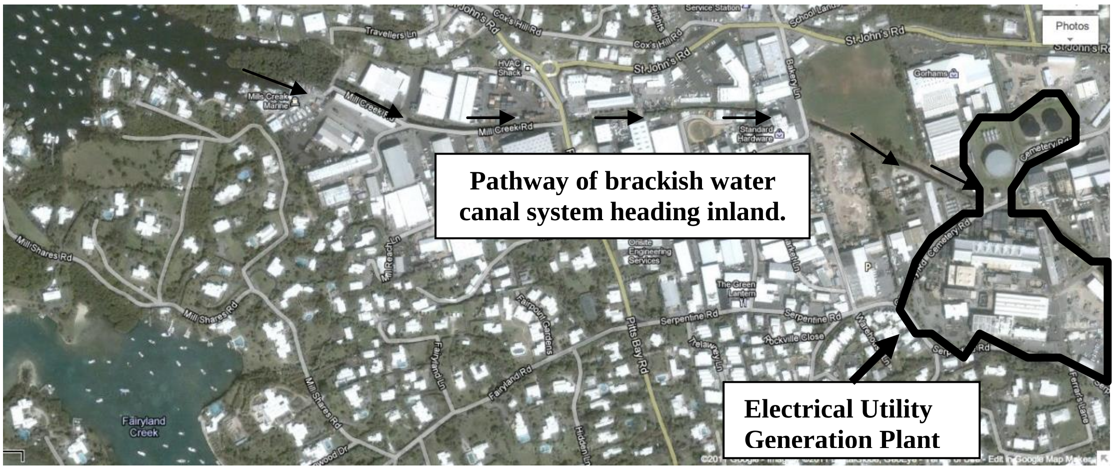
On 'urban and developed' islands like Bermuda, natural ecosystems are already significantly under threat due to development and the impact of fossil fuel use, both in terms of environmental impacts from generation processes as well as impacts associated with fossil fuel storage and energy generation physical infrastructure, can further exacerbate this problem. The further integration of renewable energy, both centralised and distributed, can greatly assist in the further mitigation of these environment associated challenges as an alternative to this fossil fuel use.

3.4.2 Weather and Climate Change

The issue of climate change also serves to intersect energy security concerns with environmental considerations. The global use and dependency on fossil fuels has resulted in global environmental problems, such as atmospheric pollution and global climate change, which often have impacts at the national/local level. Small Island States stand to be disproportionately affected on a local scale by such global environmental changes (Schneider 2001; Parry et al. 2007; Hoegh-Guldberg 2011) due to their inherent vulnerabilities as described previously. Due to their enhanced state of vulnerability, Small Island Developing States are thought to be even more susceptible to these impacts (UNESCO 1996; Barnett 2001; Strachan & Vigilance 2008). However, small islands like Bermuda may also have vulnerabilities to climate change that may be enhanced by their 'urban and developed' nature.

Small islands are at risk due to sea level rise as an implication of climate change. For 'urban and developed' Small Island States, issues relating to fuel transport along pipeline networks and fuel storage, which are already compounded by space constraints, stand to be exacerbated by any sea level rises associated with climate change. In recent years, there have already been increases in seawater intrusion and flooding along the canal area where the utility's infrastructure is located, an area already prone to frequent flooding problems due to its low-lying nature (See Figure 41).

Figure 41: Map showing location of electrical utility generation plant and the proximity of a brackish water canal system (Aerial photo by Google Maps 2011. Author's demarcations.)



Global climate change is also predicted to increase the occurrence in severe weather events such as hurricanes (Knutson & Tuleya 2004; Tompkins 2005; Parry et al. 2007), which again will disproportionately affect many Small Island State locations (ibid), many of which are already vulnerable to such events due to their geographic locations. As an 'urban and developed' Small Island State, Bermuda already has a state of heightened energy demand and the impact of such natural but extreme weather events may be even more significant. Residents are already quite conscious when it comes to hurricane outages, especially in terms of water provision, lessons learned from years of traditional hurricane management. Qualitative research data suggests many residents make domestic energy choices in consideration of the impact of hurricanes, with natural gas rather than grid-provided utility electricity being the preferred choice in these instances (See Quote 3.52 – 3.5.3).

> *Interviewer: In the home, what are the main types of energy used?*
> *"Electricity with a gas stove. The gas stove came with the house but I would have gone with the gas stove anyway due to hurricanes"* (Quote 3.5.2 - Extract from an interview with a resident [14H], 23/12/09).
>
> *Electricity and gas (stove). This was a conscious choice for the gas due to hurricanes* (Quote 3.5.2 - Extract from researcher's notes during an interview with a resident [14H], 23/12/09).

For many businesses, being without power is not an option, both for those catering to international clientele and those that are considered critical services in terms of emergencies. Renewable energy may be able to play an important function for both businesses and residents in increasing resiliency to energy supply during extreme weather events precipitated by global climate change by acting as both a method of redundancy as well as an alternative to the incumbent fossil fuel generation depended on by the utility (See Quote 3.5.4).

> *"We lost all of our swimming pool water, all of our tank water, lost everything in the fridge freezers, everything. They brought in stainless steel ones the following year but I wasn't prepared to spend that sort of money again. So we heard about the renewables coming in so we did some research and chatted and decided this was the way to go"* (Quote 3.5.4 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).

The threat of such extreme weather events also has energy security impacts linked to socio-economics as some larger businesses reported that they were given priority in receiving fuel supplies in the advent of power outages resulting from hurricane disaster. These hurricane outages may affect the less economically able more severely as food tends to spoil and thus they are not as easily able to replace their limited food supplies. This again reflects important linkages between aspects of energy security and socio-economic issues relating to sustainable development. Renewables may help to level the playing field by providing a method by which energy redundancy may be equitable across the board.

However, even for renewables, the effect of weather and climate has energy security implications. Renewable energy devices such as wind turbines (See Plate 12) and roof-mounted solar devices may be more significantly impacted by hurricanes due to their exposure to the elements when compared to large generation plant like diesel turbines, although the electrical grid itself has exposure. Systems need to be able to be taken down in these types of conditions and this may present a barrier for those who cannot afford the danger of making such a high investment only to have it damaged in a storm. Devices have had to be island storm-proofed, for example as in the case of resident owned wind turbine unit which had to have extra deep concrete footings to ensure stability. The highly corrosive atmosphere due to excess salt spray can affect system components with rust severely. Weather patterns may affect the generation rates for solar but residents with renewable systems installed have shown no real decline in power generation for PV.

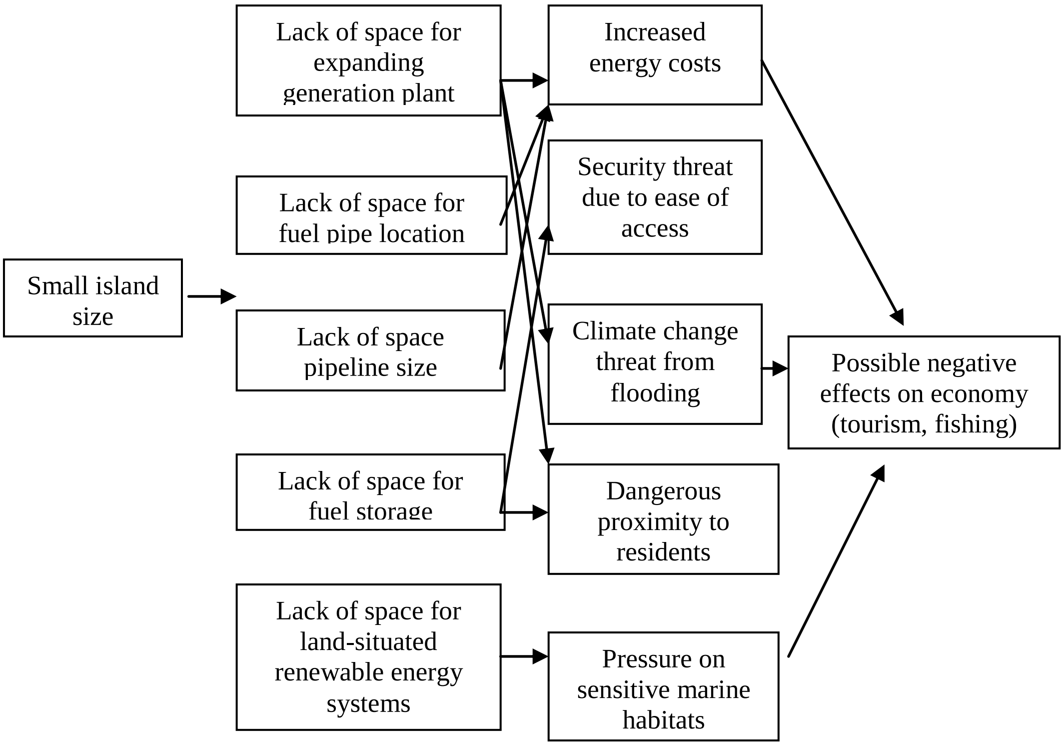
Plate 12: Wind turbine erected at a wealthy residents home. It was installed with a fast dismount mechanism for use in case of approaching storms or hurricanes. (Author 2011).

3.4.3 Environmental Geographies

Environmental geographies associated with 'smallness' also impacts on 'urban and developed' Small Island States disproportionately in regards to energy security and environmental acceptability (See Figure 43). The energy security of Small Island States is already impacted in many ways by their small size. The island's small size has also made grid construction and energy distribution via this grid network easier. This may serve to contribute to the technical lock-in already acting as a barrier to energy reforms such as the integration of renewable energy systems. This was also indicated from a technical accessibility point of view in regards to the space-constraint pressures put on import fuel transport and fuel storage capacity and safety. This lack of space was also manifested in the lack of space for distributed generation/ redundancy mechanisms for businesses. Such space constraints unfortunately may also extend to the integration of renewable energy systems, whether on an island-wide basis or in the use for entities like the utility. This has led to ideas of using offshore coastal spaces for the possible situation of large renewable energy plants which for islands are a potential threat due to aesthetics concerns as well as the marine habitat sensitivity, which can affect both tourism and businesses like fishing, a factor that influences opinions and perceptions on the ability of large scale renewable energy to ever play a significant role on-island (See Quote 3.5.5.).

> Interviewer: What types of renewable energy initiatives does Greenrock support?
> "Bermuda is never going to have large-scale renewable facilities (Quote 3.5.5 - Extract from an interview with a NGO " [2], 23/12/09).

Figure 42: Energy security concerns and their implications on environmental accessibility (Author 2011).



The 'urban and developed' nature of the island is also resulting in additional pressure on facilitating affordable and available housing needs, in particular for Bermuda's economically disadvantaged population. In response, the Bermuda Government has put in place several housing initiatives many of which have led to the construction of large multi-unit apartment complexes (See Figure 44). These types of dwellings put additional pressure on the already over-strained energy supply. They can also act as a barrier to efforts towards sustainable development as they are not conducive to the integration of renewables or to the use of traditional sustainable resource harvesting such as roof-top rain water harvesting.

Figure 43: Large multi-dwelling apartment complexes being constructed as affordable housing options for Bermuda's considerably strained housing stock (Author 2011).

The strain on available space on ‘urban and developed’ small islands means that NIMBY[53] issues can also be quite significant. This is already the case for fossil fuel generation and evidence suggests that this might be the case for renewable integration, particularly for large-scale renewable initiatives. As the integration of renewable energy is not wide-spread, there is still mostly notoriety attached to the devices currently (See Quote 3.5.6 – 3.5.10). However, as integration becomes more widespread this may change.

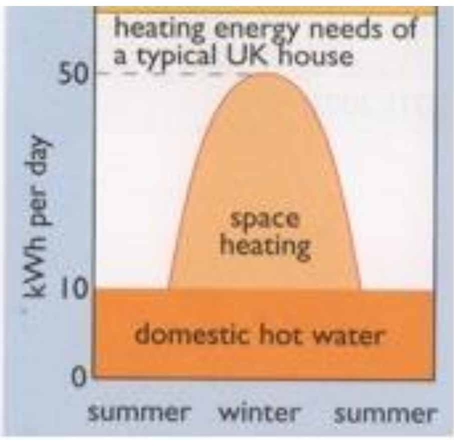
> *He has not had any NIMBY feedback from his neighbours or complaints about the aesthetics* (Quote 3.5.6 - Extract from researcher’s notes during an interview with a resident with a renewable energy system installed [RESI 1], 23/12/09).
>
> *“Then a lot of our friends are looking very interested. We have a lot of patients asking, "Can I come round and have a look?" A lot of people want to have a look*
> *Interviewer: What has been the feedback from others such as neighbours?*
> *There has been only one negative feedback. That was young lady who lived up the hill. It was not the solar panels; it was just the wind turbine. She hates it. Not because the noise, just because the turbine is there. Really strange for young people. You know the milk float that delivers milk. You know the sound it makes. That is about the sound the turbine makes. The casuarinas trees actually make more of a noise (during the wind). Our immediate neighbours have been fabulous. There was a worry at the beginning of the aesthetics of the turbine but really you only see it briefly where ever you are“* (Quote 3.5.7 - Extract from an interview with a resident with a renewable energy system installed [RESI 2], 23/12/09).
>
> *Interviewer: What has been the feedback from others - neighbours, etc.?*
> *“All fairly impressed, especially with the look of our installation“* (Quote 3.5.8 - Extract from an interview with a resident with a renewable energy system installed [RESI 3], 23/12/09).
>
> *Interviewer: Have there been any individuals that have objected to your projects?*
> *“There has been one individual. Most people do not even know are solutions are there. But when there is an outage everybody wants to come over“* (Quote 3.5.9 - Extract from an interview with a solar installation company [SI 3], 23/12/09).
>
> *“Negative – some dislike the visual impact on the neighbourhood“* (Quote 3.5.10 - Extract from an interview with a solar installation company [SI 4], 23/12/09).

[53] NIMBY is an acronym for “not in my backyard”.

3.4.4 Availability of Renewable Energy Resources as a function of Environmental Accessibility

The desire to use renewable energy and any benefits to be potentially accrued from its integration cannot be realised without the physical renewable energy natural resource being available in the local environment. While the current use of various types of renewable energy devices in Bermuda seem to attest to the occurrence of the necessary physical renewable energy resource being available, factors associated with the natural environment and climate of Bermuda will both affect the ability to harness the resources as well as how the renewable energy resource can be used to accommodate local consumer energy use trends and behaviours. This assertion is confirmed from data recorded by the electrical utility in regards to its current use of fossil fuels to generate electrical energy. Electricity demand tends to peak during the summer months, coinciding with the hottest times of the year on-island (See Figure 46). This summer demand peaking trend viewed in conjunction with Bermuda's low ratio of average heating degree days to average cooling degree days per year (BELCO 2006), suggests that cooling via air conditioning drives a big part of this load share. When daily average peak demand is considered, the data shows distinct peaks at evenings during the winter months, whereas summer months reflect more of a consistent demand over the period of the day (See Figure 47). This is opposed to energy demands in other jurisdictions like Europe where peak demands generally occur during the winter and evenings (Yohanis et al. 2008) (See Figure 45 also).

Figure 44: The availability of solar radiation and the seasonal energy demand for heating in the UK (Taken from Boyle 2004).



The recognition of these types of relationship between peak electrical demand and the heating/cooling needs of the island's residents reflects instances whereby the availability of physical renewable energy resources need to be examined in order to ascertain their best role in regards to meeting these types of energy demand needs and patterns. Interviews with residents and businesses alike also seemed to support relationships between climate and environmental conditions and energy use patterns (See Quote 3.5.11 – 3.5.14).

> *Her house gets very cold and would like to improve her heating* situation (Quote 3.5.11 - Extract from researcher's notes during an interview with a resident [10], 23/12/09).

> *"It can get damp in the winter time and so I have a heater that keeps the dampness out. I have it set at 65 degrees so the temperature doesn't go down to low"* (Quote 3.5.12 - Extract from an interview with a small business [SB 4], 23/12/09).

> *"Electricity is most important in summer for cooling"* (Quote 3.5.13 - Extract from an interview with a small business [SB 1], 23/12/09).

> *Interviewer: Is there a big change over the summer and winter seasons? Does comfort take precedence over operations or vice versa?*
> *"Operations take precedence. We have to conserve costs during the summer and winter, despite the weather. This building gets hot due to its orientation. But because of its older design, we have to make adjustments like these shutters. What we do here, you cannot do in planning today"* (Quote 3.5.14 - Extract from an interview with a large business [LB 7], 23/12/09).

Figure 45: Monthly peak demand (MW) (BELCO 2006).

