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"Beyond Implementation: Mainstreaming Residential Solar Energy in Trinidad"

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Abstract

Small, tropical islands are energy insecure because they depend on precarious fossil fuel markets. The islands of Trinidad, Barbados and Oahu were looked at. Trinidad is the central case study and has low solar technology deployment. Barbados and Oahu have widespread residential solar energy adoption and are used as comparators. The comparisons are used to answer the question: "*How could the resident population's energy culture(s) and Government's residential solar energy policies interact to mainstream distributed residential solar energy technologies in Trinidad?*"

The Multi-Level Perspective (MLP) is used to approach energy transitions (ETs) as the product of a landscape, a regime, and niche's interactions. Mainstreaming as a concept is not explicitly used in the MLP but refers to the process by which niche-innovations enter the regime. However, the MLP's definition of culture was a gap in its approach to ETs. The Energy Cultures Framework is used to define 'culture' in the regime as 'energy cultures' which have norms, practices, material culture and external influences. The study investigates the role(s) of culture in ETs through the mainstreaming of distributed residential solar energy technologies in Trinidad. It focuses on the interactions between 'culture' and 'policy'.

Trinidad's historical energy policy literature was reviewed. This was followed by conducting 33 structured interviews with residents in Barbados and Trinidad, and 22 semi-structured interviews with energy officials in Oahu and Trinidad. Inductive and deductive thematic content analyses were respectively used to analyze the interviews.

Culture can create policy niches, and be considered to determine the types, goals and designs of policies that should be used to mainstream residential solar energy in Trinidad. More broadly culture transcends the three planes of the MLP and has proactive and reactive roles - which are expressed through niche-creation; technological selectivity; adaptive capacity; resisting change; and reacting to change. Mainstreaming is a useful concept in the MLP because it links innovation-adoption to socio-technical change and studying culture in the MLP broadens the consideration extended towards behaviour in socio-technical interactions.

Keywords: Small islands; Energy transitions; Solar energy; Mainstreaming; Culture; Policy

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1.0. Introduction

This thesis investigates the role of culture during energy transitions (ETs). It does so through an emphasis on the mainstreaming of distributed residential solar energy technologies in small, tropical islands. It focuses on an ET in the residential electricity system of the island of Trinidad through the integration of distributed residential photovoltaics and solar water heating - though photovoltaics is the main technology of interest. The islands of Barbados and Oahu are also used as case study comparators.

This introduction is structured as follows: section 1.1. presents an overview of what 'small island' means; section 1.2. outlines Trinidad, Barbados and Oahu's backgrounds; section 1.3. highlights why Trinidad's residential electricity system is the ETs scope; section 1.4. spotlights why solar energy is being studied; and section 1.5. summarizes the thesis' theoretical framing, research design and methodology as well as outlines the aim, objectives, research questions and the thesis' contents.

1.1. An Overview of the Nature of Small, Tropical Islands

Kakazu (2007) states that defining islands' 'smallness' is relative and can refer to geography, demography, the economy or combinations of these. Despite the multiplicity of definitions, the literature (e.g. Wong et al. (2005), Wong (2011), Everest-Phillips (2014), Baek et al. (2015), Ioannidis and Chalvatzis (2017)) states that most small islands have defining characteristics that include one or more of the following: limited natural resources; colonial legacies; mixed cultures; small populations; high population densities; rapid population growth; high emigration; high biodiversity; high dependencies on tourism, external aid and

governmental interventions; diseconomies of scale; high energy and grid connection costs; vulnerable energy infrastructures; high dependencies on fossil fuel imports and their costs; costly shipping; environmental fragility; oceanic natures; remote locations; and small land masses.

Of these oceanic natures, remoteness and smallness intersect to create islands' insularity (Wong et al., 2005; Kakazu, 2007). However, Wong et al. caveat that the stronger an island's connectivity to the 'outside' the less distinctive its insularity. Wong et al. (2005) further outline that these characteristics create an isola effect i.e. the physical isolation of islands such that they are exposed to different kinds of marine and climatic disturbances and have more limited access to space, products, and services when compared to most continental locations.

These conditions create smaller, less diversified yet more specialized economies because limited resources constrain production and consumption capacities, and skew trade such that a wide range of goods/products are imported and only a few primary goods/products are exported (Wong et al., 2005; Kakazu, 2007; Office of the High Representative for the LDCs, Landlocked Developing Countries and SIDS, 2011; Wong, 2011).

1.1.1. An Overview of the Small-Island Energy Challenge

The small-island energy challenge can best be understood through two concepts: climate change and energy insecurity.

Small islands are marginal contributors to climate change yet are amongst the most vulnerable to its repercussions (Wong, 2011) especially when compared to continental geographies

(Szabó et al., 2015). But when climate change and small islands are mentioned it is intuitive that sea level rise is perhaps the most famous implication.

Other featured repercussions include the increased frequency and intensity of climatic disasters such as hurricanes. For instance, Hurricane Irma which hit the Caribbean in 2017 generated enough cyclone energy on its own to match what the National Oceanic and Atmospheric Administration defines as an 'average' hurricane season (Loria, 2017). Irma also had sustained 185-mile per hour winds that lasted for 37 hours which makes this the longest time that any cyclone maintained that intensity (Loria, 2017).

The world's energy is dominated by hydrocarbon markets and most small islands have little to no indigenous hydrocarbon resources. Due to this scarcity they rely on costly hydrocarbon (usually oil) imports (Office of the High Representative for the LDCs, Landlocked Developing Countries and SIDS, 2011; Dornan, 2015).

In the case of small, sovereign island States for example, they spend as much as USD $90 million per day on importing more than 900,000 barrels of oil (Rogers et al., 2012). These costs are passed on to local energy market(s) so islands have higher than average costs when compared with non-islandic geographies (Wolf et al., 2016).

The IEA (2018) defines energy security as the uninterrupted availability of energy resources at affordable prices. So energy insecurity in the context of small islands refers to a dependence on physical access to energy imports, and high energy import bills and local energy costs - both of which are coupled to the fluctuating prices on the international hydrocarbon markets. Given that hydrocarbons' prices have been historically unpredictable this therefore puts the future of small islands' energy in a precarious position.

Though adaptation has been prioritized by small, tropical islands, the implications of energy insecurity present mitigation through renewable energy as a promising intervention; renewables are a potential solution to both climate change and energy insecurity issues (Verdolini and Galeotti, 2011) even though these islands' mitigation will be negligible globally (Dornan, 2015).

Many small, tropical islands have several renewable energy resources such as wind and solar that can be utilized. Using renewables can allow these islands to reduce their carbon emissions; reduce their dependence on costly, imported hydrocarbons; reduce energy costs in their local markets; improve their energy and economic independence; and enhance their overall self-sustaining capacity since growth in renewable energy is quite often linked to growth in indigenous energy use (Ioannidis and Chalvatzis, 2017).

The shift from hydrocarbon energy systems to ones that incorporate more renewables essentially represents an energy transition (ET). ETs are shifts in an economic system's combination of energy resources and technologies (Fouquet and Pearson, 2012) which structurally affect technologies; the localization of activities; consumption; science; education; manufacturing; and transport (Kemp, 1994; Cassen et al., 2012).

Islands are small-scaled spatial laboratories (King, 2009) and testing sites for energy innovations (Ioannidis and Chalvatzis, 2017) so this presents a well-defined scope for studying ETs. But Lilienthal (2007), and Shirley and Kammen (2013) regard islands and their energy grids as overlooked opportunities for research.

Understanding small-island ETs offers insight into the future of energy. Centralized power generation constitutes the dominant systems in most of the world and decentralized

(renewable energy) systems exist in niches (Markard and Truffer, 2008). But the transition from centralized to decentralized systems is gaining prominence (Fuchs and Hinderer, 2016). The small scales of decentralized technologies are ideal for the smallness of small islands so studying islandic ETs is a valuable contribution to energy futures research.

The thesis' three case study islands, Trinidad, Barbados and Oahu, can now be looked at in more depth.