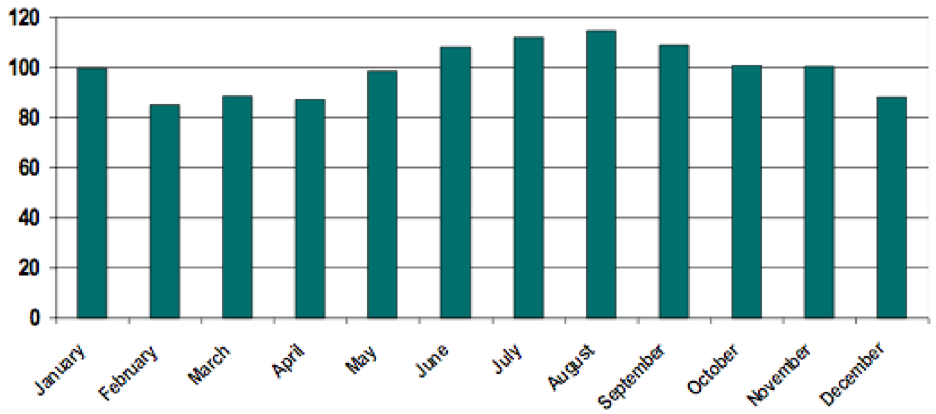
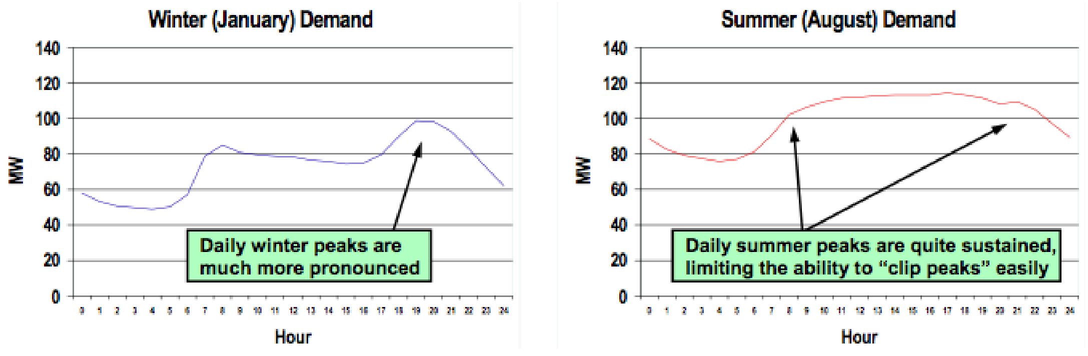


Figure 46: A comparison of a January demand day compared to a August demand day (BELCO 2006).



Bermuda's 'urban and developed' nature may also affect energy use patterns, specifically in regards to the increase in dwellings and roads as a function of increasing urbanisation, as materials such as concrete and asphalt as well as the nature of urban spatial design can act as heat sinks causing a knock-on effect resulting in increased use and dependency on energy dependent cooling (Gallo et al. 1995; Zhang et al. 2010). In view of this relationship between energy use patterns and the natural climatic conditions of the island, it is important to consider the environmental availability of the physical renewable energy resource so as to accurately determine the role that renewable energy integration may be able to play.

3.4.4.1 Solar Resource

An investigation into the solar resource available on the island reveals distinctive trends that are useful in the consideration of how renewable energy can play a role in addressing rising local energy demand. The first key factor to be considered in regard to the solar resource available on-island is the amount of solar energy that potentially can be harvested in Bermuda's geographic location. Solar energy arrives in the form of the sun's rays and is usually expressed as average irradiance in Watts per square meter (W/m^2). For this research, the year 2008 was used as a model year as a full year of instant solar irradiation data was obtainable from the Bermuda Weather Service over this period. Calculated total monthly, total annual solar irradiation, monthly averages and monthly peak solar irradiation based on this instant solar irradiation data is shown in Table 18. Although the data obtainable for other years (i.e. 2007 & 2009) was not fully available, when the available 2007/2009 data that was accessible was compared to that for 2008 (See Figure 47), the data curves (monthly average irradiance) closely matched suggesting a defined annual pattern of solar irradiation affecting the island.

Table 18: 2008 Solar Irradiation Data (Data obtained from Bermuda Weather Service. (Author's own calculations & table.)

Month	Total (W/m^2)	Monthly Average (W/m^2)	Monthly Peak (W/m^2)	Monthly Average (kW.h/m2)
January	5283771.4	119.0	1029.4	88.5
February	6410081.3	154.4	1152.4	107.5
March	7843145.7	194.5	1394	144.7
April	10301243.6	238.6	1347.2	171.8
May	10800829.8	241.9	1391	180.0

June	11788425.6	273.0	1314.2	196.6
July	13860673.2	311.6	1418.7	231.8
August	12022706.7	254.2	1273.2	189.1
September	9343514.7	216.3	1195.8	155.8
October	7860037.2	176.2	1099.2	131.1
November	5751099.2	133.1	939.3	95.9
December	4950754.5	112.2	857.8	83.4
	Total: 106,216,282.90	**Average: 202.1**	**Average: 1,201.0**	**Total: 1776 Average: 148**

Figure 47: Monthly average solar irradiation data (W/m^2) for 2007 (incomplete data set), 2008 and 2009 (incomplete data set) (Data obtained from Bermuda Weather Service. Author's own calculations & chart.)

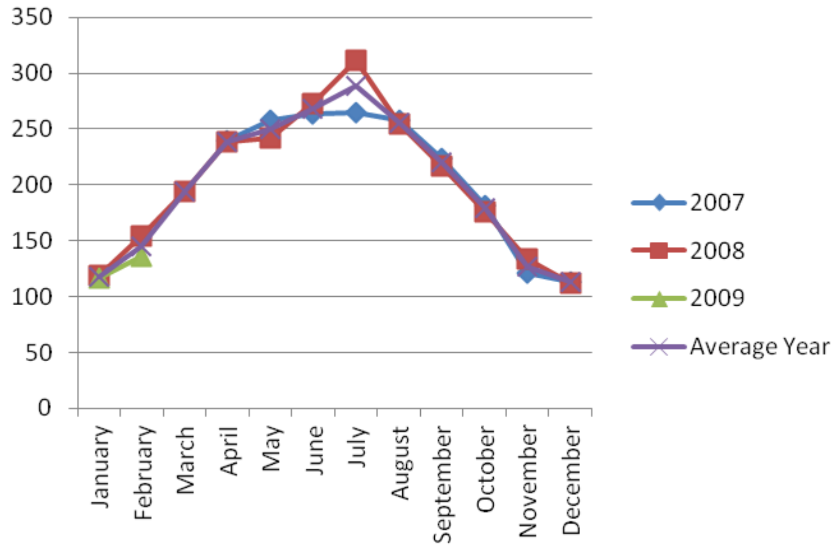
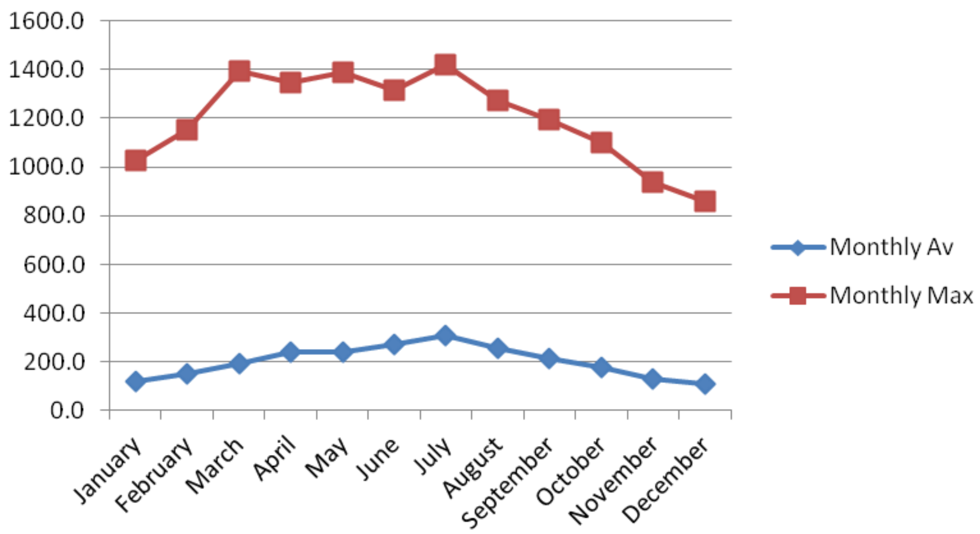


Figure 48: Monthly average and monthly maximum solar irradiation (W/m^2) for 2008 (Data obtained from Bermuda Weather Service. Author's own calculations & chart.)



When the curve for the 2008 monthly average irradiance is observed (See Figure 49 & Figure 50), a clear trend can be seen of rising solar energy availability through the summer months that peaks at mid-summer (July). In regards to solar irradiation patterns on a daily basis, there is also a clear trend in rising solar availability over the morning, peaking at mid-day and falling towards evening (Figure 51). This mid-day peaking and summer peaking trend are important factors in understanding the role that renewable energy from solar may be able to play on-island, specifically in regard to a differentiation between the role of this energy for residents versus the role for businesses.

Figure 49: Monthly average solar irradiation (W/m²) for selected months over 2008 (Data obtained from Bermuda Weather Service. Author's own calculations & chart.)

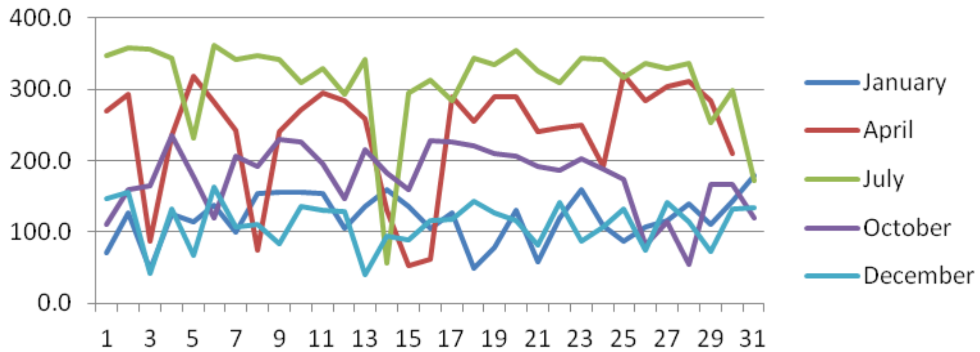
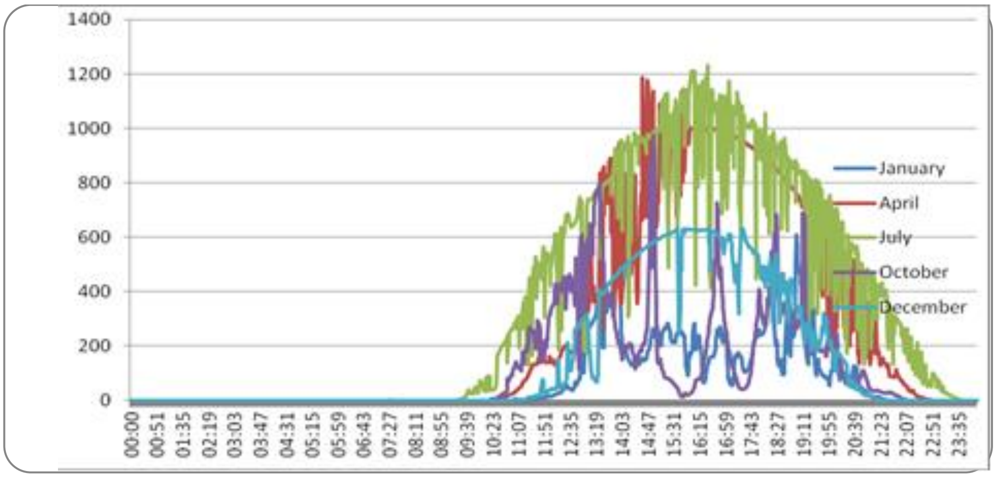


Figure 50: Daily pattern of solar irradiation (W/m²) on selected days (1st of the month) over 2008 (Data obtained from Bermuda Weather Service. Author's own calculations & chart.) N.B. Local time = - 4 hours.



Considering the two factors of renewable energy availability and the electrical demand needs of locals together, this suggests that for residents that have solar photovoltaic devices installed at their home, assuming a daytime employment pattern of these residents when they will not be at home, there will be a need to either store the renewable energy obtained from the solar photovoltaic devices using batteries so as to be used during the morning and evening times when home demand is expected,. The amount of battery storage needed is directly related to the amount of sun hours needed to store for during photovoltaic energy generation periods. Considering Bermuda's significant amount of sun hours (See Figure 52), as well as fluctuating solar irradiation even on a daily basis (See Figure 53), a large amount of battery storage capacity is needed (e.g. Plate 7) which also will incur quite a large battery purchase cost. This suggests a direct kilowatt to kilowatt exchange through a net meter arrangement with the electrical utility is potentially more desirable.

Figure 51: Monthly sun hours (Data obtained from Bermuda Weather Service. Accessed online (2011): [http://www.weather.bm/]. Author's own chart.)

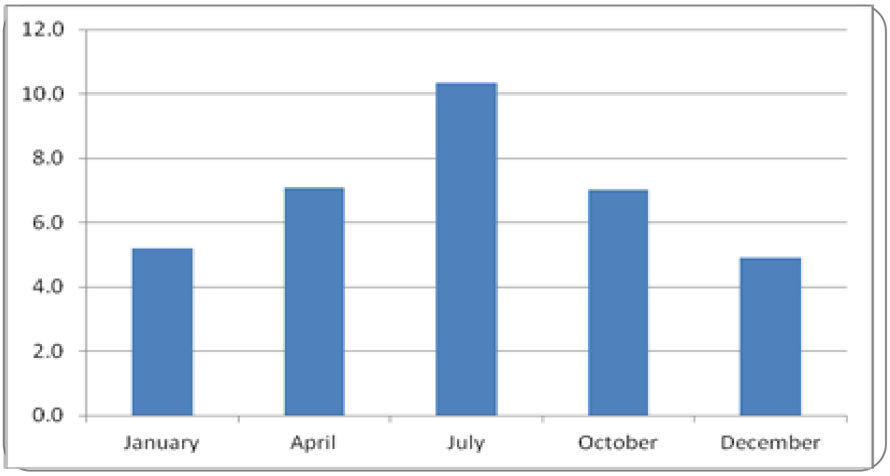
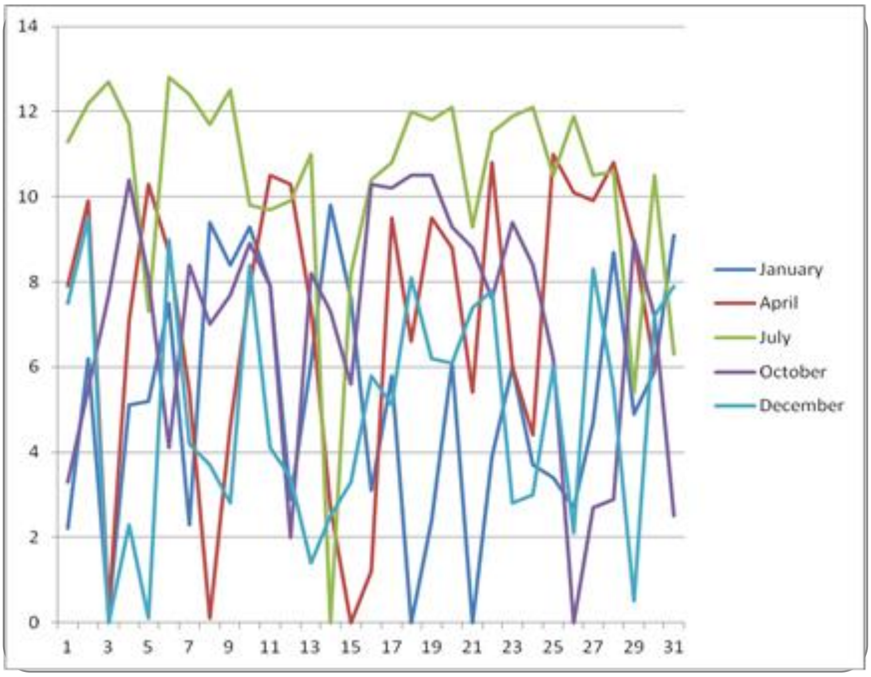


Figure 52: Sun hours per day (Data obtained from Bermuda Weather Service. Accessed online (2011): [http://www.weather.bm/]. Author's own chart.)



With this in mind, any resident working away from home that can install and make use of a solar photovoltaic device would potentially incur great benefits as the devices could generate energy over a significant time period during the day time when home use is low, especially during the summer months. These benefits could be even further enhanced if the home is modified to ensure that the most energy efficient devices are used and that energy conservation measures are enforced. For businesses, this scenario differs as peak demands generally occur during the day from the combined needs of lighting, computers and cooling, etc. and as such, business energy demand could be better facilitated by either the direct use of solar energy during the day or by a net meter arrangement. Again, the use of energy efficiency devices and energy conservation measures would be important in ensuring that as much benefits as possible is obtained from any energy generated from solar photovoltaic devices installed.

3.4.4.2 Solar Photovoltaic Whole Island Electric Demand Case Study[54]

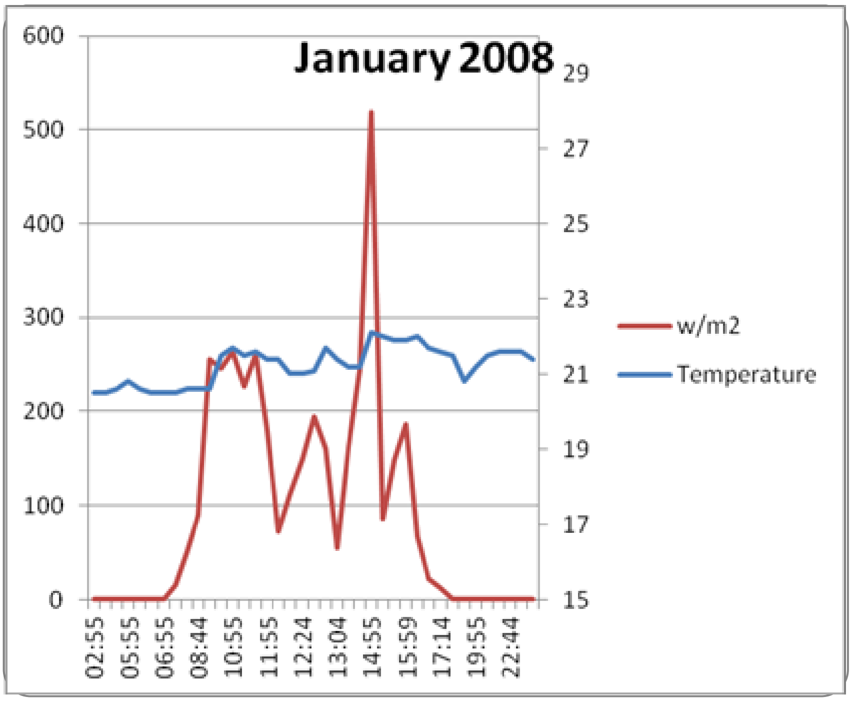
Although it is not in the scope of this research to conduct a detailed electrical output case study of local solar photovoltaic generation potential in detail, assessing the power output that could be attributed to a generalised model of a solar photovoltaic installation in Bermuda may be useful. While solar power is measured in W/m^2, solar energy is measured as a function of this solar power per unit of time, such as in Watt-hours per m^2 ($W{\cdot}h/m^2$). While equatorial areas have the highest annual total solar radiation at over 2000 $kW{\cdot}h/m^2$ (Boyle 2004) and areas like northern Europe having considerably lower values at a typical 1000 kWh/m^2 (ibid), Bermuda's calculated annual solar radiation was 1776 $kW{\cdot}h/m^2$. The average solar radiation for a typical clear July day in Europe is between 4.5–5 $kW{\cdot}h/m^2$ (ibid) whereas in Bermuda the value was 7.5 $kW{\cdot}h/m^2$. In the winter months in Europe, the average solar radiation per day was 0.5 $kW{\cdot}h/m^2$ (ibid) while in Bermuda it was 2.3 $kW{\cdot}h/m^2$.

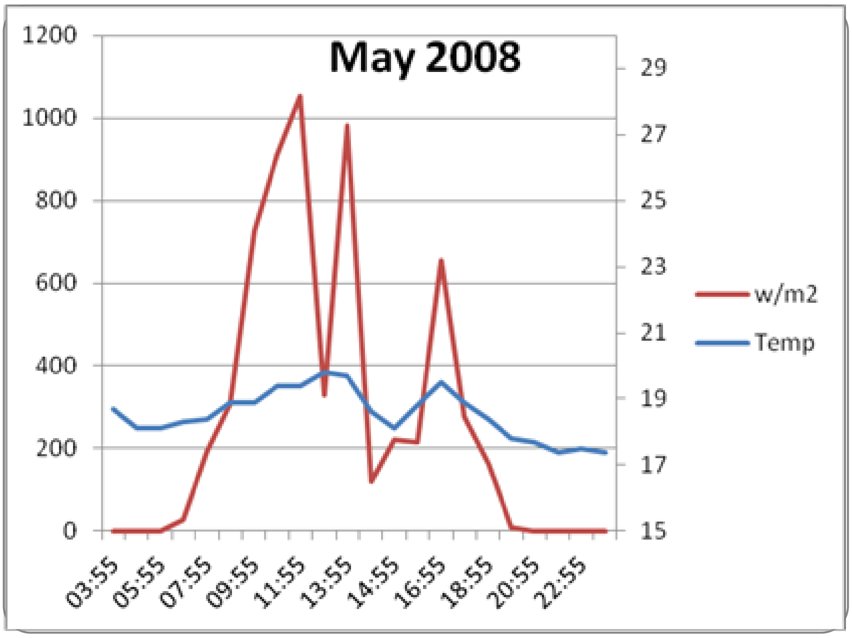
This type of data is important as it suggests expectedly that Bermuda, despite its northern mid-Atlantic positioning, can be more closely compared to southerly jurisdictions such as the Caribbean than it can to northern ones such as Europe. This

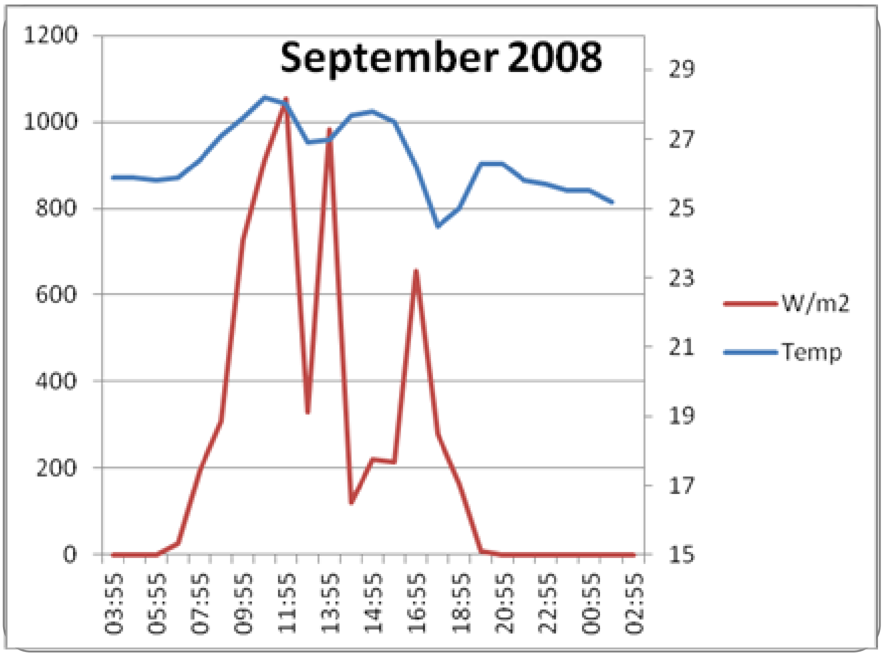
[54] All solar irradiance calculations involving Bermuda cited here in this section have been independently calculated by the researcher unless otherwise referenced. See methodology section for calculation procedures. Calculations have not been peer verified.

factor is important in that its recognition can be used to indicate what types of renewable energy devices may work best in the specific irradiation conditions of the island. The data on winter versus summer irradiation suggests that solar photovoltaic use can occur throughout the year. Factors such as ambient temperature are important to understand as well as it may affect both the performance of solar photovoltaic panels and solar thermal panels. Some types of solar photovoltaic panels such as those constructed using thin film technology perform better in higher temperatures when compared to panels constructed using amorphous silicon materials (Amin et al. 2009) whereas solar thermal panels need sufficient infrared energy from the sun to be effective. With this in mind, although solar insolation may be lower on average during the winter months in Bermuda, a snapshot comparison of a day in January, May and September 2008 (See Figure 54) shows that temperatures can still be significant even in the winter months. This reflects the usefulness of solar thermal heating applications to the island for the generation of hot water.

Figure 53: Solar irradiation and temperature profile of January 1, May 1 and September 1, 2008 (Data obtained from Bermuda Weather Service 2011. Author's own calculations & charts).







Using the solar irradiation data obtained from the Bermuda Weather Service, the total irradiation for the year 2008 was 106,216,282.90 W/m^2. Taking this total irradiance figure divided by the total number of sun hours (2473.832) for 2008, this amounted to some 42 kW·h/m^2 for the island. Hypothetically, if the whole of Bermuda (53.2 km^2) could be used as one large 100% efficient solar panel that would equal 2,284 MW·h able to be generated. However solar panels are not 100% efficient and using for example a top of the line SunPower® solar photovoltaic panel that is being sold in Bermuda[55]

55 http://www.purenergy.bm/download/sunpower_230-solar_panel.pdf

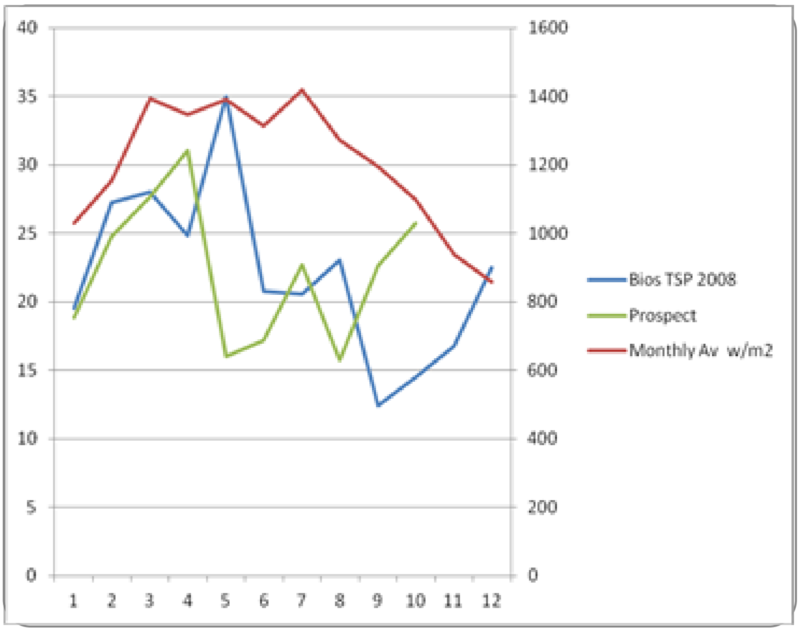
currently with an efficiency of 18.5% the total kWh/m^2 possible to be generated would be 422 MW·h, still a massive amount of energy.

In reality, the whole area of Bermuda is not available for use as a solar panel and roof area design in Bermuda offer more potential area due to aspects such as slanting roof structures. Using a 2009 Bermuda Planning Department case study by Worboys (2009, 42), an estimate of available and suitable roof area for solar photovoltaic panel installation in Bermuda would be 421,475 m^2. Using the solar panel efficiency proscribed in conjunction with this roof area and the available solar energy in 2008 as factors, Bermuda could potentially generate 3,348 MW·h. BELCO's residential demand according to the 2009 Bermuda Energy Green paper was 300,000 MW·h suggesting that generation of energy from solar photovoltaic panelling alone could impact significantly on Bermuda's electrical demand. This is obviously just an estimate, as variations on the performance of solar photovoltaic panels due to issues such as location will obviously affect solar photovoltaic yields. The estimate of available roof area available will also be significantly detracted from as currently the Bermuda Department of Planning only gives current permission for 7.4 m^2 of solar photovoltaic panel to be installed per building without the need for planning permission, surely affecting any initial desire to have such devices installed (Bermuda Government 2011, p. 30).

There is also a suggestion that unique factors such as atmospheric aerosols (aerosol optical thickness) may also impact the performance of solar photovoltaic panels and very isolated oceanic islands like Bermuda may be heavily affected by such factors (Kishcha et al. 2010). Additionally, particulates such as ocean derived salt spray and locally generated or atmospheric PM-10 particles may also have a disproportionate effect on the performance of solar photovoltaic devices on very small islands like Bermuda. An examination of any correlation between atmospheric total suspended particulates for 2008 in Bermuda in comparison to the monthly average solar irradiation on-island (See Figure 55) was carried out and yielded no significant correlation[56] between these two factors.

[56] Calculated t-value of 0.007741463 which indicates a very weak to non-existent correlation and is far below the 0.5760 critical value for alpha at 95% confidence level needed to imply significance.

Figure 54: Total suspended particulates at two locations (BIOS & Prospect) compared to monthly average solar irradiation (Data obtained from Bermuda Institute of Oceanic Sciences 2011. Author's own chart.)

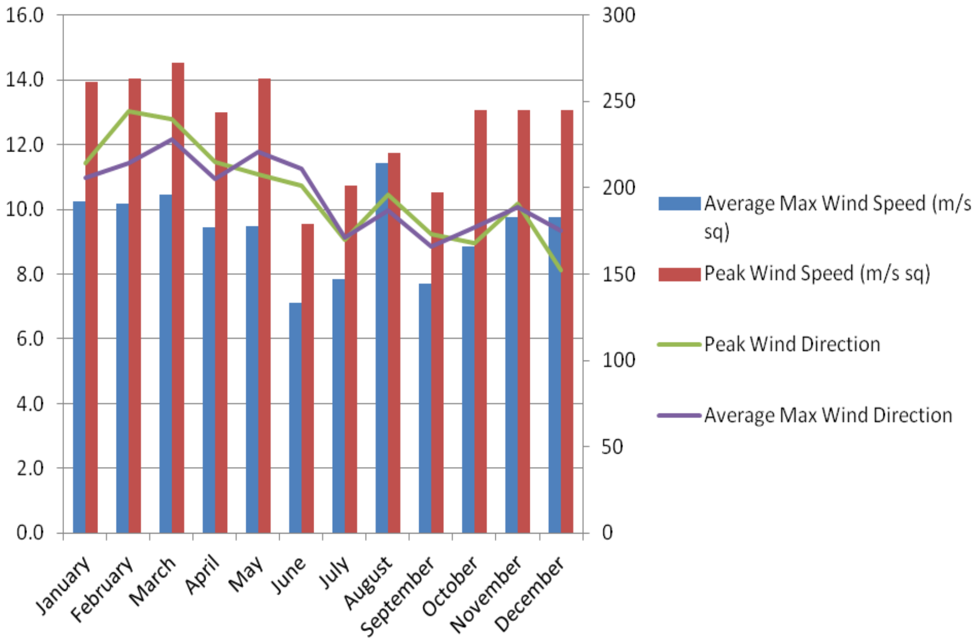


3.4.4.3 Wind Resource

The wind resource shows almost an opposite trending to that seen with the solar irradiance data. Peak months tend to be from September to May (See Figure 56). This suggest that a combination of both energy generation from solar photovoltaic systems in conjunction with wind energy systems might be an optimum renewable energy device configuration to achieve maximum harvesting of the resources available on-island. Using hourly wind speed data provided by the Bermuda Weather Service, the average max wind speed for 2008 was 9.4 m/s. According to the British Wind Energy Association (BWEA), "wind turbines start generating electricity at wind speeds of around 3-4 m/s, generate maximum 'rated' power at around 15 m/s and shut down to prevent storm damage at 25 m/s or above.[57]"

[57] http://www.bwea.com/pdf/briefings/technology-2005.pdf

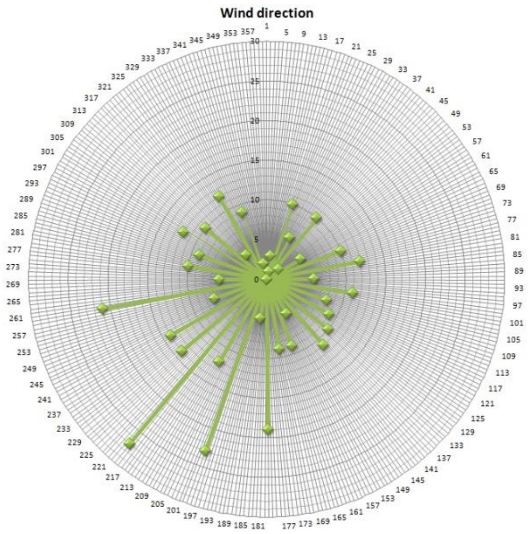
Figure 55: Average max and average peak wind speed for 2008 (Data obtained from Bermuda Weather Service. Accessed online (2011): [http://www.weather.bm/]. Author's own calculations & chart.)



Winds at good velocity emanated from all points on the compass but the majority of strong winds were seen to trend from the south to south-east direction (See Figure 57), providing a key understanding as to where suitable wind harnessing devices would be most effective over the long term, especially in the case of off-shore large scale wind energy locations. This prevailing wind directionality suggests that maximum large scale wind harvesting would be best situated along the southern coast of the island (See Plate 13), however these coastal areas consist mostly of deep shelf areas not suitable for turbine placement. Alternatively, the relatively shallow north shore lagoon area would be ideal for large scale wind turbine placement, however the turbines would have to situated at a good distance from the north coast so as to make the available fetch for wind flow as large as possible. This northern lagoon area is undesirable in that it is an area of significant biological diversity, particularly sensitive benthic marine habitats such as coral reefs. The northern coast is also very densely populated and thus any bank of large-scale wind turbines would potentially incur many objections due to the aesthetic impact on the coastal vista.

Plate 13: Google Earth® (2011) aerial photo of Bermuda.

Figure 56: Wind rose of average max wind direction for 2008 (Data obtained from Bermuda Weather Service. Accessed online (2011): [http://www.weather.bm/]. Author's own calculations.).

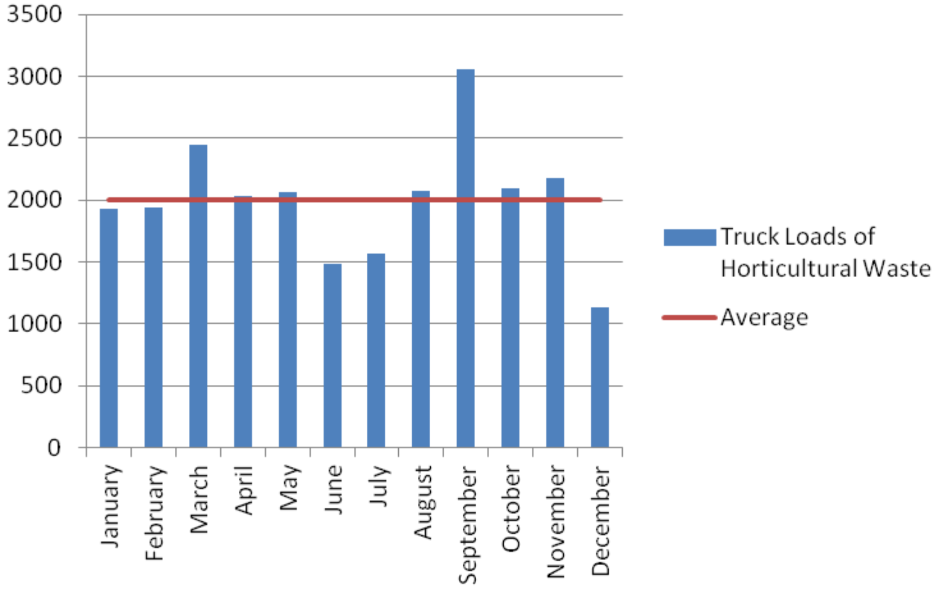


3.4.4.4 Biomass Resource – Horticultural Waste

The use of locally derived biomass is often locally mooted as a potential source of energy, in particular for the use as an additional fuel source for combustion in the local Tynes Bay waste to energy facility. Currently, the island maintains a large horticultural waste centre (Marsh Folly Centre), of which its large accumulation of horticultural waste has often been suggested as a potential energy generation source. Although the centre does not currently maintain accurate records of the waste deposits by volume, potentially the number of truckloads that are deposited at the site annually can deliver a suggestive indication of the potential for energy generation from this resource by proxy.