1.2. Trinidad, Barbados and Oahu as the Small, Tropical Island Case Studies

1.2.1. Trinidad as the Central Case Study

Trinidad and Tobago (T&T) is one country but two islands. They are the Southern-most Caribbean islands, located approximately 11Km off the coast of Venezuela, and cover approximately 5,100Km^2 (Espinasa and Humpert, 2013; Espinasa and Humpert, 2016) - see Figures 1 (next page) and 2 (page 22).

T&T experiences a dry (January to May) and wet season (June to December), and the latter is markedly affected by tropical depressions like hurricanes (Wellington, 2011; Narinesingh et al., 2013). The islands' have an average temperature of just under 28^oC but can range from 24 to 32^oC (Narinesingh et al., 2013). The annual rainfall ranges from 1,400 to 2,600mm (Narinesingh et al., 2013). Subsection 1.4.2. will provide the details on Trinidad's natural solar energy potential.

The image showing the map of the Caribbean originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Figure 1 showing the location of Trinidad and Tobago, and Barbados in the Caribbean

Adapted from Espinasa and Humpert (2016; 5) using Microsoft Word

T&T is the leading Caribbean producer of oil and gas, and has been regarded as the most industrialized territory in the English-speaking Caribbean (Mustapha, 2012; Narinesingh et al., 2013; Solaun et al., 2015). It has a USD $23 billion-dollar economy (in Gross Domestic Product (GDP) terms) (NREL[1], 2015; Economic Diplomacy, Trade Advocacy and Statistics Section, 2016). T&T's oil and gas resources account for 39 to 45% of the GDP and 80 to 83% of its economy-wide exports (Mustapha, 2012; Espinasa and Humpert, 2013; Narinesingh et al., 2013; Solaun et al., 2015; GORTT, 2016).

The image showing the map of Trinidad and Tobago originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Ezilon.com[1]. 2009. Trinidad and Tobago Mao- Physical Map of Trinidad and Tobago. Website: http://www.ezilon.com/maps/north-america/trinidad-and-tobago-physical-maps.html (accessed 17th March, 2017)

Figure 2 showing the islands of Trinidad, and Tobago

Adapted from Ezilon.com[1] (2009) using Microsoft Word

T&T is the central case study because:

T&T is a significant greenhouse gas emitter by island standards: Not only is T&T's carbon dioxide (CO_2) emissions an exception to the Caribbean trend of comparatively low emissions by global standards, it is also a standout case for the CO_2 impact amongst Small Island Developing States (Thomas, 2009); its emissions per capita are so high that at one point it was ranked 2nd in the world (Marzolf et al., 2015).

T&T has low renewable energy adoption: T&T has had no substantial renewable energy development and so, it is 'starting from the beginning' (Samuel, 2013) - and as is the case in many parts of the world solar energy still requires Government support to be competitive (WEC, 2016).

Trinidad however is being looked at specifically because:

The nation's capital is in Trinidad: Trinidad is home to the country's capital, Port of Spain, which is in the North-Western part of the island (see Figure 2 on the previous page) and is the center of governance.

Trinidad is the more populated and urbanized: T&T has 1.4 million residents (Economic Diplomacy, Trade Advocacy and Statistics Section, 2016) and is more than 70% urbanized (CARICOM Secretariat, 2009; Ministry of Planning and Sustainable Development, 2014). However over 1.2 million people live in Trinidad versus just under 61,000 in Tobago (CSO, 2011). T&T also has nearly 400,000 housing units of which 380,000 are in Trinidad (CSO, 2011).

Trinidad is the more industrialized: Tobago neither produces oil and gas nor is it as industrialized (e.g. oil-refining, ammonia production, etc.) as Trinidad.

Trinidad has the larger power generation capacity: T&T's power is provided by four producers that operate eight power plants of which six are in Trinidad and two are in Tobago (Marzolf et al., 2015; Espinasa and Humpert, 2016). The six in Trinidad amount to 2,341 Megawatts (MW), and Tobago's is rated at 85.7 MW with an undersea connection to Trinidad's grid (Espinasa and Humpert, 2016).

Trinidad has the larger residential electricity customer-base: T&T's electric utility company, the Trinidad and Tobago Electricity Commission (T&TEC), has between 385,000 to 430,000 residential customers (Marzolf et al., 2015). Based on the earlier population and housing distribution, it is expected that Trinidad has the larger share of the residential customer-base; the RIC's (2016) figures even show that Trinidad has roughly 94% of the T&TEC's total active customer accounts.

Trinidad has the higher energy demand: Based on the preceding points, Trinidad has more residents, households, technical generation capacity as well as residential electricity customers than Tobago. Therefore, it is expected that it has a higher residential electricity demand than Tobago.

1.2.2. Barbados as Trinidad's Cultural Case Study Comparator

Barbados is a sovereign island-State in the Southern Caribbean. It is the Eastern-most island and is about 160Km from its nearest neighbours, and 402Km North-East of Trinidad and Tobago (T&T) (Tout, 1968; Jensen, 2000; Ministry of Physical Development Environment, 2001; Ministry of Environment, Water Resources and Drainage, 2010; Moore et al., 2014). Barbados has an area of 430Km^2 (Moore et al., 2014) and the capital, Bridgetown, is located in the South-West of the island as shown in Figure 3 on the next page; Figure 1 (page 21) shows the island's location in the wider Caribbean.

Barbados has an average temperature between 20 to 30^oC (Ministry of the Environment, Water Resources and Drainage, 2010). Its annual rainfall varies from 2,000mm in the wettest areas to 1,300 mm in the driest though most locations get between 1,400 to 1,600mm (Tout,

1968; Ministry of the Environment, Water Resources and Drainage, 2010). Subsection 1.4.2. will provide the information on Barbados' natural solar potential.

The image showing the map of Barbados originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Ezilon.com[2]. 2009. Barbados Map- Physical Map of Barbados. Website: http://www.ezilon.com/maps/north-america/barbados-physical-maps.html (accessed 14th March, 2017)

Figure 3 showing the island of Barbados

Adapted from Ezilon.com[2] (2009) using Microsoft Word

Like T&T, Barbados experiences a dry (December to May) and wet (June to November) season (Ministry of Physical Development Environment, 2001; Ministry of the Environment, Water Resources and Drainage, 2010). The climate is also affected by trade winds, tropical depressions, easterly waves, and hurricanes (Ministry of Physical Development Environment, 2001; Schlegelmilch, 2010).

Similarly to Trinidad, Barbados is an oil and gas producer. But it only produces between 850 to 1,000 barrels of oil per day and between 290 to 500 barrels of oil equivalent per day (boe/day) of natural gas which are shipped to Trinidad for refining and later imported (Gischler et al. 2009; Castalia Limited, 2010; SEforALL, 2012; Samuel, 2013; Ince, 2017); Barbados imports over 9,000 boe/day (Gischler et al., 2009; Castalia Limited, 2010; SEforALL, 2012; Government of Barbados, 2015).

Barbados has a USD $4.3 billion-dollar Gross Domestic Product economy (Gray et al., 2015; World Bank, 2017). The economy is finance, insurance, business and tourism-oriented with a growing offshore financial services sector (Ministry of Physical Development Environment, 2001; Schlegelmilch, 2010; Ministry of the Environment, Water Resources and Drainage, 2010; Samuel, 2013). However light industry and tourism make up the largest portion of the GDP and the latter is the most significant foreign exchange earner and economic driver (Schlegelmilch, 2010; Jackson and Lorde, 2012; Government of Barbados, 2013; Cain, 2016).

Barbados is being used as a cultural case study comparator for Trinidad because:

Barbados is a geographical neighbour: Barbados and Trinidad are both neighbouring Caribbean islands - see Figure 1 on page 21.

Barbados is socio-culturally similar to Trinidad: Trinidad and Barbados were British colonies; were sugar-producing economies; are English-speaking with similar dialects; have strong African heritages due to the influence of slavery which include folklore and demographics; and share similar climates. They even have similar levels of economic development (Mustapha, 2012). It is therefore reasonable to assume that this common

background keeps the islands' socio-cultural contexts and variables relatively comparable.