Using data obtained from the Bermuda Department of Solid Waste, 24,006 truckloads of horticultural waste were recorded as tipped at the Marsh Folly Centre in 2008 (Figure 58).

Figure 57: Truckloads of horticultural waste tipped at the Bermuda Marsh Folly horticultural waste drop-off for 2008 (Data obtained from Bermuda Government Department of Solid Waste 2011. Authors own chart.)



As a case study on potential energy generation, if the payload value (4695 kg[58]) of the largest truck sold (See Plate 14 for use in Bermuda towards commercial horticultural tipping (See Plate 13) is used as model proxy for the monthly truck loads, the total annual yield would be 112,700,513 kg. Using an online database for biomass energy calculations called PHYLLIS[59] to model the energy composition of the biomass characteristic of the typical waste horticultural composition, the energy yield from that mixed wood waste would equate to a calorific value in of 18,645 kJ/kg, equalling some 2,101,301,061 kJ per year of energy able to be generated. This converts into kilowatt hours (kW-hrs) as 583,741.4348[60] kW-hrs. When the modelled proxy annual yield was used in the SWM-GHG Calculator[61] developed by IFEU Heidelberg to calculate greenhouse gas emissions from waste recycling and incineration, an estimated 15,384

58 http://www.hwponline.com/content/cars/Nis-Diesel-Dumper-2007-02-28.swf

59 http://www.ecn.nl/phyllis/info.asp: using the designation of the horticultural waste as untreated wood, Subgroup - other soft wood, soft wood, Material - mixed.

60 1 kilojoule = 0.2778 watt hours

61 SWM-GHG Calculator - www.ifeu.org: Using a default 95% country specific GHG emission factor, and assuming a 100% garden and park waste component.

tonnes CO^2-eq/yr would be saved if the material could be incinerated as a substitute for any other non-renewable resources.

Plate 14: UD Condor truck – The largest model truck available for typical commercial trucking in Bermuda (Photo accessed online (2011): [http:// www.udtrucks.com/]).

3.5 *Political Accessibility as a Function of Energy Security*

3.5.1 Interest to Installation – A Complex Pathway

Both internationally and locally, all parts of the energy services structure are governed in some way by regulations emanating out of policy arrangements between governments, providers of energy supply and consumers. From an international level, political arrangements determine characteristics of local import regimes such as where fuel is allowed to be imported from or exported to, which company regimes are allowed to operate across borders and the international price of fuel commodities as established by supplier organisations such as the Organisation of Petroleum Exporting Countries (OPEC).

On a national level, local government regulations have a more direct impact on local energy services including regulating the local price of energy services such as electricity and fuels as well as governing various issues relating to the safe storage and distribution of energy commodities. Levels of regulatory readiness are influenced by the political maturity of nation states and thus both of these factors, maturity and readiness, act as an important criterion for the successful running of effective local energy services networks. For those countries looking to increase the uptake of renewable energy technologies as an aid to increased energy security and sustainable development, the effective integration of such technologies is greatly assisted when the political environment is conducive and responsive to the development of regulations necessary for energy reform.

Small Island Developing States (SIDS) often have depressed levels of political maturity accompanied by poorly developed regulatory environments in regards to energy, which alongside an under-developed technical energy services delivery structure and lack of economic resources results in increased levels of energy insecurity. Integrating renewable energy technology within such developing states is often suggested as a method to increase access to energy services for those most vulnerable in pursuit of sustainable development. However, a lack of regulatory responsiveness to accommodate efforts towards renewable energy integration and overall energy reform as a result of politically immature systems of governance can act as barriers to renewable energy integration progress in these developing jurisdictions.

Confirming the complexity of a regulatory environment responsive to renewable energy integration, research into the process of renewable energy device installation in the UK (England) reveals a complex network of pathways that evolve from initial customer interest to the final installation of a device and involve numerous diverse actors and agents as part of the regulatory process (See Figure 59). This process involved participation of not only commercial institutions facilitating the installation process but also other actors and agents such as utilities, government bodies in the form of local planning authorities as well as fringe agents such as quangos[62] and trade associations.

[62] 'Quango' is an acronym meaning "quasi-autonomous non-governmental organisation".

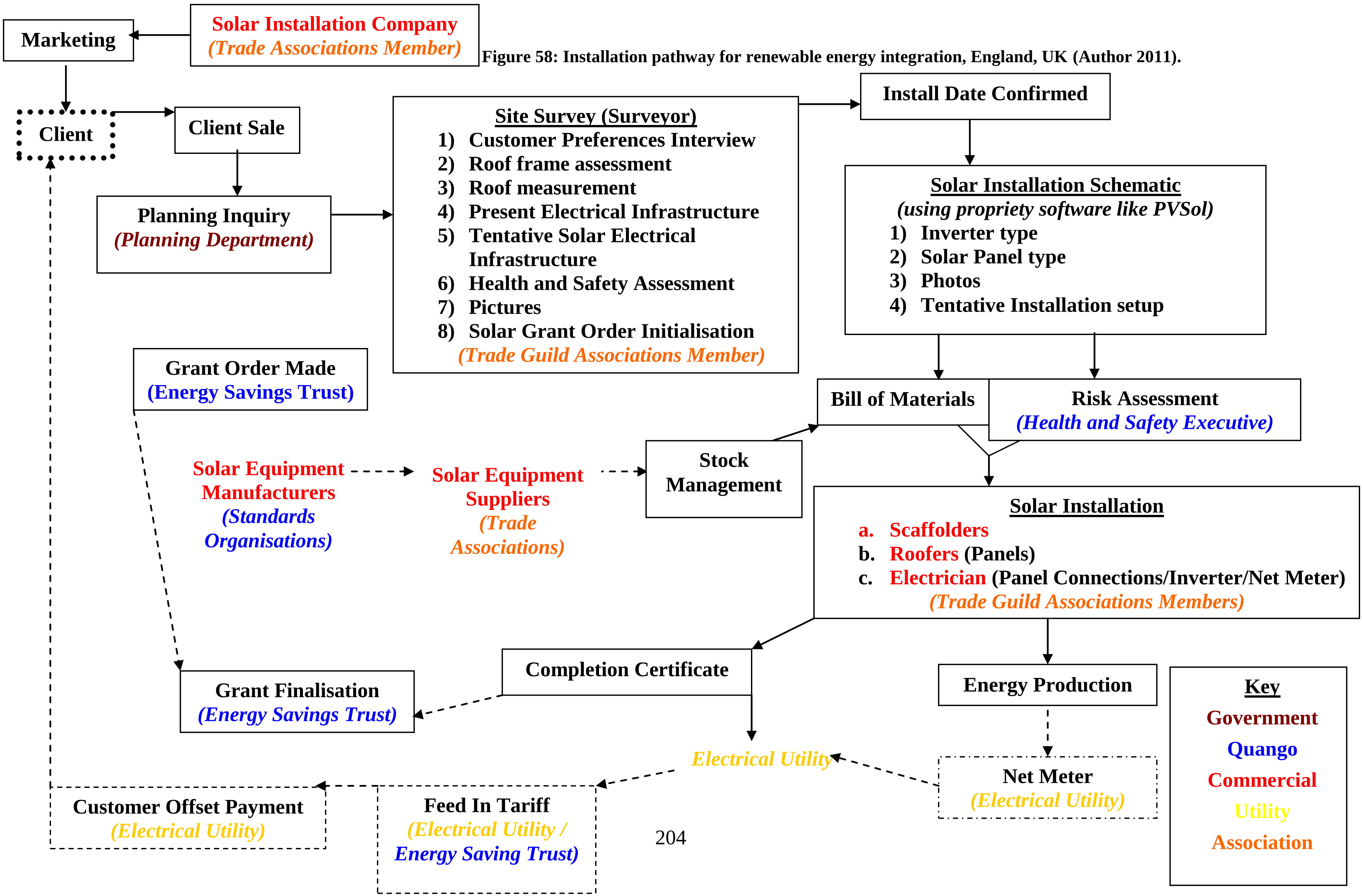


Figure 58: Installation pathway for renewable energy integration, England, UK (Author 2011).

Counter to the state of political and regulatory maturity exhibited in many Small Island Developing States, 'urban and developed' Small Island States like Bermuda have a political structure that is quite mature owing to its long history of governance resulting in a well-defined regulatory structure in regards to local energy services. Relevant government ministries control prices and there is a responsive legislative environment whereby laws can be proposed and adopted when desired. The economic climate is also quite robust in these countries and energy services such as electricity grids and transportation networks are well developed due to a long history of use on-island. In contrast to the experience cited above in regards to Small Island Developing States, this type of political maturity, robust economy and regulatory responsiveness to beneficial legislative change seems to bode well for 'urban and developed' Small Island States like Bermuda in any efforts towards integration of renewable energy technology and low carbon regimes in pursuit of sustainable development.

However, although 'urban and developed' Small Islands States like Bermuda are seemingly better placed to facilitate the development of a complex regulatory infrastructure needed for renewable energy integration as displayed in the UK 'interest to installation' scenario (See Figure 59), this 'interest to installation' process may become more sophisticated and potentially problematic in these island locales due to the intensely urban nature of the island and the existence of unique island cultural practices (such as the practice of roof-top drinking water collection, etc.), both which inevitably add island-specific dimensions to the planning and regulatory process. In addition, renewable energy systems in isolated and exposed small islands like Bermuda have to be island-proofed outside of the building standards normally approved for use in other jurisdictions, a factor which potentially adds even further considerations for important regulatory considerations such as the planning approval process.

The research showed that the technical lock-in of embedded fossil fuel use based energy associated with the 'urban and developed' nature of the island might also negatively impact the overall responsiveness of the energy regulatory environment in regards to energy security needs. A case in point in this regard is the potential for energy generation by way of distributed generation methods, which could help to take demand pressure away from the sole electrical utility as well as introduce aspects of competition and diversity in the local electricity industry. Local larger businesses, in particular for those of whom energy use is a priority and large cost factor, demonstrated that they could potentially benefit from having access to such distributed generation capabilities. However, despite this potential, there was a clear void in the regulation that would enable such distributed generation facilities. There was also a perceived hesitance by the utility to allow for the introduction of a widespread differentiated tariff regime, also a function needed to be preceded by a clear regulatory structure, whereby companies could be incentivised for having their own generation sources (See Quote 3.6.1 - 3.6.3).

> *"Outside of the renewable, in general for generation, you are not allowed to have synchronised generation on the grid. That goes back to an Act"* (Quote 3.6.1 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

> *"So you talk to BELCO and they would say yes, we have always been regulated but as far as we are aware that was a very light regulation"* (Quote 3.6.2 - Extract from an interview with an executive at the Bermuda Government Department of Energy, 23/12/09).

> *"I think having a good regulatory environment is important and that would permit you to adapt quicker. For example, if oil hits $300 a barrel next week, at the moment, it would be difficult to react quickly to that, because we have a monopoly provider. They are not required to permit people to interconnect. They can past that cost on to the consumer due to the regulatory environment. Consumers would have to turn switches off because they would have to react. In terms of national energy supply and transport as well, it would be very difficult to react in a timely manner where as if we had that regulatory environment, even without an energy plan, renewable companies could spring up and people could start using solar panels on their roofs and they could adapt more quickly. I think having the regulation and having a fair market are important"* (Quote 3.6.3 - Extract from an interview with an executive at the Bermuda Government Department of Energy, 23/12/09).

In response to the integration of renewable energy in Bermuda, there are many gaps that exist currently, many of which are critical to having an effective 'interest to installation' process (See Quote 3.6.4). The lack of a defined interconnection standard is a key gap in this regard.

> *"BELCO recently submitted an interconnection proposal which is an essential part to get people investing in that technology. So the Energy Commission is going to have to sit down and go through that policy and ask ok, are we going to accept it as is or are we going to recommend changes or just reject. Also, the interconnection, I am really referring to the technical standards; there is also the rate aspect as well. So you know, what is the fair rate for BELCO to pay these guys, what is actually needed for these guys to be a realistic investment and if there is a gap between those two, what is the option for filling that gap until such time that oil prices increase enough that it is naturally a sound economic choice to go to solar, so that's the kind of thing the Energy Commission would be doing"* (Quote 3.6.4 - Extract from an interview with an executive at the Bermuda Government Department of Energy, 23/12/09).

The lack of regulatory effectiveness can act as a source of inequity. Those who can afford to navigate an environment of unclear regulations or who have sufficient access, whether politically or economically, to bypass unclear aspects of the energy installation chain will be able to integrate renewable energy devices before others (See Quote 3.6.5).

> *"I would say that the high net worth customers will always be first in a market without policy and regulatory intervention...You have people that think they are going to generate power and provide it through lines that they do not have to pay for. That creates unfair competition as well. So the regulators have to regulate and address all of that"* (Quote 3.6.5 - Extract from an interview with a solar installation company [SI 3], 23/12/09).

The lack of a defined and effective' interest to installation' process and accompanying regulatory environment can also be a source of mistrust from the community, especially in the context of a perceived national commitment towards sustainable development (See Quote 3.6.6).

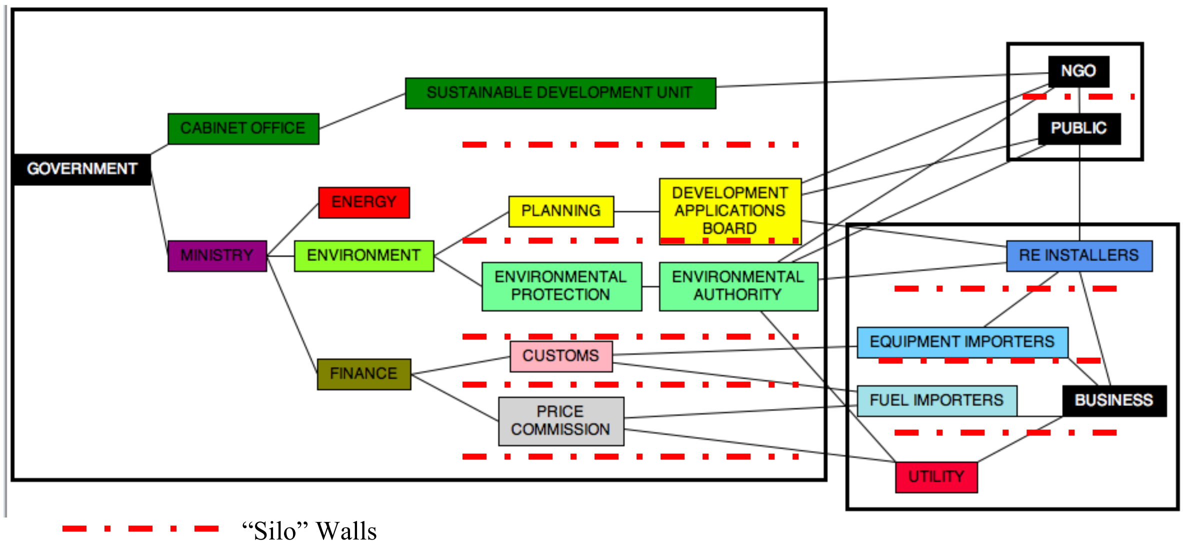
> *"Greenrock feels that an independent energy authority or trust needs to be created to ensure the pricing and financing of renewable energy projects are properly established to avoid any conflicts of interest by Government Officials or by energy providers. This authority can help initiate and financial support projects so that projects are not politically hijacked or become delayed through bureaucracy. By having this independent authority, it has the power to raise capital through debt instruments which can provide an investment vehicle that can supplement the traditional investments that pensioners relied on when it came to dividend income"* (Quote 3.6.6 - Extract from an interview with a NGO [2], 23/12/09).

For small islands like Bermuda, there is a good check and balance system, one that is integrated between government and layman, but without this system, renewable energy integration may develop ad hoc. The use of legislation currently governing energy policy in Bermuda in 'adopted and adjusted' forms can lead to conflicts by the various actors, agents and stakeholders in the interest to installation process as a result of inappropriate accommodations by the legislation or unmatched laws. Potentially for Small Islands States hoping to see renewable energy integration play an increasing role from a national sustainable development perspective, it may be wise to focus on the creation of regulatory infrastructure (building codes, tariffs, etc.) in the short term as an aid to the eventual long term readiness of the political regulatory environment for eventual renewable energy uptake rather than just on direct efforts to increase physical and technological access to renewable energy devices.

3.5.2 Actor and Agent 'Silos' as Barriers

The political maturity of Bermuda has resulted in a well-developed governmental structure. However, although well developed, the island's small size and an economy lacking in diversity has led to a governmental structure that takes up a large percentage of the labour force. With so many local workers being dependent on government for employment, the government has also become much compartmentalised in nature. This compartmentalisation can serve to create undue bureaucracy in the movement of regulatory change and act as a barrier to transition to initiatives directed at improving energy security and sustainable development such as the integration of renewable energy technology. This type of bureaucratic barrier was reflected in 'silo-like" relationships that seemed to have developed between the various government departments involved in regulating the differing aspects of the energy services network as well as those responsible for encouraging efforts towards sustainable development on the island (See Figure 60). The compartmentalisation of responsibility within government potentially creates barriers between discrete aspects important to differing aspects of the energy services structure: i.e. fuel costs (Price Commission) versus aesthetic concerns (Planning Department), integration of renewables (Sustainable Development Unit) versus tourism (Development Application Board).

Figure 59: 'Silo-creation' as a barrier to efficient regulatory change in 'urban and developed' Small Island States (Author 2011).



The ‘silo-like’ relationship also seemed to extend beyond the inner departments of government and also impact other actors in the local energy services network. Government departments responsible for differing aspects governing renewable energy integration often come into conflict over initiatives that are counter-productive to each agencies mandate (See Quote 3.6.7 – 3.6.8).

> *“For example, the Planning Department – their mandate and our mandates, they do not run on the same track necessarily...so they are trying to preserve the Bermuda image which is nice white washed roofs. We are trying to put black panels on those roofs because we know it’s important for reducing fossil fuel dependency.”* (Quote 3.6.7 - Extract from an interview with an executive with the Bermuda Government Department of Energy, 23/12/09).

> *“That goes to some of the planning discussions. When we put a planning application in for infrastructure, whether it be system or plant, it interfaces with three Ministries. Environment, Energy and Works and Engineering. So you are dealing with three different applications or three different sensitive bodies. So you got to kind of bring them all together. So you basically spend three fold efforts in trying to educate all of them to get the appropriate permissions. Whether its Works and Engineering for construction for example, if it’s a canal issue or a road issue its Works and Engineering, if it’s a general application its Planning Dept., if its operating license its the Environmental Authority, so you are kind of dealing with all of these entities in government and I think they are very much silo. I do not think there is a common entity that is taking over energy responsibility as a whole. I think the Ministry of Energy is moving in that direction. They have taken over the Ministry of Finances responsibility for the rates for BELCO but it would be curious to see if our regulatory framework will mirror much of what exist already in North America and Europe. Will there be a central point of contact in government which we can then move all these topics forward both the short term and the long term topics. I think that is what we need from a BELCO perspective”* (Quote 3.6.8 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

As a result of the barriers towards cooperation between government departments created by these ‘silo’ conflicts, the electrical utility expressed a concern with what they saw as a lack of national long-term forward planning, citing this as a source of frustration in their ability to predict and cope with increasing energy demand. This lack of forward planning may potentially act as a source of capital waste in government creating a sense of frustration in the sustainable development process but problematically may be ignored as a possible result of Bermuda’s relative affluence over the years (See Quote 3.6.9).

> *Interviewer: How important is the planning process in the fore sighting for a utility like BELCO in being sustainable?*
> *"I break the planning process into two parts – one is internal and one is external. Externally, the planning process is very poor being that the developers of either commercial properties or large scale hotels see infrastructure as an afterthought not as a forethought. So they kind of look at it as if should not be a problem. So when they come from an environment of North America or Europe, where the grid or the infrastructure behind their location is of an infinite nature. They can basically connect anything they like. People do not really appreciate coming into a small island utility, as surprising as it may sound, that the utility and the infrastructure here has limitations. That we are very much an isolated community and very much we have grown and adapted to the needs of the country over time. You just cannot build a major hotel development for example without being sensitive to what that impact really means to water, sewage and electricity.*
>
> *So we have seen a lot of that lately. So we are in a mode now where we have three major sub-stations that have to be shifted over the next 12-18 months. We have the hospital development which has to make way for the new site so we have to move the entire substation of the hospital to a new location. We have Par-la-ville car park, which has been in discussion over nine years, which is threatening to move ahead potentially soon. So that substation is going to have to be moved. That is in the middle of the city which is not the easiest thing to do. The third one is National Stadium. As we expand the National Stadium to include the new Olympic pool, the demand load up there will exceed the existing substation to such a point that we have to build a new substation so these have been on the horizon and if you check the probability of these things happening, they kind of come and go. It goes back to our fundamental belief that if this country that Bermuda wants to embrace it wants to be in the top 20 financial jurisdictions in the world, one of the things we feel very strongly about is that you have to start with infrastructure. There isn't a comprehensive planning process that looks at infrastructure. I think the sustainable development discussions of the government were a good start to that but we have issues with sewage, water and electricity today that people are not really fully aware of. Electricity we can discuss somewhat here but sewage is a similar nature. We have sewage dumped off the south shore. We have cess pits that are contaminated the island. These things are going to get worse over time…."* (Quote 3.6.9 - Extract from an interview with an executive at the sole electrical utility BELCO, 23/12/09).

The relationship between the utility and other stakeholders can also be affected by the development of 'silo' interests between these respective parties. While residents are often desirous of integrating and installing renewable energy devices at both a residential level and in terms of national interests, they often perceive the utility to be a barrier to this process (Quote 3.6.10).

> *Interviewer: Have you ever thought about the concept of having a renewable energy device for the home?*
> *"Lots. I would love to set some wave energy up because I live on the ocean. I would love to put a wind turbine up but BELCO and planning have done a good job of stifling that at the home. I have had friends who have tried to do it and there is a lot of push back to stop turbines going up."* (Quote 3.6.10 - Extract from an interview with a resident [14H], 23/12/09).

This same conflict can arise between residents and government, with residents feeling as if the government is placing barriers on their progress towards renewable energy installations (See Quote 3.6.11).

> *The respondent doesn't feel government is moving fast enough on the subject of renewable energy. The difficulty of the planning process, the need for a license based on a bank of solar photovoltaic panels needed for a controlled plant. Her PV installer was optimistic but was getting frustrated due to government. She says "planning has a fear" about aesthetics due to the new Bermuda Plan's desire to protect aesthetics for tourism. She feels that the presence of renewable energy devices in Bermuda would enhance tourism from an eco-tourist perspective* (Quote 3.6.11 - Extract from researcher's notes during an interview with a NGO [1], 23/12/09).

This trend for potential conflict also arises between many of the actors necessary to co-exist and cooperate in the interest to installation process, including between renewable energy installers and government, the utility and consumers (See Quote 3.6.12).

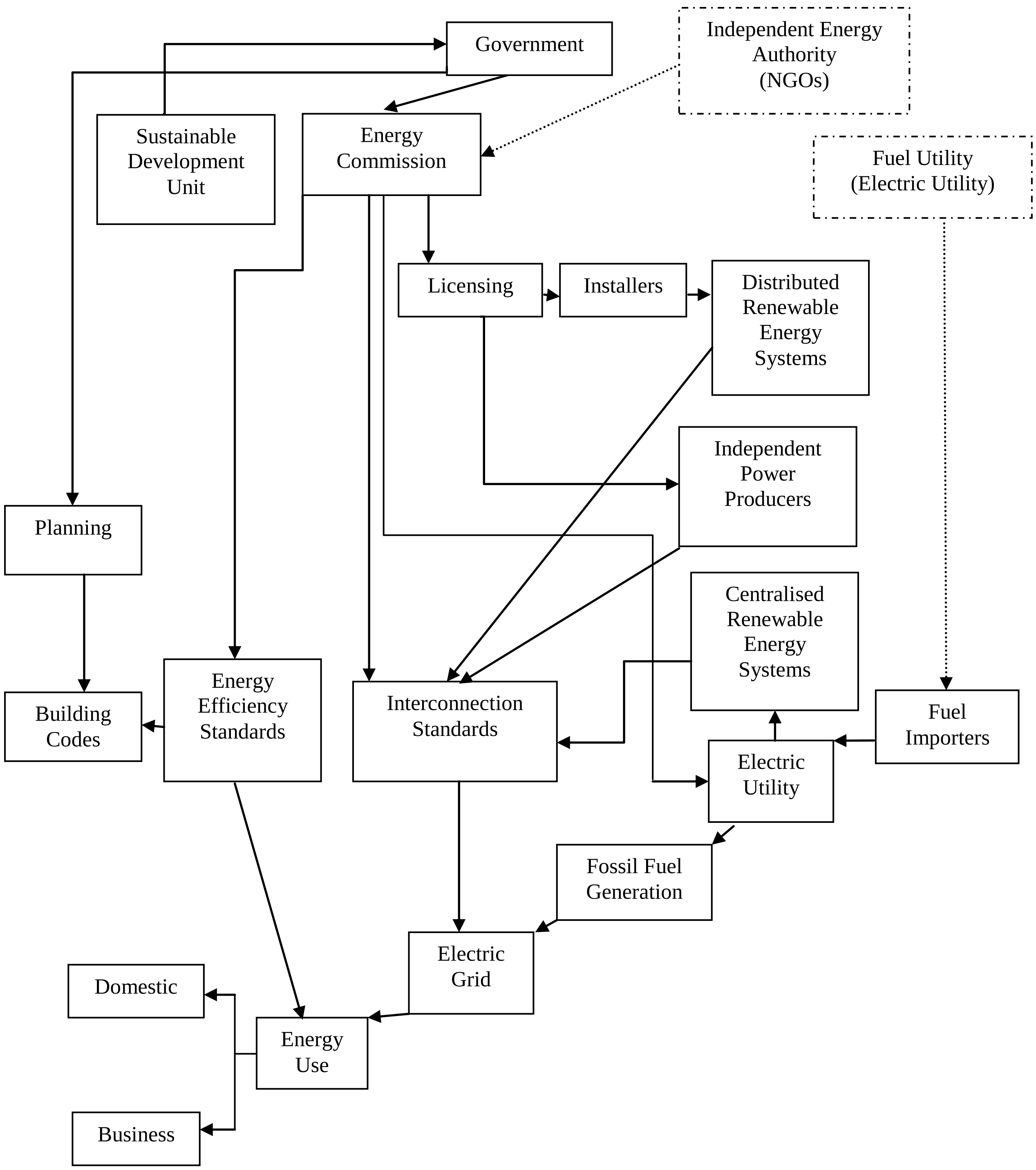
> *Interviewer: What has been the company's experience with the Bermuda Planning department?*
> *"What we found is that they are learning. The experience that I have had is that some applications that took us long as 9 months, some if I would have projected out would have taken as long as 18 months. Some were used to feel their way through the process. My experience with planning is that they are governed by legislation and so if the law hasn't changed they have requirements that they have to meet. This inhibits their ability to get the technical officers to get certain things done. You couple that with the Development Applications Board, that is pretty much layman base and so they may be asking questions that are not within the remit of the planning office so what I found is that you really have to educate and involve all stake holders in the process – i.e. the government and various department staff within Planning. They are mostly concerned with aesthetics, and potable water. I found Panning to be fairly reasonable when they are aware. When they bring in the people that have the expertise to address these systems, I think they will get to a planning system that works"* (Quote 3.6.12 - Extract from an interview with a solar installation company [SI 2], 23/12/09).

Overall, the effect of these silo-type barriers seems to have resulted in a lack of relationship between the various stakeholders necessary to effect regulatory change. While large businesses seem to have direct active links with the utility smaller businesses and residents have less influence, potentially resulting in energy reform largely directed and motivated by the utility and the interests of large business and not from government and local residents. This barrier seems to have been recognised by some, as renewable energy integration will necessitate multi-stakeholder participation (See Quote 3.6.13).

> *"There are many entrepreneurs who have jumped on the renewable energy bandwagon and are trying to carve out their 'piece of the pie'. And they are trying to raise their concerns to both BELCO and the Bermuda Government. However, as I had stated in Question #4, unless an independent authority is given the power to tackle this issue, much of what will be created will at the expense of the long-term, sustainability of this evolution"* (Quote 3.6.13 - Extract from an interview with a NGO[2], 23/12/09).

Using the regulatory needs identified by the multiple stakeholders interviewed during the research process, an idealised regulatory structure has been conceptualised in Figure 61.

Figure 60: Idealised regulatory structure governing the energy use in Bermuda (Author 2011).



Dashed boxes represent desired regulatory bodies as expressed by energy stakeholders indicated in brackets.

3.5.3 Politically Mature yet Colonially Bound

Bermuda's political status as an Overseas Dependent Territory of the United Kingdom also seems to impact its political readiness to deal with energy matters. Bermuda's small size and relative political obscurity due to its on-going colonial status means that it may be overlooked in internationally ratified environmental and energy policy, such as those related to climate change. The Bermuda Government Sustainable Development Unit expressed concern and uncertainty as to Bermuda's international liability in terms of its climate change commitments as a result of international agreements that may be entered into by the United Kingdom (See Quote 3.6.14).

> *"In terms of the UK specifically, as far as I am aware, they are pretty much hands off. You would have to talk to environmental protection. There may or may not be an obligation under the Kyoto Protocol for Bermuda. I think the UK as part of the Kyoto Protocol had to reduce emissions by like 8% on 1990 levels by 2008 to 2012. We are not entirely clear as an overseas territory as to whether we also would have to reduce our emissions by 8% or whether the UK has already done it and we don't need to. I don't quite know where that relationship is"* (Quote 3.6.14 - Extract from an interview with a representative at the Bermuda Government Department of Energy, 23/12/09).

Environmental policy from abroad seemed to have an influential nature on local policy through NGO lobby pressure, as well as affect international fuel suppliers, which in turn could impact on Bermuda. This was also reflected during participant observation experiences (See 2.6.2.5) with international consultants whereby much of the local renewable energy policy direction was directly authored by external agencies not grounded in the realities and actualities of local energy dynamics. In this stead, it was found that the government, solar installers and the utility all relied in some way on external consultants to advise them on energy policy involving renewable energy integration (See Quote 3.6.15 – 3.6.17).

> *"When it comes to specifics, we do have a consultancy firm we are using in the US and so if there is area we are not comfortable with than we will contact them and allocate them a particular project. There is also a degree of overlap as well so like the interconnection policy came in and it's a really important document because that is going to set a precedent for the coming years. So we reviewed it and provided our opinion but we also asked the consultant to take a look through it and also to provide us with their slant"* (Quote 3.6.15 - Extract from an interview with a representative at the Bermuda Government Department of Energy, 23/12/09).

> *"We are also working with an outside UK company to study offshore wind, which could be 30-40 MW"* (Quote 3.6.16 - Extract from an interview with a solar installation company [2], 23/12/09).

> Interviewer: Do you think it makes a difference between local Bermudian companies consulting on renewable energy in Bermuda and the involvement of foreign companies?
> *"It is far better to be home-grown because if you are home-grown you tend to know more as to what is going on. You are also aware and tuned into aesthetics and price as well as having a longer term view rather than out to make a quick buck"* (Quote 3.6.17 - Extract from an interview with a solar installation company [2], 23/12/09).

In terms of Bermuda's international relations and thus exposure to international energy policy, this may produce a blockage that sees international business-related environmental policy amplified while those that may cater to the grass roots hindered such as through organisations like Small Island Developing States Network (SIDSNet). The Director of Bermuda Government Sustainable Development Unit exclaimed (See Quote 3.6.18):

> *"It was embarrassing because the relationships that Jamaica, Belize, St. Vincent, Trinidad, etc. had made with SIDS organisation were well along the way but because of the Bermuda's status as an Overseas Dependent Territory we are not in the frame"* (Quote 3.6.18 - Extract from an interview with the Director at the Bermuda Government Sustainable Development Unit, 23/12/09).

Evidence from the business arena demonstrated this discrepancy between the impact of national policy and political motivation on the creating of momentum towards transitioning to low carbon energy regimes compared to the momentum caused as a result of corporate policy mostly fuelled by the influence of international company policy on local businesses (See Quote 3.6.19).

> *Interviewer: How much of the influence to change comes from local pressure or international pressure?*
> *"I would say that locally we have a management team that is really committed to sustainability. Globally it is a mandate that we implement sustainable measures in our corporate real estate world. I think the bank recognises that Bermuda is tremendously behind the world in implementation of sustainable practices. Businesses here have just not done it and residential just have not done it. I think there is some lag and I think that our management wants to be at the fore front. For example, in our new Harbour View building, we will be installing photovoltaics on the roof. The photovoltaic installation at Harborview is not going to give us energy in large amounts. However, we are going to do it as we want to show the public that if we are doing it, you should do it – It is a showpiece"* (Quote 3.6.19 - Extract from an interview with a large business [LB6], 23/12/09).

4 Conclusion

This thesis contributes to debates in multiple arenas around the role of renewable energy integration towards sustainable development in Small Island States. From its outset, this study viewed the discourse of sustainable development, as the dominant global environment discourse of the late 20th and early 21st century (Dryzek 1997), through a highly critical lens, especially in regards to its appropriateness for application in Small Island States such as Bermuda. Specifically problematic for small island locales is that the germination and evolution of the sustainable development discourse over time seems to have occurred predominantly as a product of high-level international discussions dominated by the presence, and thus contribution and considerations, of larger nation states (See Section 1.1). In this regard, the island of Bermuda's current National Sustainable Development strategy directly stems from the desire to be aligned with these types of international discussions, namely the Johannesburg Declaration on Sustainable Development which was adopted at the 2002 World Summit on Sustainable Development.

However, this research shows that there is a danger in the blanket adoption of a 'one size fits all' strategy, particularly for the deployment of increased renewable energy integration towards greater energy security. Weisser (2004) suggests that integration of renewable energy systems in Small Island States can help improve economic efficiency, environmental performance and energy security through enhancing diversity. Yet, such studies assume that these island locales will have access to renewable energy resources which can easily and cheaply replace fossil fuels. Resulting environmental and social benefits are also assumed. Such potentially misaligned renewable energy integration policy may be counterproductive to the actual needs that such policies are looking to address. Kotzebue et al. (2010) labels such practices as 'spatial misfits' and cites the Small Island State of Malta's adoption of policies towards the pursuit of large-scale renewable energy projects over small scale technologies, a direction counter to many aspects of Malta's unique spatial considerations such as ecological boundaries and culture. As such, approaches towards sustainable development that merely attempt to transfer generic tools, models, concepts and techniques from developed to developing countries are often based on an assumption of transferability and often fail to appreciate “the cultural, social, environmental complexities, constraints and resource limitations faced” (White et al. 2008, p. 1) by these locales.