Barbados is a regional leader in residential solar energy: Barbados is a pioneer in Caribbean sustainability (Haraksingh, 2001). It has been hailed as a regional leader in energy sustainability and global leader in solar water heating because of its widespread adoption of the technology (see Figure 4) and the establishment of an indigenous manufacturing and retail industry (Samuel, 2013; IEA-ETSAP and IRENA, 2015; Gray et al., 2015; Government of Barbados, 2015; Ince, 2017).

The image showing the solar water heating market penetration in select Caribbean countries originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Gray, F., J. Koo, E. Chessin, W. Rickerson and J. Curti. 2015. Solar Water Heating Techscope Market Readiness Assessment. Reports for: Aruba, Bahamas, Barbados, Dominican Republic, Grenada, Jamaica, St. Lucia, Trinidad and Tobago. Division of Technology, Industry and Economics, Global Solar Water Heating Initiative, United Nations Environment Programme. Website: http://www.solarthermalworld.org/sites/gstec/files/story/2015-10-16/activity_5_-_swh_techscope_assessments_of_eight_caribbean_countries_report.pdf?ref_site=ppiaf (accessed 24th February, 2018)

Figure 4 showing the solar water heating (SWH) market penetration in Barbados and select Caribbean islands based on 2014 estimates

Note: kWth stands for kilowatt-thermal and is a unit of heat.

Adapted from Gray et al. (2015; 9) using Microsoft Word

The Barbadian solar hot water industry was around since the 1970s when Solar Dynamics, the first consolidated solar hot water company and market leader, entered in 1974/1975 followed

by SunPower and Aqua Sol (now Solaris) in 1978 and 1981 respectively (Bugler, 2012; Rogers et al., 2012; Samuel, 2013; CDB, 2014; Husbands, 2016). This means that there is an industry that can manufacture, install as well as repair the technologies being put on the market; the technology and its services were made readily accessible to the island's residents.

The Government also implemented several policies to promote the adoption of solar water heaters over the history of the island's usage of solar hot water e.g. in 1974 20% tax breaks were offered for solar water heater manufacturing; 30% tax on electric water heaters; tax refunds for eligible solar water heater systems for homeowners; and legally requiring new-build governmental housing to have solar hot water (Bugler, 2012).

In addition to the above policies and establishment of an indigenous manufacturing and retail industry, retailer-led marketing and advertising (specifically from Solar Dynamics) and the 1970s oil price hikes were also factors that made solar water heating in Barbados an attractive economic option (Bugler, 2012).

As a result of such a retail market, access to the technology, available policies and subsidies, and international developments, 80 to 90% of Barbadian households have solar water heating (Gray et al., 2015; CEIS, 2015; IEA-ETSAP and IRENA, 2015). Barbados' market accounts for between 55 to 60% of the Caribbean's solar water heaters and 80% of its manufacturing (Ministry of Physical Development Environment, 2001; Bugler, 2012; Samuel, 2013). Barbados' solar water heating market is therefore saturated (IEA-ETSAP and IRENA, 2015).

However, as the 2nd point illustrates, Barbados is solely being used as the cultural comparator given its similar socio-cultural context to Trinidad's; it uses solar water heating as the case

technology to investigate how culture can potentially influence and be influenced by energy transitions. It is not being used as a policy comparator because it does not have any significant adoption of residential photovoltaics which is the key technology that the thesis is interested in, and Oahu has a longer history of residential photovoltaics utilization as it relates to elements such as policies, markets, and industries for example (see subsection 1.2.3.)

The pervasive adoption of solar hot water in Barbados makes it likely that solar water heating impacted residents' norms, practices and material culture - what Stephenson et al. (2010; 2015) refer to as an energy culture (this will be discussed in Chapter 2).

So given that the wider cultural context should be more or less comparable, this leaves room to specifically look for differences between the household energy cultures of residents in Barbados and Trinidad that may be attributable to the adoption of solar water heating and that may influence the adoption of solar water heating. This is a useful approach since van de Vijver and Leung (1997) state that if identifying differences is the objective, then looking at similar cultures is a good starting point.

1.2.3. Oahu as Trinidad's Policy Case Study Comparator

Hawaii is the 4th smallest State of the U.S. and is located 3,800Km West of the mainland in the Pacific Ocean (Mogil, 2013; DBEDT[1], 2017). The State is over 28,000Km^2 in area and has 8 main isles out of a total of 137 islands: Hawaii Island, Maui, Kahoolawe, Lanai, Molokai, Oahu, Kauai, and Niihau (DBEDT[1], 2017). Figure 5 on the next page shows the 8 main islands.

The image showing the map of the State of Hawaii originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Ezilon.com[3]. 2009. Hawaii Map- Physical Map of Hawaii. Website: https://www.ezilon.com/maps/united-states/hawaii-physical-maps.html (accessed 25th February, 2018)

Figure 5 showing the 8 main isles of the State of Hawaii, and the island of Oahu as the inset

Adapted from Ezilon.com[3] (2009) using Microsoft Word

Hawaii's rainfall can be quite variable due to tropical cyclones and cold fronts (Mogil, 2013) and Stidd and Leopold (1951) state that Oahu's annual rainfall varies between 450 to 6,200mm. The DBEDT[1,1] (2015; 2017) also quote average temperatures between 21 to 29ºC. Subsection 1.4.2. will provide the details on Hawaii's solar radiation.

According to Jones (2015) and the DBEDT[1] (2018) Hawaii's most significant economic sectors are tourism, defence, agriculture, manufacturing and the service industry; it has developed a growing USD $80 billion-dollar Gross Domestic Product (GDP) economy (Bureau of Economic Analysis, 2016; DBEDT [2,3], 2018).

Hawaii is being used as a case study and comparator because:

Prior MSc. research: Neale and Jardine (2015) looks at social housing's solar potential through an indexing framework called the Geographic Insolation Potential and its Index. They indexed and mapped all the States of the U.S., Provinces and Territories of Canada, and Municipalities of Trinidad and Tobago. Of the 79 locations, Hawaii topped the list and was the only location to achieve the Index's benchmark performance.

Oahu is specifically looked at because:

The State's capital is in Oahu: Oahu has housed the State's capital, Honolulu, since 1845 and is the centre of business and State governance (Hawaii Tourism Authority, 2015; World Population Review, 2015; DBEDT[1], 2015; DBEDT[1], 2017). It can be seen in Figure 5's inset map (previous page) in the South-Eastern side of the island.

Oahu is the most populated and urbanized: Hawaii is the most isolated population centre on the planet with an estimated 1.4 million residents of which 64 to 89% live in its urbanscape that covers 10% of the State's land space (DBEDT, 2002; Kaya and Yalcintas, 2010; DBEDT[1], 2015; Bureau of Economic Analysis, 2016; DBEDT[1], 2017). The State has an estimated 530,000 housing units and over 440,000 households (Tian, 2014; DBEDT, 2014; DBEDT[1], 2015; DBEDT[1], 2017). However, Oahu has nearly 70% of the State's population, 65% of its housing units, and 69% of its households (Tian, 2014; DBEDT, 2002; HNEI, 2008; World Population Review, 2015; DBEDT[1], 2017).

Oahu is the State's energy gateway: Hawaii has no indigenous hydrocarbons so the State relies on costly imports (Alm, 2015). 80% of Hawaii's energy is imported as petroleum (State

of Hawaii[1], 2018). The imports are delivered to Oahu, refined and then shipped to the other islands (U.S. EIA, 2014).

Oahu has the greatest power generation capacity: The State's electricity is generated by two companies operating 4 electric utilities i.e. the Kauai Cooperative in Kauai, and the Hawaiian Electric Industries (HEI) that services the rest of the archipelago; the HEI is made up of the parent company, the Hawaiian Electric Company (HECO) on Oahu, and its subsidiaries, Maui Electric Light that electrifies Maui, Lanai and Molokai, and the Hawaii Electric Light Company on Hawaii Island (DBEDT, 2014). The HEI provides 95% of the State's electricity but this is dominated by the HECO's generation (Pintz and Morita, 2017).