The need to prevent such ‘spatial misfits’ underlines the importance of considering and valuing the role of ‘place and context’ in influencing the implementation of renewable energy technology. This research has highlighted a specific set of contextual issues concerning place, including factors relating to technical and institutional lock-in, that suggest a clear difference regarding the role of renewable energy integration in Small Island States that are already well developed compared to those that are still developing. The island of Bermuda is a unique case study location in respect to other Small Island States as it is characterised by an ‘urban and developed’ socio-economic profile. Small Island States with this type of socio-economic profile have previously not been studied as unique entities amongst island locales, particularly in regards to how issues relating to sustainable development and the integration of renewable energy may be impacted by their urban and developed nature. ‘Urban and developed’ Small Island States like Bermuda, and potentially including others such as Singapore, Mauritius and Malta, have mixed characteristics, such as an unsustainable reliance on fossil fuels but yet an urban nature which often acts as a barrier to large-scale adoption of renewable energy, and these mixed characteristics often conspire to reduce flexibility towards sustainable energy reform. In some ways these ‘urban and developed’ Small Island States are more similar to large continental states, such as the US, whereby generation and distribution structures are locked-in due to the vast financial and techno-centric infrastructural commitments that exist while at the same time sharing similar characteristics to most Small Island States in regards to constraints placed on expansion due to lack of space (Mayer 2000).

Resource management and urban planning have significantly impacted each other over history, and sustainable development serves as a formal and critical link between the two themes (Agudelo-Vera et al. 2011). Related research elsewhere has shown that environmental conditions in urban areas are different than those in non-urban contexts (e.g. Short et al. 2009) and that issues of urbanization can directly affect the management of environmental resources in Small Island States, further emphasizing the importance of recognising that a ‘one size fits all’ approach to renewable energy integration for Small Island States will not work (White et al. 2008). Bermuda’s ‘urban and developed’ socio-economic profile influences a diverse range of energy-related factors, namely the hindrance towards upgrading fuel storage and transportation infrastructure towards more energy efficient fuels, the hindrance towards the expansion of generation plant to include large-scale renewable energy devices as well as the aiding of energy apathy in residential and business approaches towards energy use. Drawing these together, it is clear that Small Islands States with ‘urban and developed’ socio-economic profiles will be more prone to suffer from both institutional and technical lock-in to existing fossil fuel infrastructure made more secure by a very high energy intensity promoted by a hyperactive economy.

This research also provides new understandings of how social roles, such as age and wealth, act independently as well as collectively to influence energy literacy and notions of power and, in turn, act as potential barriers to the uptake of renewable energy systems. Socio-economic attitudes facilitated by the urban and developed conditions, such as ‘comfort over cost’, result in little to no impetus towards energy reform in the form of increased integration of renewable energy. Even when programmatic incentives such as energy buy-back schemes are put in place aimed at promoting renewable energy, it is often the wealthy that are able to benefit as first adopters. Other vulnerable groups, such as the disabled or very small businesses such as sole-proprietorship taxis, may also be left out of these strides towards renewable energy integration as they may have different energy needs than what characterises the larger, more dominant status quo. The research also found that the creation of energy redundancy was valuable but seemed to be trumped by energy efficiency as an energy sustainability strategy for such locales. This was made clear by the uncovering of significant differences on how energy was used and viewed amongst different socio-economic groups, with the suggestion that renewable energy integration is less easily adopted due to various energy costs and understanding factors when compared to the relative ease by which aspects of energy efficiency technology and behaviours could be implemented.

Kammen et al. (2011) highlight that creating a conducive environment for renewable energy means adopting policies that respect the multitude of a country's characteristic traits in their various interactions. It is suggested by this research that non-urban and developed states are easier to reform as there is less investment (economic, technical, social and political) in the energy infrastructure. However, in some Small Island Developing State renewable energy studies, such as the Praene et al. (2012) study on the island of Reunion, the rising cost of land due to a lack of construction space has had a severe impact on the potential to build renewable energy facilities. For Bermuda, its challenges with increasing urbanisation interlock and exacerbate these types of existing inherent constraints associated with 'small islandness'. As urbanisation increases, demand for fossil fuel energy also rises, creating lock-in effects for existing fossil fuel energy infrastructure both from a physical, financial, institutional and social (i.e. employment) point of view. These lock-in factors heavily influence technical accessibility towards renewable energy, particularly in regards to the ability of the utility to expand into areas of centralised renewable energy devices, as well as act as a barrier to an increase in the general technical understanding of renewable energy devices due to a lack of sustained renewable energy penetration and promotion amongst the general public and businesses. Importantly, issues of 'small islandness' exacerbated by the 'urban and developed' nature of Bermuda influence the role of renewable energy from a perspective of environmental accessibility, as issues related to NIMBY conflicts could arise from any moves to integrate large scale renewables. The impact of Bermuda's urban density also influences energy use patterns, such as the increase in the need of air conditioning due to the effect of urban heat retention. Such influences have been confirmed in other studies researching the energy flux associated with summertime urban heat island effects and the impact of varying amounts of solar photovoltaic panelling on differing coloured rooftops (Scherba et al. 2011). Interestingly, with Bermuda's long-existing island culture of traditional white roof buildings, a large increase in rooftop shading or covering with solar panels has not sufficiently been considered for its beneficial or detrimental potential effects.

It is clear from this research that physical geographical factors, such as place, scale and urbanisation interact closely with socio-economic factors like literacy, wealth and age to influence the role of renewable energy systems in efforts towards sustainable development. As a result of the urban and developed context, the island was made more vulnerable to influence by 'international to local' relationships (i.e. effect of import dynamics on cost), as well as those involving 'exterior to interior' energy geographies on various aspects of local energy security (i.e. incumbent fossil fuel energy technologies influencing current interior energy use behaviour and structure such as 'comfort over cost'). As a result, urban and developed Small Island States, especially those very small and isolated ones like Bermuda, may be counter-intuitively more vulnerable and less resilient than what may be assumed in the face of global environmental challenges such as fossil fuel depletion, energy poverty and climate change. Environmental effects relating to global climate change such as sea level rise will disproportionately affect these locales as their urban and developed conditions severely limit their adaptability regarding fuel storage and transportation and energy generation, even in regards to the use of renewables. As such, the formation of environmental policy concerning sustainable development and the potential role of renewable energy must directly consider effects bought on by the urban and developed nature of islands and care must be taken to see such islands as having unique vulnerabilities far different than those of their sister Small Island Developing States. Finally, along with the issue of high energy costs inherent in most Small Island States, Bermuda's 'urban and developed' nature and the resulting high energy intensity plays a conflicting role between being a pillar for economic prosperity through the facilitation of employment and business, but yet at the same time such prosperity only being able to be maintained through the continual disbursement of significant proportions of locally generated foreign exchange offshore for the importation of fossil fuel resources. Paradoxically, when the consideration of the lock-in effects described earlier are taken into context, the pursuit of economic development as a symbol of continued prosperity for the island, then, may actually assert an opposing incentive to the ease of renewable energy uptake on-island. This is a significant consideration that must be considered by the government and society in general who may find themselves between two desired but conflicting ideals towards sustainable development. Recognising the dangers of such spatial misfits, Kotzebue et al. (2010) emphasize the importance for renewable energy policy to find an appropriate fit with contextual factors such as physical and ecological boundaries and other functions of place. It is a need that seems to be especially important when policy direction affecting 'on-the-ground' change is potentially heavily influenced by external stakeholders as is often the case in Small Island State locales, Bermuda included.

4.1 Taking the Bermuda Government Efforts Further

"Fears for seniors facing rising Belco bills" - June 19, 2012
Article title from the Royal Gazette newspaper, Bermuda.

The Government of Bermuda, like many other Small Island State governments globally, is currently seriously considering the role that renewable energy can play towards their national sustainable development efforts. These considerations are reflected in real time in major policy implementation such as the creation of a new government Department of Energy, passing of an Energy Act, the recent publication of a formal Energy Green and White Paper as mentioned and the creation of new legislation aimed at incentivising increased renewable energy integration. The implementation of such initiatives, along with the financing, infrastructure changes and society adjustments that may happen as a result, mean that the stakes of 'getting it right' on the island are raised even higher. Although the Government of Bermuda's recent Green and White Energy Papers examined Bermuda's energy challenges in a detail never previously done on a national level, these same policy documents in many ways expose why there is a distinct need to consider the role of renewable energy more deeply. While this research found agreement with these governmental publications in regards to there being a clearly established basis to be concerned over Bermuda's long-term energy security from many aspects of supply and demand, including aspects related to social accessibility, economic accessibility (affordability) and environmental accessibility (acceptability), there are also many gaps that have not been recognised and have the potential to create the ‘spatial misfits’ scenarios discussed above.

Along with the importance of recognising the significance that Bermuda’s ‘urban and developed’ nature plays in differentiating the role that renewable energy may be expected to play in the island’s efforts towards sustainable development when compared to other Small Island States, this research study also uncovered other critically important factors in this regard. While the Green and White Energy Papers on energy make much of Bermuda’s energy consumption and its resulting impact on local energy security and greenhouse gas contributions, this research found that Bermuda’s developmental characteristics as an ‘urban and developed’ Small Island State had unconsidered significant influence on aspects of its energy security and the potential role of renewable energy and energy reform. In particular, the interface between energy security and sustainable development in regards to social factors seems to have been somewhat downplayed and at times disregarded in the government’s assessment of renewable energy’s role towards sustainable development efforts.

For example, the confirmation and identification of particularly vulnerable energy user groups by this research, such as the ‘disabled consumer’, was a significant research outcome not recognised in the Government of Bermuda’s energy reform efforts, outside of general references to small business owners and poorer communities. Additionally, small business operators such as taxi owners emerged as a particularly vulnerable group in regards to technical accessibility to renewable energy, highlighting the need for care in the widespread integration of renewable energy technologies in Small Island States as some sort of sustainable development panacea. Of particular concern to this group was their inability to diversify energy sources needed for their businesses and the high cost of operating their vehicles as a function of high energy costs.

Kaza et al. (2011) assert that energy factors, such as energy price affect urban form. For example, disruption in energy supply, whether economically or as a result of availability, could result in the disruption of vital water supplies, as island-specific challenges such as the provision of fresh water through desalination is an energy-intensive activity usually based on fossil-fuel sources. In this respect, while the Government of Bermuda's energy publications did well to recognise the disparity arising between the more and less economically able in society in regards to energy poverty, this research suggest that social factors have an even deeper lying influence and also may affect and be affected by urban form. In particular, social factors showed a distinct influence on user access to energy and energy use behaviour and of particular interest was the relationship between energy access and power, a relationship that suggested increasing levels of access to energy may have direct implications on socio-economic development. Education and wealth both had a direct influence on the exposure of residents to concepts involving renewable energy technology and were important drivers in who was seeking to integrate this type of technology into their domestic energy regime. Age also played a role as the elderly were at a particular disadvantage in regards to issues relating to energy literacy.

While access to renewable energy seemed to have the potential to reduce the dependency on imported fossil fuels as well as break lock-in scenarios incumbent as a result of the long-term use of fossil fuels on–island, social factors such as socio-economic ability had significant influence on this potential role as well, as those who were wealthy, in positions of power, or those large businesses operating locally were able to more effectively navigate the regulatory and financial barriers to eventual installation of renewable energy technologies and other aspects of energy reform. Such barriers to increasing energy diversity were not just demonstrated from the perspective of larger, external devices towards physical supply, but also in relation to issues of social accessibility across the local scale, specifically in this sense, technical and institutional lock-in to a fossil fuel high consumption lifestyle affecting the island's interior energy geographies.

The issue of economic accessibility (affordability) to energy and its relation to renewable energy integration also presented itself as not as straightforward as what the general consensus seems to suggest in regards to Small Island States, that is, the high energy cost associated with these locales acts as a strong driver to the increased integration of renewable energy technology, a position also reinforced in the Government of Bermuda's energy reform publications. The research found that despite local high energy costs engendering definite feelings of discontent towards the government and the local utility, ‘comfort over cost’ was a trend reflected by many residents across ranges of socio-economic abilities. It is suggested that issues relating to both technical and institutional lock-in as well ‘socio-technical’ lock-in as a function of Bermuda’s urban and developed nature play a role in these opposing realities. Although renewable energy integration has achieved cost savings for those who have been able to install such systems, it was clear that the wealthy were able to become first adopters and thus they would disproportionately realise any benefits, economically and socially, to further incentivise renewable integration. Key to addressing this dilemma is the need to facilitate suitable financing mechanisms to allow those economically less able to integrate and uptake renewable energy technologies.

This disparity in achieving access to energy as a function of economic position as well as influencing the potential for renewable energy to be of benefit was also observed in the business arena. While large businesses could potentially achieve cost savings from high energy consumption with the integration of renewable energy, there was hesitance in moving towards such initiatives as they did not want to be first adopters of little proven technologies. Instead, many businesses were turning to measures of energy efficiency, such as the replacement of light fixtures with more energy efficient ones, as a less risky, quicker and more cost effective energy and cost saving initiative. Small business had less of a need for the integration of such initiatives, as energy use was not a major proportion of their business related cost, with things like rent being more significant. In many cases, small business owners did not even receive indications of their energy use (which may have provided a signal towards conservation or renewable energy use) as a disparate item in their business expenses as it was often bundled in a single bill that included rent and other facility expenses. Other issues related to socio-economics in this regard also played a role, specifically the disparity between ownership of business properties, with most large businesses operating out of commercial facilities owned by the companies themselves whereas small business were often renting their business units.

The high cost of renewables as a barrier to increased implementation is an often mooted point in regards to its role in Small Island States, such as in Praene et al. (2012) similar research study of the island of Reunion. However, this impact is usually only considered from an economic point of view and not often from the perspective of inter-twining social paradigms and its emanation from energy use behaviour and interior energy geographies. The consideration of interior energy geographies is also flagged as important (Shirley et al. n.d.) which highlights the role of understanding interior energy use behaviours and how such geographies may impact and influence energy use behaviour. This highlights an unexpected incentive potentially not recognised by the Government of Bermuda towards the integration of renewable energy, which is that increased integration could be used to facilitate socio-economic empowerment for those less socio-economically able in Small Island States. However, special user groups such as the disabled were identified as having unique energy needs to which momentum towards further integration of renewable energy would have to be mindful of so as not to create further energy disparities from this and other already often marginalised social groups.

In island locales such as Bermuda, the design of energy systems is crucial to making them appropriate towards sustainable development (ibid). In reality, all the presumptions in regards to the potential benefit of renewable energy extend from assumptions of the availability of these energy sources for use. Although it is often assumed that most Small Island States have bountiful amounts of physical renewable energy resources potentially able to be harvested for use, this research's assessment of Bermuda's renewable energy resource base showed a clear need to understand the limitations of these resources, especially in the context of local energy use patterns, a consideration not often made. With a clear pattern of high solar irradiation availability year round but peaking in the summer, as well as year round sufficient temperatures indicative of high solar infrared radiation arriving on Bermuda's geographical area, there is an obvious role for both solar photovoltaic devices as well as solar thermal. However, considering issues of the high demand due to air conditioning needs in the summer, which occur on a diurnal cycle, there is a distinct segregation of how the solar energy could be used to facilitate these types of energy use patterns, especially in view of the differing trends between domestic and business use. Additionally, wind energy was shown to be in good synergy with decreasing solar irradiation over winter periods, particularly for those who may be able to install such devices to make use of the prevailing south-westerly winds. Other potential energy resources such as the use of locally derived biomass could potentially serve to offset some of the import of fossil fuel energy supplies but realistically would only act as a relatively minor additional fuel source.

This type of information was useful not only from a perspective of how much renewable energy may be available and when, but also from the perspective of understanding what types of technology would be best and for who. This again shows the differentiation of roles that renewable energy may take in varying Small Island States depending on issues of development and geography, as not all technology types can be optimally facilitated in all island locales based on these factors. Issues related to culture and environment may be a further factor in the potential technical role that renewable energy can play in Small Island States. The Bermuda building code may need to be significantly "Bermuda-proofed" in regard to installation of small-scale renewable energy devices, as the island's unique architectural and cultural concerns place demands on how the renewable energy technology is installed. Islands with unique social, cultural and/or environmental practices such as Bermuda, where, for example, roof-top water collection is widespread across the island, may find existing renewable energy technology to present barriers when attempting to integrate with these island specific uses. Frequent occurrences of extreme weather events such as hurricanes and the chance of future predicted climate change impacts on energy infrastructure also presented opportunities for the use of renewable energy as a form of redundancy but also presented challenges to existing energy infrastructure as Bermuda's energy generation and storage facilities were high risk for exposure as a result of rising sea level.

At this point some mention should be made of the part played by local energy utilities as these entities are known to be heavily influential in terms of energy reform in Small Island States due to the frequent existence of utility monopolies. Bermuda is no exception in this case.

In terms of Bermuda, residents interviewed expressed a clear openness to the idea of renewable energy integration on a large scale as well as to be installed in their homes. In surprising similarity to renewable energy projects in other Small Island States such as Dornan's (2011) research in Fiji, Bermudian homeowners expressed a clear desire to have control over any renewable energy devices installed in their homes. However, if such renewable energy integration is to be successful, the policy environment needs to be made more productive in encouraging efforts towards uptake. Specifically, increasing technical accessibility towards the facilitation of such energy reform becomes critically important. The Government of Bermuda's Energy Green and White Papers highlight that an important factor for this desired energy reform towards renewable energy to happen in Bermuda is the devolution of the traditional energy technical structure, such the transfer of the national grid from a monopoly 'managed and owned' entity to one that is fit for purpose for a modernised open-access energy infrastructure that caters to distributed generation such as that involving small and large-scale renewables. This step in increasing technical accessibility to the national grid infrastructure is far from being realised and there appears to be significant inertia to the motivation of the monopoly stakeholder utility controlling the grid at this time to it happening. It is encouraging that this current research study found that existing levels of technical qualification on-island seemed sufficient to provide an adequate labour force to accommodate any increase in levels of renewable energy integration and further development of this commercial sector could increase employment opportunities locally.

However, although the government's desire for speedy integration of renewable energy technology is bolstered by the existence of such local human technical capacity to support the growing renewable industry, the research found that in many other ways both industry and political stakeholders were not ready for such changes. For example, the Government of Bermuda's desire to see large growth in electric vehicle usage in Bermuda was reticently looked at by the local energy utility due to capacity fears. Many residents who had attempted to install renewable energy devices spoke of a lack of urgency and cooperation that seemed to emanate from the energy utility, especially in regards to net metering.

In terms of sustainability in regards to reduction in the importation and use of fossil fuels, efforts towards the promotion of energy efficiency as a primary energy reform towards sustainable development may be of greater importance to the island than the introduction of renewable energy devices. Roper (2005, p. 114) asserts that "the cheapest kilowatt is the one that does not have to be generated" but few energy efficiency measures seem to have been adopted by Small Island Developing States, although they are often ideal for energy efficiency programs. Rather than make large investment in unproven renewable energy systems as first adopters, many of the large businesses spoken to were preferring to invest in energy efficiency programs, allowing them to make cost savings as well as meet corporate-social responsibility mandates in terms of environmental sustainability. Residents too were finding it easier to invest in energy efficiency measures, both passive and active, rather than investing large finances in the purchase and installation of renewable energy devices. Such measures would obviously be more accessible for residents and business in lower socio-economic brackets. For those residents who were wealthy enough to install renewable energy systems at home, installers were insistent on the incorporation of energy efficient devices in the home as a precursor to installation, also emphasizing the significance of energy efficiency in regards to efforts towards sustainable development, both in energy reform efforts involving renewable energy and those without.

Roper (2005) asserts that most Small Island Developing States do not have the organizational, technical nor financial capacity to participate in the level of energy reform needed to progress with integration of renewable energy technology. Stuart (2006) asserts that the social and political links that Small Island States often have with other larger nation states are important in the facilitation of renewable energy technology integration and as such, lack of support from these external entities or lack of internal support towards engaging with them may be an obstacle towards energy reform. However, for Bermuda as an already 'urban and developed' Small Island State, concerns relating to a lack of organizational, technical nor financial capacity or a lack of external or internal support do not seem to be overly problematic. More problematic are barriers emanating as result of organizational conflict between the stakeholders critical to energy reform on-island. This recognition of organizational conflict as a barrier to progress towards effective energy reform was identified as a key gap missing in the growing number of energy policy initiatives being developed in Bermuda during this research study.

Despite the development of government-led initiatives as described earlier to encourage the integration of renewable energy and other aspects of energy reform, such organizational conflicts were clearly apparent in aspects of local political accessibility to progress energy reform. Particularly, the existence of organisational 'silos' served to prevent local stakeholders, both intra-governmental, public and private entities, from effectively working with each other, a problem found in other island research as well (Praene et al. 2012). It is clear that Small Island States like Bermuda have to better develop their regulatory regimes so as to facilitate greater political accessibility towards energy reform, including that concerning the integration of renewable energy.

4.2 Future Directions for Research

In closing, Bermuda, as with many other Small Island States (Loy & Farrell 2005), clearly sees a potential role for renewable energy and renewable energy systems. While there seems to be sufficient literature available on experiences involving renewable energy and renewable energy systems in Small Island States, there seems to be very little specific to Bermuda and Small Island States similar to it with an 'urban and developed' developmental profile. The geographical coverage of research into renewable energy and Small Island States has also proven to be somewhat uneven, with an overrepresentation of Mediterranean islands and an under representation of islands in other parts of the world (Jaramillo-Nieves & del Río 2010).

As such, this research towards the role of renewable energy and renewable energy systems for Small Island States efforts towards sustainable development provides an excellent case study and makes useful contributions to the research literature in this area. Some of the insights highlighted in this study can be vital for policymakers and planners in these types of locales in their development of energy policy that is geared towards encouraging the production of energy that is non-disruptive from a social, economic and environmental aspect, as well as being secure in its supply, and which can break lock-in scenarios that act as barriers to renewable energy use and renewable energy systems integration. Going forward with further research, potentially how best the subsidization of traditional fossil fuel energy economies like those which characterise most Small Island States, and which are often monopolistic in nature, can be realigned to promote those of renewable energy technologies is an important area of future research that needs to be considered. Any research conducted on these types of topics can help to assist Bermuda and other Small Island States on the way forward concerning issues of energy security, energy policy and the role of renewable energy and renewable energy systems.

For these Small Island States with their undoubted plethora of possible renewable energy resources to utilise, this current research study has shown that assessments on how to integrate renewable energy technology must not only involve quantitative assessments on the level of renewable energy resources available but ones that also explore which energy systems would be most appropriate by determining how the use of renewable energy and renewable energy systems may be impacted socially, environmentally and economically. The social dimension of the contribution of renewable energy systems to the sustainable development of islands has hardly been tackled in much of the past research into this area (Jaramillo-Nieves & del Río 2010). This perspective is important not only in the context of the challenges faced by Bermuda, but potentially common challenges faced by Small Island States globally in regards to energy reform involving renewable energy integration towards sustainable development. Such research is crucial before renewable energy systems integration is specifically designated as a viable sustainable development approach and can provide a critical background for development of future sustainable development strategies involving renewable energy and renewable energy systems going forward.

Care should be made to view sustainable development as a process and not an endpoint (Barrow 1995; Weisser 2004) and thus future research should attempt to understand and consider the integration of renewable energy in terms of ‘context and place’. Any efforts towards sustainable development for Small Island States should attempt to incorporate approaches that are integrated and responsive between the relevant diverse indicators of vulnerability for Small Island States as has been outlined in the above research and highlighted in the research of others. Additionally, issues concerning sustainability cannot be looked at in isolation from obvious politics and connections to those attempting to define it (Forsyth 2003) and this research has shown this to be very significant considering the impact and influence of socio-economics and culture on seemingly techno-centric issues such as renewable energy technology. In many ways, it is socio-political developments that have served the most to influence the growth of renewable energy systems integration over the past decade (Sawin 2004). The functioning of social institutions and the resilience of social systems all influence how societies can cope with change (Tompkins 2005b). Consideration of spatial and temporal dynamics inclusive of both interior and exterior geographies have also proven to be significant as well, specifically in determining ‘what is sustainable and to who (ibid.).’

As such, sustainable development strategies such as that of increasing the use and integration of renewable energy cannot be techno-centric alone; rather understanding and changing social systems and behaviour may be more critical (Meadows et al. 1992). This again emphasizes the importance of considering the dynamics of interior energy geographies, how they are shaped by energy use behaviours and the impact that such dynamics will have on shaping roles of renewable energy in the sustainable development efforts in Small Island States. It is surprising how resilient islands can be, having to deal with so many inherent vulnerabilities, and many may have solutions from the past for problems of the future (Stuart 2006). Being open and aware of new uses for old technologies may bring surprisingly appropriate results and the exploration of traditional and cultural energy strategies and technologies already existent in island locales is also another interesting area for future research.

Resiliency is seen of particular importance to sustainable development principles (Folke, Carpenter, Elmqvist, Gunderson, Walker, et al. 2002; Hermans & Knippenberg 2006) and combining such techno-centric and social mechanisms that serve to facilitate participation may help to increase resiliency (Larsen & Gunnarsson-Ostling 2009). The Bermuda Government's use of a public consultation system in its original thrust to develop an energy green paper is a notable example of this but such efforts must go beyond the initial policy idea stage. Systems striving for sustainable development should attempt to be adaptive as a function of resiliency and not focused on seeing maximum exploitation of resources as a yield and whatever the specific stratagems being employed towards sustainable development, a strategic formulation of sustainable development as a process on the above principles is clearly crucial. For Small Island States, especially those with additional considerations impacting its efforts towards sustainable development such as Bermuda and its 'urban and developed' nature, the development of unique resilient strategies towards sustainable development can offer much hope in how to further develop as they look to face the challenges caused by their inherent vulnerabilities.

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Appendices

5.1 Appendix I – Key Figures on World Renewable Resource Supply

Figure 61: Annual Growth of Renewables Supply from 1971 to 2004 (IEA 2007).

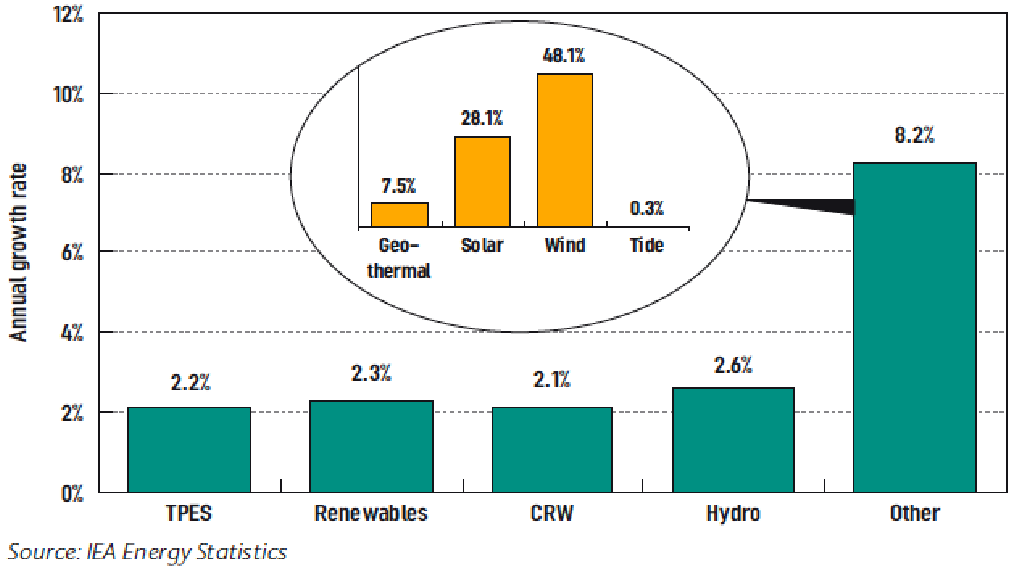
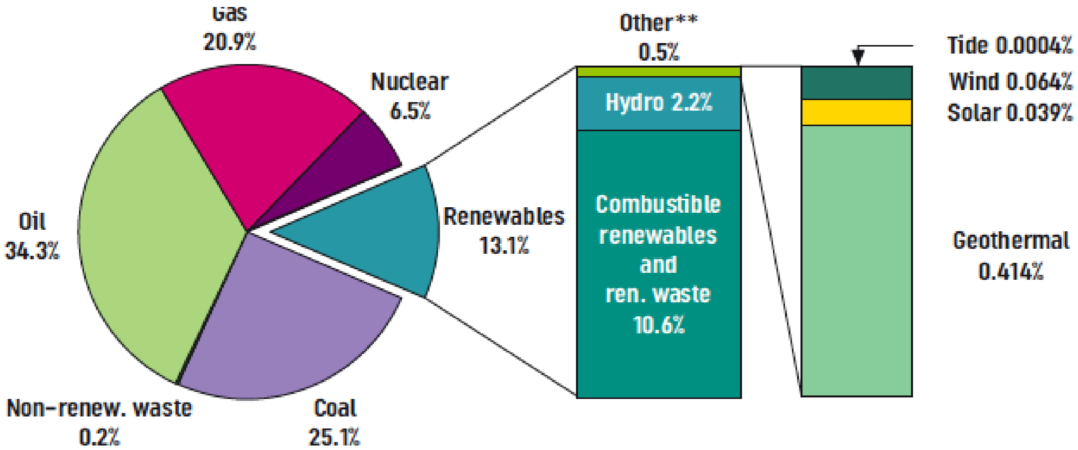


Figure 62: Fuel Shares of World Total Primary Energy Supply* (IEA 2007)



* TPES is calculated using the IEA conventions (physical energy content methodology). It includes international marine bunkers and excludes electricity/heat trade. The figures include both commercial and non-commercial energy.
** Geothermal, solar, wind, tide/wave/ocean.
Totals in graph might not add up due to rounding.
Source: IEA Energy Statistics

Figure 63: 2004 Regional shares in renewable energy supply (IEA 2007).

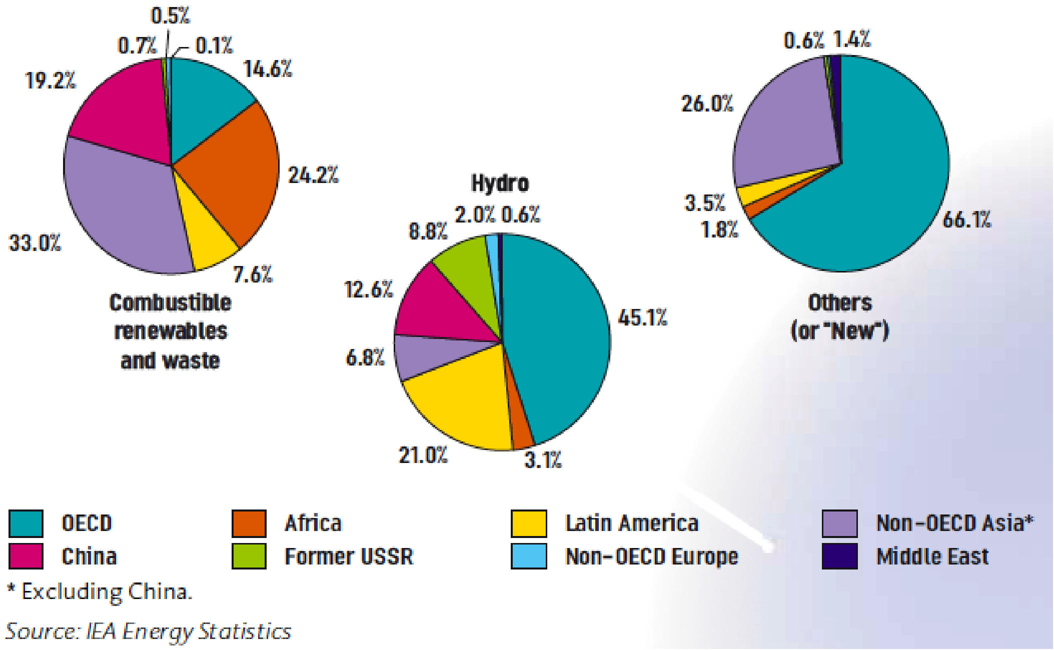
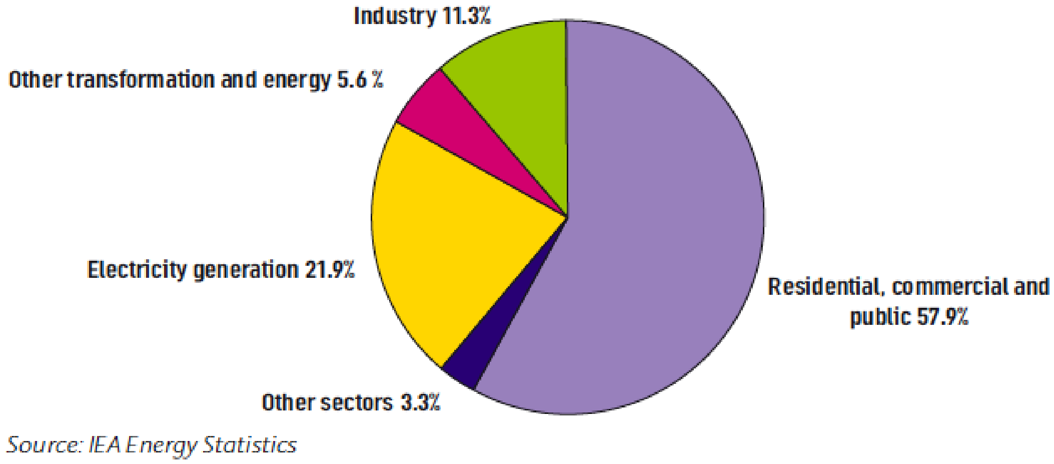


Figure 64: Global sectoral consumption of renewable energy (IEA 2007).



5.2 Appendix II – Energy Diversity Calculations

The Shannon–Wiener index (*H*) can be used as a simple measure of diversity based on the two categories of variety and balance, with p_i representing the share of fuel *i* in the energy mix or the market share of supplier *i*. The higher the value of *H*, the more diverse the system is. This index rises monotonically with increasing variety and balance.

$$H = -\sum_i p_i \ln p_i$$

Table 19: Diversity calculation by available fuel type on-island (Author 2011).