Oahu has the highest energy demand: Oahu has the highest energy consumption of any of the islands under the HEI's jurisdiction (HNEI, 2008; GE Energy Consulting, 2015). Each of the Hawaiian Islands' electricity grids are also independent so this means that their respective generation capacities need to meet their demand - hence the complementary nature of Oahu's generation and demand dynamics in its selection rationale.

Oahu has the largest residential electricity customer-base: Of the HEI's estimated 400,000 residential customers Oahu has over 300,000 which means that the HECO has the largest customer-base (DBEDT[1], 2015; HECO Incorporated[1], 2018).

Oahu (and by extension Hawaii) has an extensive residential solar energy policy history: Oahu's policymakers have implemented several different policies which supported and still support multiple dimensions of the island's growth in solar photovoltaics (and renewable energy). Examples of policies and initiatives are renewable portfolio standards, net energy metering, the feed-in tariff, customer grid-supply and self-supply, standard interconnection

agreements, as well as federal and state tax credits. The North Carolina Clean Energy Technology Center provides a detailed compilation of the policies the State of Hawaii has implemented. Their website lists 56 different initiatives that are registered of which 32 support solar photovoltaics.

Oahu leads Hawaiian solar: The HECO's customer-sited photovoltaic generation capacity (>500 Megawatts (MW)) and number of systems installed (>51,000) is almost 5 times greater than any of the other utilities' (DBEDT[1], 2015; HECO Incorporated[2], 2018). Figure 6 also reflects Oahu's standout solar energy development since most of the State's proposed solar energy projects (12 out of 15) were in Oahu.

The image showing the proportional amount of proposed renewable energy projects in the Hawaiian Islands in 2011 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Lim, R. 2011. DEBT Energy Plan. HCEI Plenary Session. Department of Business, Economic Development and Tourism. State of Hawaii. Website: http://www.hawaiicleanenergyinitiative.org/storage/media/1-Lim.pdf (accessed 13th April, 2017)

Figure 6 showing the proportional amount of proposed renewable energy projects in the Hawaiian Islands in 2011

Adapted from Lim (2011; 8) using Microsoft Excel

Oahu has the largest renewable energy industry: The County of Honolulu (which is the county designation for Oahu) has almost 62% of the State's green energy jobs across all the industries (Lim, 2011). In the wider scope Figures 6 and 7 (next page) show supporting

contexts for the industry where Oahu had the most renewable energy projects (26 out of 66) in the pipeline and the HECO's recognized number of distributed renewable energy systems and installed capacity was the largest respectively.

The image showing the Hawaiian utilities' recognized distributed renewable energy systems and capacity installed from 2001 to 2010 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Lim, R. 2011. DEBT Energy Plan. HCEI Plenary Session. Department of Business, Economic Development and Tourism. State of Hawaii. Website: http://www.hawaiicleanenergyinitiative.org/storage/media/1-Lim.pdf (accessed 13th April, 2017)

Figure 7 showing the Hawaiian utilities' recognized distributed renewable energy systems and capacity installed from 2001 to 2010

Adapted from Lim (2011; 7) using Microsoft Word

1.3. Trinidad's Residential Electricity System as the Sectoral Scope

Trinidad's hydrocarbon history includes national celebrations and festivals. For example, the national instrument, the steelpan, is made from old oil drums and the popular carnivals often have costume and character portrayals that revolve around oil. These are what Gallivan and Srite (2005) refer to as symptoms of culture. This was the initial inspiration for studying the relationship between the island's people and their interactions with 'energy'.

Trinidad's residents and their lifestyles span energy spaces beyond homes but the residential electricity sector is the research scope because:

Energy and shelter are basic human needs: All living things need energy to survive and all anthropogenic activity is connected to energy (Eni, 2016). The household is also the general framework in which most individuals identify with since the majority live in households and it is made up of persons living together i.e. sleeping and sharing meals together (CSO, 2011). So, based on these notions there is an anthropological link between consuming energy and sheltered living.

This is more interestingly set in the context of households traditionally being consumers of energy. But with the adoption of household photovoltaics, households can become prosumers i.e. consumers and producers of electricity (Eid et al., 2014; Georges et al., 2014) which represents a fundamental change in the nature of households as spaces facilitating shared living arrangements.

The residential sector is a key electricity consuming sector: The residential sector consumes roughly 29% of the electricity which makes it the 2nd highest consumer after the industrial sector (Espinasa and Humpert, 2016).

The residential sector has more electricity customers than other sectors: Each household legally connected to the grid is the utility company's customer. This means that the sheer number of households suggests that this sector has the largest number of customers. Table 1 (next page) shows the Trinidad and Tobago Electricity Commission's customer count for each of their tariff bands and the residential category, Rate A, dwarfs the others.

The table showing the Trinidad and Tobago Electricity Commission's customer forecast for 2016 originally presented here cannot be made freely available via ORA because of copyright. The data and information were respectively sourced from:

Marzolf, N. C., F. C. Cañeque and D. Loy. 2015. A Unique Approach for Sustainable Energy in Trinidad and Tobago. Inter-American Development Bank. Website: http://www.energy.gov.tt/wp-content/uploads/2016/08/A-Unique-Approach-for-Sustainable-Energy-in-Trinidad-and-Tobago.pdf (accessed 12th January, 2017)

Table 1 showing the Trinidad and Tobago Electricity Commission's 2010 customer forecast by rate category for 2016

Note: A is Residential (Domestic); B is Commercial; D1 is Small industrial; D2 is Medium industrial; D3 and D4 are Large industrial; D5 is Large industrial (Standby); E1, E2 and E3 are Industrial rates (Very large load); E4 and E5 are Industrial rates (Very large industrial); and S is Street lighting.

Generated by the Author but adapted from Marzolf et al. (2015; 13) using Microsoft Word

The residential sector has more potential independent generators than other sectors: The households i.e. Rate A in Table 1 make up the largest portion of the utility's customer base. This means that relative to power generation and the centralized versus decentralized dichotomy, households likely to be distributed power generation agents will potentially account for the largest number of independent power generators. This would especially be relevant if grid-connected policies are considered where households can generate, export and sell their solar power to the utility company.

Distributed solar energy is more likely given the limits of land area in small islands: Small islands have limited land space. This means that land use conflicts could potentially be more contentious given this scarcity. Centralized solar energy uses considerably larger land

space than its decentralized counterparts. For example, in the U.S., utility-scale solar requires an average of 36 square meters per Megawatt of which 30 square meters is directly used (WEC, 2016). Households' rooftop surface areas are suited for distributed solar energy systems so would minimize the opportunity costs involved with competing land uses.

Household solar installations do not benefit from economies of scale: There are many types of housing which will affect the size of a given residential solar energy installation. But most residential installations will be individual projects since private households make up the largest segment of the residential sector. This means that these smaller-scaled installations do not benefit from the economies of scale that larger projects benefit from.

1.4. Solar Energy as the Resource of Interest in Trinidad

1.4.1. The Motivations for Looking at Solar Energy

The MEEA (2012) and Khan and Khan (2017) state that Trinidad should invest in renewable energy because it can enhance energy security; mitigates the impacts of climate change; uses reliable energy sources; creates employment; diversifies the economy; reduces the dependence on finite hydrocarbons; and promotes national and industrial development. But solar energy is particularly being studied because:

Solar energy is one of the most ubiquitous renewable energy resources available for small, tropical islands: Small, tropical islands have small landmasses and an abundance of sunshine which makes solar energy a geographically ubiquitous resource.

Solar energy is one of the most viable renewable energy options in Trinidad: Trinidad has

a limited suite of renewable energy options but solar energy is one of the most viable (Renewable Energy Committee, 2011; IRENA, 2012; Solaun et al., 2015; Marzolf et al., 2015) - and the market penetration pattern for solar systems is a useful indicator of the general transition towards using renewable energy resources (Sawyer, 1982).

Distributed residential photovoltaics is the key technology that the work is interested in but this and solar water heating are being looked at because:

Photovoltaics and solar water heating are well-established technologies: Photovoltaics and solar water heating are relatively old renewable energy technologies; solar collection was around since the late 1700s, solar water heating from the late 1800s, and photovoltaics from the 1950s (U.S. Department of Energy, 2004). They have gone through generational research and development to a point where today's systems are more efficient and cheaper. They are also two rapidly growing technologies; Figures 8 and 9 (next page) illustrate the global growth in photovoltaics and solar water heating respectively.

The image showing the global photovoltaics capacity from 2006 to 2016 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Renewable Energy Policy Network For The 21st Century. 2017. Advancing the Global Renewable Energy Transition: Highlights of the REN21 Renewables 2017 Global Status Report in Perspective. Website: http://www.ren21.net/wp-content/uploads/2017/06/GSR2017_Highlights_FINAL.pdf (accessed 25th April, 2018)

Figure 8 showing the global photovoltaics capacity from 2006 to 2016

Extracted from the Renewable Energy Policy Network For The 21st Century (2017; 28)

The image showing the global solar water heating collector capacity from 2006 to 2016 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Renewable Energy Policy Network For The 21st Century. 2017. Advancing the Global Renewable Energy Transition: Highlights of the REN21 Renewables 2017 Global Status Report in Perspective. Website: http://www.ren21.net/wp-content/uploads/2017/06/GSR2017_Highlights_FINAL.pdf (accessed 25th April, 2018)

Figure 9 showing the global solar water heating collector capacity from 2006 to 2016

Extracted from the Renewable Energy Policy Network For The 21st Century (2017; 29)

Photovoltaics and solar water heating are the main solar technologies being considered in Trinidad: Solar energy technologies have been popularized throughout the world (Kabir et al., 2018). But photovoltaics and solar water heating are the two technologies being considered relative to designing Trinidad's residential solar energy policies as shown by work such as Haraksingh (2001), Marzolf et al. (2015), Espinasa and Humpert (2016), and Khan and Khan (2017).

Photovoltaics and solar water heating are the most popular technologies in the case study comparators: Distributed residential photovoltaics and solar water heating are the two technologies most widely adopted by residents in Oahu and Barbados respectively. Subsection 1.2.2. provided more information on why Barbados and its solar water heating was selected as a case study comparator in light of the key focus on solar photovoltaics.

Distributed residential solar energy technologies can have a potentially greater socio-cultural impact on households: Solar and wind energy are the key renewable energy options that Trinidad is considering. Work from Chadee and Clarke (2018) suggest that large-scale wind can be cost-competitive with the incumbent natural gas used for power generation based on the levelized costs of electricity. This makes this centralized power design one of the few, if not only, economically feasible renewable energy design for the island.

However distributed residential solar energy technologies are decentralized, smaller-scaled energy technologies. This means that compared to centralized, large-scaled energy technologies e.g. the wind systems from Chadee and Clarke (2018), there are more direct interactions occurring between an adopting household and the distributed technologies due to their proximity to the energy users and where the energy is being used; there are closer links between the energy resource and the practices that use the energy supplied.

For example, a household using power from a centralized wind farm located offshore would be unlikely to know where their power is coming from let alone what it is being generated from. However, with rooftop photovoltaics for instance, householders will likely have a closer cognitive (and by extension cultural) connection to their energy resource and technology - which raises their energy conscientiousness and affects their household practices.

1.4.2. The Case Studies' Solar Energy Resources

Neill and Granborg (1986) suggest that before installing any renewable energy system the resource's potential should be considered. The amount of incident solar radiation is one of the most important factors for using solar technologies and it is measured in kilowatt-hours per

square meter (kWh/m^2) per time (WEC, 2016). Figure 10 shows that Trinidad, Hawaii and Barbados are well-endowed with sunshine.

The image showing the distribution of solar insolation in the world originally presented here cannot be made freely available via ORA because of copyright. This top image was respectively sourced from:

Saving our planet. 2016. Solarenergie. Website: http://saveourplanet.info/uploads/images/rikd9q20151228153425.png (accessed 27th February, 2017)

As per the copyright advisory for the bottom image, a link to the original image is here:

Free World Maps. 2009. Printable white-transparent political blank world map C3. Website: http://www.free-world-maps.com/printable-white-transparent-political-blank-world-map-c3 (accessed 2nd March, 2018)

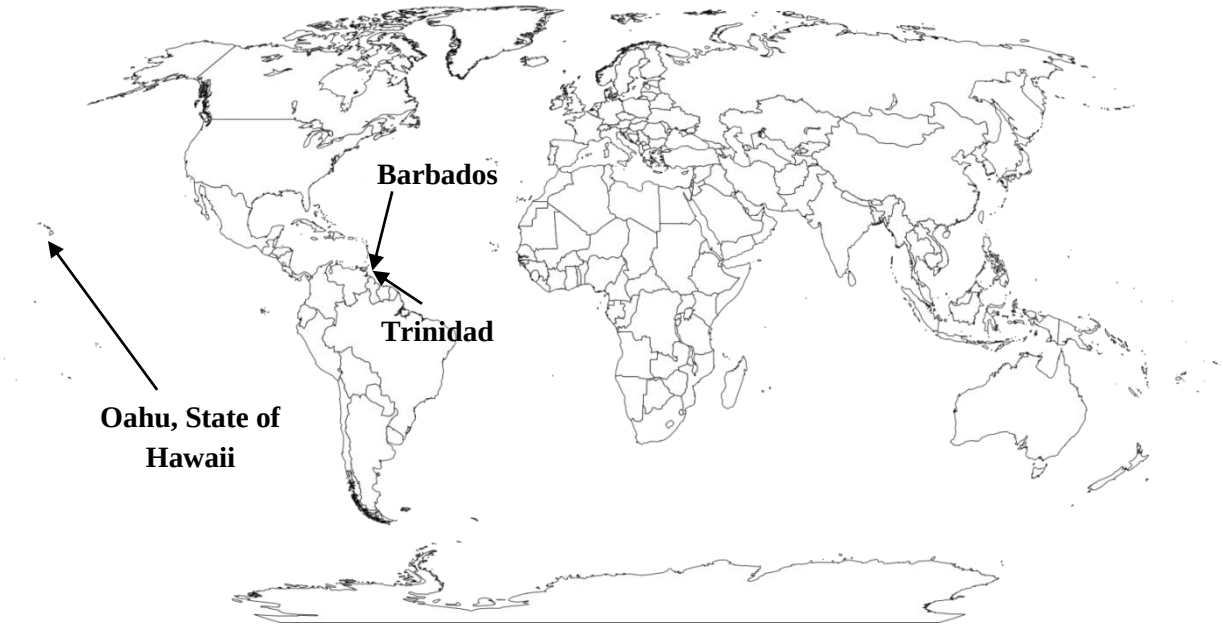


Figure 10 showing the locations of the thesis' case study islands in the solar insolation world

Note: kWh/m^2 in the top image is the kilowatt-hours per square meter

Adapted from Saving Our Planet (2016) (top image), and Free World Maps (2009) (bottom image) using Microsoft Word

Trinidad receives an estimated 2,124 kWh/m^2/year on a horizontal surface, Oahu receives 2,175 and Barbados gets 2,252; these figures were calculated using National Aeronautics and Space Administration Atmospheric Science Data Center data. This shows that the islands have similar resource potentials. These figures can also be contextualized by considering that locations in Southwestern Germany such as Freiburg which have significant amounts of household photovoltaics adoption (Dharshing, 2017) for example receive 1,117 kWh/m^2/year (WWF, 2012).

Despite the islands' abundant solar resources, if there is no access to the harnessing technologies, then the availability of the energy source does not amount to much (Khan and Obaidullah, 2008). The issue is therefore being able to fully utilize the rich resource available (Chivers, 2015) and as shown earlier, Barbados and Oahu have tapped into their solar resources.

This subsection is particularly useful because it shows that there is no solar resource disparity that may account for their varied extents of residential solar energy deployment in the case study islands. This opens the door to further delve into the theory behind the underlying phenomenon i.e. an energy transition in the next chapter.