Fuel Type (*i*)	**Import Volumes**	***pi***	**ln *pi***	***pi* * ln *pi***
Low-Sulphur Diesel	131,000	0.074906024	-2.591520959	-0.194120532
High Sulphur Diesel	186,469	0.106623294	-2.238453277	-0.238671261
Gasoline	251,000	0.14352223	-1.941265343	-0.278614731
Gas (LPG/Propane)	58,000	0.033164499	-3.406275272	-0.112967414
Jet-A	236,000	0.134945204	-2.002886477	-0.270279925
Heavy Fuel Oil	886,389	0.506838748	-0.679562376	-0.344428544
Total = 1,748,858		Sum =1	Sum = 1.439082407	

H = 1.44

Table 20: Diversity calculation by available fuel type on-island assuming an even spread across (Author 2011).

Fuel Type (*i*)	**Import Volumes**	***pi***	**ln *pi***	***pi* * ln *pi***
Low-Sulphur Diesel	291476.3333	0.166666667	-1.791759469	-0.298626578
High Sulphur Diesel	291476.3333	0.166666667	-1.791759469	-0.298626578
Gasoline	291476.3333	0.166666667	-1.791759469	-0.298626578
Gas (LPG/Propane)	291476.3333	0.166666667	-1.791759469	-0.298626578
Jet-A	291476.3333	0.166666667	-1.791759469	-0.298626578

Heavy Fuel Oil	291476.3333	0.166666667	-1.791759469	-0.298626578
Total = 1,748,858		Sum =1	Sum = - 1.791759469	

H = 1.79

Table 21: Diversity calculation by fuel suppliers on-island (Author 2011).

Fuel Importer (*i*)	**Import Volumes**	***pi***	**ln *pi***	***pi* * ln *pi***
Rubis	440,000	0.251592754	-1.379943556	-0.347183799
Exxon Mobil	422,469	0.241568498	-1.420602211	-0.343172742
BP	886,389	0.506838748	-0.679562376	-0.344428544
Total = 1,748,858		Sum =1	Sum = - 1.034785086	

H = 1.03

Table 22: Diversity calculation by electrical energy generation entities on-island (Author 2011).

Power Generator (*i*)	**Power Generation (% Proportion)**	***pi***	**ln *pi***	***pi* * ln *pi***
Belco	97.8	0.978	-0.022245609	-0.021756206
Tynes Bay	2.2	0.022	-3.816712826	-0.083967682
	100	1		-0.105723888

H = -0.1

Table 23: Diversity calculation by electrical energy generation entities on-island assuming an even share (Author 2011).

Power Generator (*i*)	**Power Generation (% Proportion)**	***pi***	**ln *pi***	***pi* * ln *pi***
Belco	50.0	0.5	-0.693147181	-0.34657359
Tynes Bay	50.0	0.5	-0.693147181	-0.34657359
	100	1		-0.693147181

H = -0.7

Table 24: Diversity calculation by electrical energy generation entities on-island as is minus 10% from BELCO, which is distributed in the form of 'proxy' renewable (Author 2011).

Power Generator (*i*)	**Power Generation (% Proportion)**	***pi***	**ln *pi***	***pi* * ln *pi***
Belco	87.8	0.878878879	-0.129108185	-0.113470457
Tynes Bay	2.2	0.022022022	-3.815712325	-0.084029701
Renewable A	3.3	0.033033033	-3.410247217	-0.112650809
Renewable B	3.3	0.033033033	-3.410247217	-0.112650809
Renewable C	3.3	0.033033033	-3.410247217	-0.112650809
	100	1		-0.535452585

H = -0.5

5.3 Appendix III – Energy in Bermuda Survey (Sample)

Energy in Bermuda Survey (SAMPLE)

All multiple-choice responses may be indicated by a √ or by circling your desired response.

1. ***Energy is an important issue in your household.***

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree O Don't know

2. In your home, what do you feel are the most important activities that rely on energy provision? O Don't know

Your Response:____

3. For Bermuda as a country, what do you feel are the major things the island depends on energy for? O Don't know

Your Response:____

4. Do you know where your home electricity meter is located? YES / NO

5. Is the term "renewable energy" familiar to you? Indicate by circling your response. YES / NO

6. If yes to Question 5, do you or anyone you know have any renewable energy installations at home? YES / NO

7. You often receive information about renewable energy in Bermuda from which of sources below.

O newspaper O mail O BELCO O Government O I do not often receive information O Don't know

8. The information you receive about renewable energy in Bermuda concerns which of the issues below.

O purchasing from private companies O BELCO's plans O Government plans O I do not often receive information O Don't know

9. Which one of the following documents are you aware of?

OBermuda Sustainable Development Strategy O Bermuda Energy Green Paper O Bermuda Climate Change Report O None

10. Have you read the contents of any of the following documents?

OBermuda Sustainable Development Strategy O Bermuda Energy Green Paper O Bermuda Climate Change Report O None

11. Did you participate in the public consultation for any of the following documents?

OBermuda Sustainable Development Strategy O Bermuda Energy Green Paper O None

9. When purchasing home appliances, buying energy efficient appliances is important to you?

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree O Don't know

10. You understand how electricity is delivered to your home.

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree

11. You would consider buying an electric vehicle.

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree

12. If offered an electric vehicle, what would be your major concerns, if any? O Do not have any concerns

____

13. I would consider having my home's energy supply provided for from a home renewable energy device.

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree O Don't know

14. What do you feel may be the best type of renewable energy for Bermuda?

O Wind O Solar PV O Wave O Tidal O Biomass O Other O Don't know

15. If I had a renewable energy system at my home, you would prefer to do which of the following?

O Manage it myself O Have an outside company manage it O Doesn't matter O Don't know

16. ***You make an attempt to conserve energy at home.***

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree O Don't know

17. You feel that your work place encourages energy conservation.

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree O Don't know

18. The issue of energy is important to the government of Bermuda.

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree O Don't know

19. You feel that global climate change will affect Bermuda in some way.

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree O Don't know

20. Power outages reduce your quality of life.

O Strongly disagree O Disagree O Somewhat Agree O Agree O Strongly Agree

21. **Your age is**: ○ 20 - 30 ○ 30 - 40 ○40 – 50○ 50 - 60 ○ 60 and above

22. ***Your gender is:*** ○ MALE ○ FEMALE

23. ***Your ethnicity is:*** ○ White Bermudian ○ Black Bermudian ○Portuguese Bermudian ○ Other

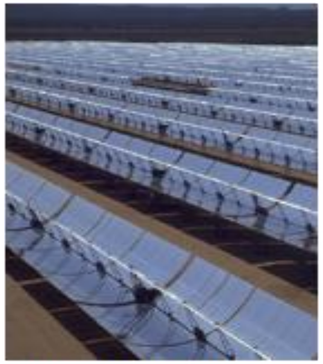
24. ***Your highest level of education is***: ○Primary ○Secondary ○College Diploma
○University – Undergraduate ○University – Postgraduate

25. ***Your income bracket is:***
○ Below $20,000 ○$20,000 to $30,000 ○$30,000 to $40,000 ○$40,000 – $50,000 ○$50,000 to $60,000
○ $60,000 to $70,000 ○ Above $70,000

Solar Photovoltaic (PV) Panel

Wind Turbine

Wave Energy Devices



Concentrated Solar Power System

Biomass Fuel

Solar Hot Water Panel

26. Which of the above renewable energy sources are you familiar with? Choose from the responses below and indicate in the boxes above.

1 Not familiar **2** Somewhat familiar **3** Familiar **4** Very Familiar

5.4 Appendix IV - Aide de Memoirs

5.4.1 Semi-structured Interview Aide de Memoir - For Residents

1. What would you describe as major activities dependent on energy in the home?
2. What would you describe as minor activities dependent on energy in the home?
3. Who is control of decisions concerning energy use in the home?
4. Who is control of the financial management of energy in the home?
5. What investments have been made in regard to energy, energy efficiency or energy conservation in the home?
6. What behaviours towards energy conservation and/or energy efficiency are made in the home?
7. What is more important in the home – comfort or energy conservation?
8. What information (psychological strategies) enter the space of the home in regard to energy?
9. Would you be willing to have a renewable energy system in your home?

5.4.2 Semi-structured Interview Aide de Memoir - For Businesses

1. State name and position.
2. What are the main types of energy used in the businesses?
3. How critical is energy to the business operations?
4. What is the main source of energy? Is there any independent generation or back up power?
5. What’s the relationship between the business and the power provider like?
6. Are there any special human resource requirements for the provision of power?
7. Does the business have an energy management program?
8. Does the business receive feedback from the government or the utility on energy management strategies?
9. How does the physical infrastructure (building, physical plant, etc.) play a role in the energy management of the business?
10. Is there any role foreseen for renewable energy?

5.5 Appendix V - Register of Interview Participants (Anonymous)

5.5.1 Residents

1H: Gender – Male, Age - >60, Ethnicity – Black, Occupation - Unknown

2H: Gender – Male, Age - ~40, Ethnicity – Black, Occupation – Marine and Ports worker

3H: Gender – Male, Age - 24, Ethnicity – Black, Occupation – Grocery store worker

4H: Gender – Male, Age - ~40, Ethnicity – Black, Occupation – Not steadily employed, Other Notes: Has a family of three.

5H: Gender – Female, Age - 37, Ethnicity – Black, Occupation – Not known

6H: Gender – Male, Age - >60, Ethnicity – Black, Occupation – Retired

7H: Gender – Male, Age - >40, Ethnicity – Black, Occupation – Electrical engineer, Other Notes: Has a family of three. Own home.

8H: Gender – Male, Age - 28, Ethnicity – Black, Occupation – Administrative Assistant, Other Notes: Has a family of three. Rent studio apartment.

9H: Gender – Female, Age - 33, Ethnicity – Black, Occupation – Cleaner, Other Notes: Lives with mother and father at home.

10H: Gender – Female, Age - >60, Ethnicity – White, Occupation – Executive, Other Notes: Lives alone. Owns 3 bedroom home.

11H: Gender – Female, Age - 34, Ethnicity – Black, Occupation – Self-employed cleaner, Other Notes: Has a family of three but lives with mother and sister in 3 bedroom house.

12H: Gender – Female, Age - 67, Ethnicity – White, Occupation – Secretary, Other Notes: Lives with husband in condominium complex. Expat with long term residency.

13H: Gender – Male & Female, Age - ~50, Ethnicity –White (Husband), Portuguese Bermudian (Wife), Occupation – Husband (American) is an insurance executive while wife (Bermudian) is human resource executive, Other Notes: Rent 4 bedroom home and have two university age children.

14H: Gender – Male, Age - 40, Ethnicity – White, Occupation – IT professional, Other Notes: Has a family of three. Owns 2 bedroom/2 bathroom home.

15H: Gender – Male & Female, Age – 37 & 34, Ethnicity – White, Occupation – Husband (Bermudian) is a land surveyor while wife (Australian) is a financial controller, Other Notes: Has a family of four. Owns 2 bedroom home.

16H: Gender – Male, Age - >50, Ethnicity – Black, Occupation – Landlord, Other Notes: Just completed the building of city multi-apartment building, May 2008. 9 units with 1 ½ baths each.

17H: Gender – Male, Age - >60, Ethnicity – Black, Occupation – Electrical engineer, Other Notes: Family of three. Owns 2 bedroom home with 2 bath. Newly renovated.

5.5.1.1 Disabled Residents

1D: Gender – Female, Age - 33, Ethnicity – Black, Occupation – Not known, Other Notes: Lives with sister. Long term disabled, wheel chair bound. Uses manual wheel chair.

2D: Gender – Female. Age – 36. Ethnicity – Black. Occupation – Executive. Other Notes: Mother of two. Long term disabled, wheel chair bound. Uses motorised electric wheel chair.

5.5.1.2 Residents with Renewable Systems Installed

RESI 1: Gender – Male. Age – 80. Ethnicity – Black, Occupation – Former electrical engineer. Now Retired. Other Notes: Owns large multi-unit home. Has renewable energy system comprising of 14 solar PV ground mounted solar panels in total – eight 175 W, four 110 W and four 55 W.

RESI 2: Gender – Male & Female. Age – >50. Ethnicity – Black (Husband), White (Wife). Occupation – Husband is a dentist. Wife is dental administrator. Other Notes: Own large multi bedroom home with pool. Has renewable energy system comprising of eight solar PV ground mounted solar panels and 10 roof mounted solar thermal panels plus a micro-wind turbine.

RESI 3: Gender – Male. Age – Unknown (~50). Ethnicity –White. Occupation – Unknown but very wealthy. Other Notes: Own large 3 bedroom home with pool. Has renewable energy system comprising of 71 solar PV roof mounted solar panels with a bank of 12 batteries.

5.5.2 Business

5.5.2.1 Small Business

SB1: Type – Motor bike retail. Staff Size - ~ 4. Other Notes: Rent small self-contained shop, storage and workshop units.

SB2: Type – Barber. Staff Size - 1. Other Notes: Rent small shop unit within a larger commercial building.

SB3: Type – Book retail. Staff Size - ~ 2. Other Notes: Rent small shop unit within a larger commercial.

SB4: Type – Surveyor. Staff Size - ~ 2. Other Notes: Own small office unit.

5.5.2.2 Taxi Business

TB1: Type – Self-owned taxi. Gender – Male. Age – Not known.

TB2: Type – Self-owned taxi. Gender – Female. Age – 60.

TB3: Type – Self-owned taxi. Gender – Male. Age – Not known.

5.5.2.3 Medium Business

MB1: Type – Advertising. Staff Size - ~2. Other Notes: Rent small office. Rent advertising space on outdoor solar panel powered advertising boards on the island.

MB2: Type – Pharmacy. Staff Size - 40-45. Other Notes: Own self-contained building unit.

5.5.2.4 Large Business

LB1: Type – Publishing. Staff Size - >30. Other Notes: Own substantial commercial property housing printing press and offices. Also operate multiple sister companies in other Caribbean islands.

LB2: Type – Mobile Telecommunications. Staff Size - >50. Other Notes: Part of an international mobile telecommunications firm. Rent local office space. Have multiple mobile signal transmission antenna located around island.

LB3: Type – Insurance. Staff Size - >20. Other Notes: Own self-contained office building in city centre.

LB4: Type – Insurance. Staff Size - >50. Other Notes: Large international insurance and reinsurance firm. Own substantial commercial property housing offices in city centre. LEED certified building.

LB5: Type – Construction. Staff Size - >30. Other Notes: Large local construction firm partnered with an international Canadian partner. Own substantial commercial property.

LB6: Type – Bank. Staff Size - >100. Other Notes: Large international bank operating in Bermuda. Own multiple commercial properties across island with particularly large units in the city centre.

LB7: Type – Retail Grocer. Staff Size - >100. Other Notes: Large local retail grocery chain with multiple stores located across island.

LB8: Type – Insurance. Staff Size - >100. Other Notes: Large international insurance and reinsurance firm. Own substantial commercial property housing offices in city centre. Have innovative ice tank chill units used to store energy during the evening and circulating the chilled melt water through the building during the day. They receive favourable night rates from BELCO for using this thermal storage unit used to conduct

LB9: Type – Retail Hardware and Home Supplies. Staff Size - >50. Other Notes: Own large commercial unit.

LB10: Type – Hotel. Staff Size - >50. Other Notes: Own multiple guest house units over large property. Solar thermal panels have been installed on the properties for over 20 years and are still in use to supply the self-contained guest cottages with hot water.

LB11: Type – Telecommunications. Staff Size - >100. Other Notes: Own large commercial office unit in city centre and multiple technical building units across island. Also have large fleet of service vans.

LB13: Type – Commercial Estates Quango. Staff Size - Unknown. Other Notes: Own large areas of commercial and rental real estate on-island containing both dwelling units, commercial units and other service orientated entities.

5.5.3 Special Stakeholders

5.5.3.1 Renewable Energy Installers

SI1: Staff Size - ~5. Company conducts both residential and commercial installations specialising in the installation of solar photovoltaic units as well as LED lighting systems and other energy saving devices.

SI2: Staff Size - ~5. Company conducts both residential and commercial installations specialising in the installation of solar photovoltaic units, solar thermal units as well as LED lighting systems and other energy saving devices.

SI3: Staff Size - ~10. Company conducts both residential and commercial installations specialising in the installation of solar photovoltaic units, solar thermal, micro-wind as well as LED lighting systems and other energy saving devices.

5.5.3.2 Government Bodies

- **Department of Energy**
- **Sustainable Development Unit**
- **Waste Management Section**
- **Labor and Training Department**
-

See www.gov.bm for more information.

5.5.3.3 Utilities

Bermuda Electric Light Company (BELCO): Bermuda's sole commerical electrical utility Bermuda Electric Light Company Limited (BELCO) is Bermuda's sole supplier of electricity, operating a generating plant and transmission and distribution systems throughout the Island. The utility has 165 megawatts of generating capacity and over 35,668 metered connections. (See www.belco.bm for more information.)

BELCO Meter Reader: A meter reader was asked about the net meter program at BELCO in regards to the technical installation and commercial arrangements as well as his experience in terms of customer feedback on the program.

5.5.3.4 NGOs

Bermuda Environment and Sustainability Taskforce (BEST): BEST is a local environment and sustainability NGO that attempts to act as monitoring and advocacy group locally for issues concerning environment and sustainable development. The group has often found itself at odds with the current government in regards to environment and development issues, in particular with the government's past use of 'Special Development Orders' (SDOs).(See www.best.org.bm for more information.)

Greenrock: Greenrock is a local environmental advocacy group that campaigns for local environmental issues in Bermuda. The company is not as adversarial as BEST in their public approaches to government policies but have conflicted with development oriented initiatives in the past. (See www.greenrock.org/ for more information.)

5.5.3.5 Major Support Services

King Edward VII Memorial Hospital (KEMH): KEMH is the island's main hospital complex. It is located close to the city center and serves as a point of treatment for most major emergency, surgical and long term acute patient care locally. (See http://www.bermudahospitals.bm/ for more information.)