1.5. The Thesis' Theories, Research Design and Structure

1.5.1. The Theories and Theoretical Framework

Since the thesis focuses on energy transitions (ETs), the literature surrounding ETs was reviewed. The Multi-Level Perspective (MLP) of socio-technical energy transitions is used to

approach residential ETs through distributed residential photovoltaics and solar water heating - and particularly so the idea of mainstreaming photovoltaics in Trinidad's residential electricity system.

However, the role(s) and definition of culture in the MLP was not well-articulated. This presented a gap in the MLP's approach to ETs. Given this limitation, the ETs literature review was complemented by a literature review of work at the intersection of energy and culture. The Energy Cultures Framework (ECF) is used to define culture as an energy culture.

The MLP and ECF are used to develop the theoretical framework for exploring the role of culture in the MLP and ETs through mainstreaming as a concept. Additionally, mainstreaming does not exist as a precise term in the MLP and it will be defined.

1.5.2. The Aim, Research Questions and Objectives

The next chapter's literature review on energy transitions (ETs) shows that technology is central to the Multi-Level Perspective (MLP) of socio-technical energy transitions and culture is a gap in its understanding of ETs. The thesis sought to understand the role(s) of culture in socio-technical ETs by looking at the mainstreaming of distributed residential solar energy technologies in Trinidad. But policies are often used to incentivize the adoption of technologies. Therefore, there are three key elements investigated: culture, technology and policy.

The thesis' main research question is:

"*How could the resident population's energy culture(s) and Government's residential solar*

energy policies interact to mainstream distributed residential solar energy technologies in Trinidad?"

This main question is answered through two sub-questions:

1) "*How could the adoption of distributed residential solar energy technologies and the residential energy culture(s) of Trinidad affect each other?*"

2) "*What are the Government's State-level residential solar energy policy options in Trinidad?*"

The study's objectives were:

- To understand where residential solar energy fits in Trinidad's wider ETs legacy
- To outline how culture influences and is influenced by socio-technical ETs
- To identify suitable distributed residential solar energy policies for Trinidad
- To position residential solar energy policies as facilitators of cultural change

1.5.3. Using Barbados and Oahu as Case Study Comparators

Trinidad's residential electricity system is the central case study and Barbados and Oahu's are used as comparators. The thesis firstly compares Barbados and Trinidad's energy cultures, and then Oahu and Trinidad's institutions and policies. The findings from the Barbados-Trinidad comparison answers sub-question 1 and the Oahu-Trinidad comparison answers sub-question 2. Answering these sub-questions identified the ways in which culture and policy

may potentially interact in Trinidad so this answered the lead research question.

1.5.4. Methodology Overview

The thesis uses a qualitative research approach to answer its research questions. A review of Trinidad's energy policy literature and energy history was done to set the context for Trinidad as the central case study. 33 structured interviews with householders in Barbados and Trinidad, and 22 semi-structured, key-informant interviews with high-level policy officials in the energy sectors of Oahu and Trinidad were conducted. The data from the two comparisons were analyzed using inductive and deductive thematic content analyses respectively.

1.5.5. The Thesis' Structure and Contents Overview

1.5.5.1. Structure rationale

The thesis has nine chapters. Chapter 2 is the literature review and presents the theoretical frameworks used; Chapter 3 is the methodology; and Chapter 4 provides background context on Trinidad as the central case study.

Chapters 5 to 8 are the main results chapters; Chapters 5 and 6 look at the energy cultures comparison between Barbados and Trinidad, and Chapters 7 and 8 looks at the policy comparison between Oahu and Trinidad. The cultural results are presented first to be consistent with the research questions and nature of energy transitions (ETs).

The lead research question has three main variables: the residential population's energy culture(s), the Government's residential solar energy policies, and distributed residential solar

energy technologies in that order. This led to the first research sub-question being related to the energy cultures comparison between Barbados and Trinidad.

Additionally, the Multi-Level Perspective approaches ETs as the product of a landscape exerting change pressures on a regime which creates opportunities for innovations to grow out of their niches to change the incumbent regime. This process will be detailed in Chapter 2, but the literature review and results show that culture can exist in the landscape - hence why the cultural results were put first.

Following on from these results chapters is Chapter 9 - the central discussion chapter that ties the cultural and policy-based deductions together and answers the overarching research question.

1.5.5.2. Chapter contents structure and overview

1.5.5.2.1. Chapter structure

Each chapter begins with a synopsis followed by its main content. Chapters 4 to 8 also have interim conclusion sections that capture each chapter's main takeaways. Chapters 5 and 6's conclusions also include subsections that present more specific conclusions which address the first research sub-question as well as the implications these may have for policymaking.

Chapters 7 and 8 do not have a subsection which answers the second research sub-question because this is answered in Chapter 9; one of the interactions identified between culture and policy is that culture can help determine which policies should be implemented and this answers the second research sub-question. Chapters 7 and 8 do however have a subsection

that deals with the policy conclusions' implications for culture.

It is important to reiterate that the thesis primarily focuses on photovoltaics but solar water heating is looked at in Chapters 5 and 6 because of the reasons that Barbados was selected as a case study comparator (see subsection 1.2.2.); Barbados is the closest cultural comparator to Trinidad that has widespread adoption of household solar energy.

In addition to Chapter 4, these four results chapters further include a subsection that looks at the respective takeaways that characterize mainstreaming as a concept. These mainstreaming subsections were particularly important to include because mainstreaming is an underlying theme in the thesis' central investigation of culture and energy transitions (hence the thesis' title), and characterizing mainstreaming as a concept is a theoretical contribution (as will be shown in Chapter 2).

1.5.5.2.2. Chapter Overview

Chapter 2 is the literature review and its contents have been outlined in subsection 1.5.1. Chapter 3 is the methodology and its contents have also already been touched on in subsection 1.5.4.

Chapter 4 sets the overarching context for Trinidad as the central case study by highlighting its major historical economic transitions from sugarcane to natural gas, and characterizing barriers to solar energy development. Even though it is not directly connected to the flow of the thesis' cultural and policy results chapters, it was important to include to give the background context of the regime that residential solar is potentially entering.

Chapter 5 is the first of two cultural results chapters. It comparatively explores energy usage, costs and supply as domains of the Barbadians and Trinidadians' energy cultures to understand their underlying structures. Chapter 6 compares the understanding of solar energy and solar water heating in the energy cultures to identify what adopting solar water heating entails. Both these chapters answer the first research sub-question.

Chapter 7 is the first of two institutional/policy chapters. It institutionally compares Oahu and Trinidad's residential electricity regimes. Chapter 8 outlines the use of residential solar energy policies in moving distributed residential solar energy out of niches by looking at Oahu's most influential policies and Trinidad's intended policies.

Chapter 9 is the thesis' central discussion chapter. It looks at the role of culture during energy transitions (ETs), outlines the interactions between policy and culture during ETs, and presents the recommendations for mainstreaming residential solar energy in Trinidad. It answers the second research sub-question and overarching research question. This chapter also critiques the role(s) of culture in ETs and use of mainstreaming as a concept in the Multi-Level Perspective as well as points out the thesis' contributions to the field.

2.0. Literature Review: Using the Multi-Level Perspective of Socio-technical Energy Transitions and Energy Cultures Framework as the Theoretical Framework

Synopsis

As stated in the previous chapter, the overarching research question is: "*How could the resident population's energy culture(s) and Government's residential solar energy policies interact to mainstream distributed residential solar energy technologies in Trinidad?*" It is being approached in the context of an energy transition (ET) and culture and policy (as well as technology) are also the key interacting variables in the research question.

The chapter outlines the two theories being used in the thesis i.e. the Multi-Level Perspective (MLP) of socio-technical energy transitions and Energy Cultures Framework (ECF), justifies their use, and reviews their existing literature. This gives the theoretical basis for the key concepts used through the thesis e.g. mainstreaming, ETs and energy cultures. It also gives the theoretical framework for the thesis' methods which will be outlined in Chapter 3.

The chapter is structured as follows: section 2.1. gives an overview of the nature of ETs and outlines the MLP's approach to ETs; section 2.2. characterizes mainstreaming in the MLP; section 2.3. spotlights where culture fits in the MLP; section 2.4. outlines the ECF; and section 2.5 highlights the theoretical links between the MLP and ECF.

2.1. Literature Review on the Multi-Level Perspective of Socio-technical Energy Transitions

2.1.1. An Overview of Energy Transitions

Without using energy, the quality of life cannot be much higher than that of primitive man (McVeigh, 1984). But no living organism produces more energy than it uses, or produces any by itself (Crosby, 2006); they are all dependent on external fuel sources (Crosby, 2006). Today's energy intensive consumption depends on the extraction of external fuel sources like fossil fuels (Horta et al., 2014; Urry, 2014).

But the way in which these resources have been historically used suggests that today's consumption and socio-economic systems are unsustainable (Pérez-Lombard et al. 2008). Westphal (2012) states that enhancing the energy system's sustainability requires the integration of renewables and the wider sustainable energy transitions (ETs) literature suggests that renewables will eventually be a part of future energy systems (Steg et al., 2015) because the world is transforming how it accesses and uses energy (Manning, 2015).

Energy systems are complex; are central to any economy; and are made up of multiple sectors and institutions as well as (re)sources (WEF, 2018) as shown in Figure 11 one the next page. But having used the term 'transition' above, the term suggests that changes are not sudden and are rather prolonged processes (WEF, 2013). This consequently requires considering what constitutes an ET.

The image showing the structure of an energy system originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

World Economic Forum (WEF). 2018. Fostering Effective Energy Transition: A Fact-Based Framework to Support Decision-Making. Insight Report. Website: http://www3.weforum.org/docs/WEF_Fostering_Effective_Energy_Transition_report_2018.pdf (accessed 25th April, 2018)

Figure 11 showing the structure of the energy system

Extracted from the WEF (2018; 9)

To answer this question it is important to firstly acknowledge that humanity craved solar energy in one form or another (Crosby, 2006), and there have been many forms over humanity's energy history. Authors have tended to characterize ET chronologies through technological developments and usage of energy types (Gismondi, 2018).

The world's ET history involved the metabolic energy of human and animal labour as well as biomass being phased out for coal followed by today's oil, gas, and electricity (Grubler[1], 2012; Grubler[2], 2012; WEF, 2013; Pain, 2017; Buchanan, 2017). Figure 12 on the next page illustrates this as the biomass and coal contributions decreased from the 1800s and 1900s respectively, and those of oil, gas and forms of electricity increased. The last is a quintessential part of modern transitions (Smil, 2016) because it changed the way the world related to energy and became connected through energy (Namias, 2008; Love and Garwood,

2013; WEF, 2013).

The image showing the historical share of fuels in the global energy mix from 1800 to 2008 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

World Economic Forum (WEF). 2013. Energy Vision 2013. Energy transitions: Past and Future. Energy Industry Partnership Programme. Website: http://www3.weforum.org/docs/WEF_EN_EnergyVision_Report_2013.pdf (accessed 10th January, 2018)

Figure 12 showing the historical share of fuels in the global energy mix from 1800 to 2008

Extracted from the WEF (2013; 6)

Today's global energy is dominated by fossil fuels (European Commission, 2011; Smil, 2016) and they were able to become the dominant global energy resources within a half-century of their introduction (Kemp, 1994). However renewable energy is the next envisioned transition paradigm (Herrera, 2015). Brinkworth (1985), Westphal (2012), the IEA and IRENA (2017), and Grayson (2017) suggest that though the transition from fossil energy will take a long time the process has already been set in motion.

Figure 13 on the next page illustrates the trend in the growth in renewables. Specific examples are the global solar photovoltaics and wind energy capacities growing from 6 to 303 Gigawatts (GW) and from 74 to 487GW respectively between 2006 and 2016 (Renewable Energy Policy Network For The 21st Century, 2017).

The image showing the global renewable energy share of the total final energy consumption from 2004 to 2014 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Renewable Energy Policy Network For The 21st Century. 2017. Advancing the Global Renewable Energy Transition: Highlights of the REN21 Renewables 2017 Global Status Report in Perspective. Website: http://www.ren21.net/wp-content/uploads/2017/06/GSR2017_Highlights_FINAL.pdf (accessed 25th April, 2018)

Figure 13 showing the world's renewable energy share of the total final energy consumption from 2004 to 2014

Extracted from the Renewable Energy Policy Network For The 21st Century (2017; 10)

These trends are suggestive of a global ET. However, Elias and Victor (2005), and O'Connor and Cleveland (2014) outline that defining and by extension quantifying ETs has been historically difficult. Araújo (2014) and Sovacool (2016) further state that there is no universal definition for it thus far (see Figure 14 on the next page).

O'Connor and Cleveland (2014) suggest that one reason is because energy systems are dynamic structures. Cherp et al. (2018) suggest that the diversity of disciplinary approaches available to study energy systems is another. Tied to these are the terminologies and scopes since they vary together with their methods of analysis e.g. 'energy transition' versus 'low-carbon transition' or 'sustainable transitions' for instance (Cherp et al., 2018).

Definition	Source
A change in fuels (e.g., from wood to coal or coal to oil) and their associated technologies (e.g., from steam engines to internal combustion engines)	Hirsh and Jones [22]
Shifts in the fuel source for energy production and the technologies used to exploit that fuel	Miller et al. [23]
A particularly significant set of changes to the patterns of energy use in a society, potentially affecting resources, carriers, converters, and services	O'Connor [24]
The switch from an economic system dependent on one or a series of energy sources and technologies to another	Fouquet and Pearson [25]
The time that elapses between the introduction of a new primary energy source, or prime mover, and its rise to claiming a substantial share of the overall market	Smil [26]

Figure 14 showing 5 definitions of energy transitions

Extracted from Sovacool (2016; 203) (https://creativecommons.org/licenses/by/4.0/)

O'Connor (2010) suggests that ETs affect energy resources, carriers, converters and services. It is commonly characterized via primary energy supply quantifications (Miller et al., 2013; Herrera, 2015; Smil, 2016; Fouquet, 2016), total final energy consumption, final energy intensity, electricity consumption or electricity and fuel prices (Hauff et al., 2014). Despite such a variety of metrics, the IEA and IRENA (2017) state that the definition of ETs needs to transcend both energy supply and demand; Grubler[1] (2012), and Fouquet and Pearson (2012) state that the understanding of ETs has been too heavily weighted by the supply side (see Figure 14).

Therefore ETs should be approached through socio-technical systems thinking (Palm, 2006; Miller et al., 2013). These are systems of knowledge, practices and networks linked to energy technologies (Cherp et al. 2018) which develop over decades and tend to exhibit path

dependency that resists change (Kuzemko et al., 2016; Geels, 2018); the 'socio' relates to the social elements and the 'technical' to the technological components.

Socio-technical ETs can be thought of as large-scale societal transformations which fundamentally change the structure and nature of the socio-technical energy system (Rhodes, 2007; Kuzemko et al., 2016). ETs are socio-technical because without the 'socio', it is not a complete systems-level transition and elements that inherently shape the transition run the risk of not being duly considered e.g. people's beliefs that drive their energy use which in turn affects the technical requirements of the energy system.

Based on this an ET is a fundamental change that affects either the supply and demand sides of an energy system, and which has implications for both once the change occurs - the Multi-Level Perspective of socio-technical ETs is used to approach ETs in this way.

2.1.2. Characterizing the Multi-Level Perspective

The thesis is an energy transitions (ETs) study set within the socio-technical scholarship that spans evolutionary economics; science and technological studies; ecology; ecological economics; political science; history; institutional theory; and environmental studies (Lawhon and Murphy, 2011; Sovacool and Hess, 2017). Socio-technical system theories explore the interactions between the social and technical elements of systems. There are many existing theories e.g. diffusion of innovations, path dependency and actor-network theories, and Sovacool and Hess (2017) present a useful overview of 14 them.

The thesis uses the Multi-Level Perspective (MLP) of socio-technical ETs. It is a vertically

structured theory built on temporal and structural scales (Raven et al., 2012; Hargreaves et al., 2013), and draws on the historical and sociological exploration of technology largely through explanations based on processes and contexts (Geels, 2018).

The MLP is used because it adequately examines and simplifies complex processes (Jenkins et al., 2018) and provides a relatively simple but highly adapatable framework for thinking about ETs (Hargreaves et al., 2013). Figure 15 (next page) shows the MLP.

The diffusion of innovation theory was not used because it only explicitly explains one element of ETs i.e. the adoption of innovations as a process which is limited to the niche-regime space of Figure 15. Path dependency was not used as an explicit theory because the MLP considers path dependency and puts it into the context of wider positive and negative feedbacks. The actor-network theory was not used given its limited approach to systems as network-oriented structures and its consideration for the equal agency between human and non-human elements.

One of the most significant conceptual approaches to the socio-technical transitions is the multi-level perspective (MLP) (Kuzemko et al., 2016; Jenkins et al., 2018). For instance, in Sovacool and Hess (2017), of the 96 theories covering 22 disciplines that arose from their work related to the theories commonly used to approach socio-technical change, the MLP was the most frequently cited. The MLP provides systems-level context for ETs by looking at interactions between a socio-technical landscape, socio-technical regime, and niche-innovations. Each will now be looked at in more detail.

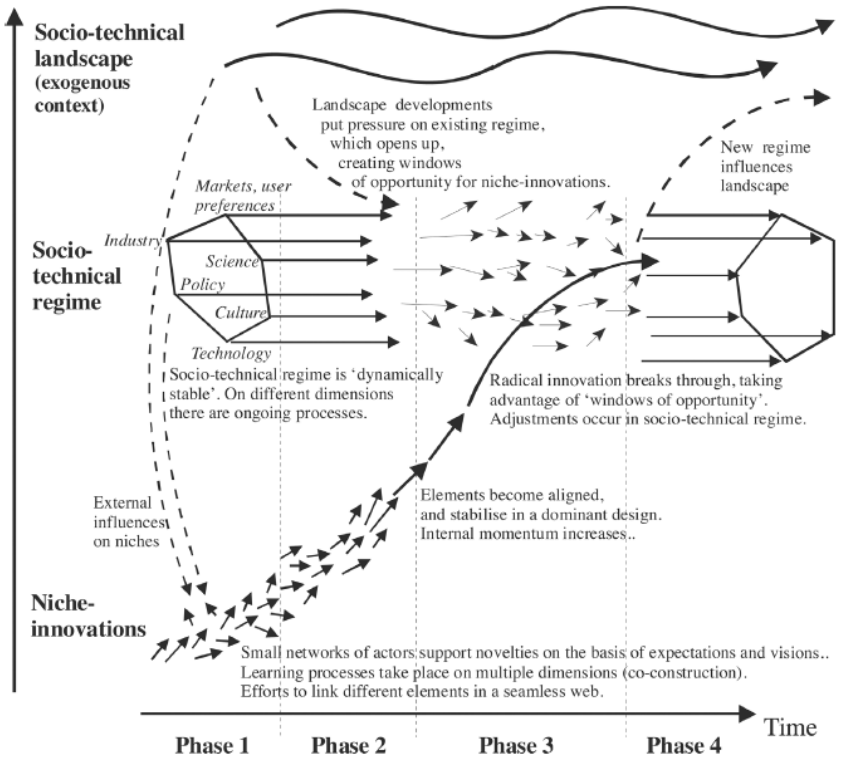


Figure 15 showing the Phases of the Multi-Level Perspective

Extracted from Geels (2018; 226)

The landscape plane of the MLP is the most structured (Geels and Schot, 2007). Geels and Schot (2007), Kern and Smith (2008), Raven et al., (2012), and Lockwood et al. (2013) characterize it as an exogenous plane that indirectly exerts change-pressures on the regime and niches over prolonged periods of time. These change-pressures create opportunities for niche-innovations to enter the regime depending on the latter's response to these pressures (Geels and Schot, 2007; Smith et al., 2010; Lockwood et al., 2013; Mattes et al., 2015).

Landscape-forces are long-term structures (Markard and Truffer, 2008) capable of changing over time (Raven et al., 2012) and examples are oil prices, wars, major discoveries and wider social trends (Truffer and Coenen, 2012). The downward, dotted arrows from the landscape to

the regime and from the landscape through the regime to niches in Figure 15 (previous page) illustrate its influence.

Smith et al. (2010) define regimes as structures made up of a co-evolutionary alignment of features. Geels and Schot (2007) specify that it is an alignment between science, policies, markets, industries, technologies and cultures, as well as the various actors within these spaces (see Figure 15). Examples of regime structures are centralized power generation plants and national electricity grid networks.

Cherp et al. (2018) outline that regimes exert an inertia which resists change. However, Markard and Truffer (2008) suggest that regimes are not completely resistant to change. Over time they are faced with new change-pressures (Schot et al., 1994; Smith et al., 2010) so their responses to changes not only vary depending on the change factors but also the evolutionary nature of those factors (Smith et al., 2010; Truffer and Coenen, 2012).

Smith et al. (2005) add that the more disruptive change-influences are the more resistant to change the regime is since there is a greater allocation of resources dedicated to maintaining its incumbency. Regimes therefore exhibit an adaptive capacity by responding to influences and is one reason why niche-innovations face challenges in catalyzing ETs (Smith et al. 2005; Markard and Truffer, 2008; Smith et al., 2010; Cherp et al., 2018).

Geels and Schot (2007), and Hargreaves et al. (2013) suggest that an ET can be thought of as a shift from one socio-technical regime to another in the MLP. Therefore Figure 15's left polygon evolving into the one on the right means that a transition is sugeestive of a movement from one state to another (Sarrica et al., 2016).

Shifts in regime-states are often thought to be incremental (Mattes et al., 2015). But Smith et al. (2005) argue that if the resources needed to stimulate a regime-change are present internally, only then would the transition be incremental and non-disruptive - and incremental development is part of the nature of technological and mainstream changes (Kemp, 1994; Smith et al., 2010; Winskel et al., 2014; Klitkou et al., 2015).

A caveat is that such incremental development has the possible risk of the incoming structures being seamlessly encapsulated into the incumbent (Kern and Smith, 2008). This is because a regime supports niche-innovations that display characteristics which align with its incumbent orientation (Strebel, 2011).

The technologies or energies that have become dominant have had their origins in niches (Fouquet, 2016). Niches are the least aggregated level of the MLP (Markard and Truffer, 2008). Smith et al. (2010), and Grubler[1] (2012) describe niches as early trials and learning spaces. They harbour the novelties of transitions, are advocated for by small social networks, and offer some degree of protection for innovations that are not yet competitive enough to make it into the regime (Geels and Schot, 2007; Smith et al., 2010; Fouquet, 2016; Cherp et al., 2018).

Niches are successful when they dissolve (Schot, 1998) because their innovations no longer need protection from mainstream forces and can compete with the incumbent regime (Yanosek, 2012). When this occurs, an innovation becomes part of the mainstream because it is more widely adopted (Berkhout et al. 2003). Examples of niche-level elements are innovation policies for early adopters; lead markets; incentivizing the provisioning of cheaper services; subsidized demonstrations; and adoption and experimentation projects (Smith et al.,

2010; Fouquet, 2011; Green et al., 2014).

Geels (2002; 2004), and Kuzemko et al. (2016) identify with the need for innovation-protection through the above examples because innovations are usually expensive and have low technical performances; innovations supported by protective mechanisms often have better chances of success (Kemp, 1994; Green et al. 2014).

Innovations can be product-related, process-oriented or managerial, and exist technologically, psychologically or even socio-culturally (Daghfous et al., 1999; Zailani et al., 2015). ETs show a trend toward cheaper, cleaner, more abundant and reliable fuels which is complemented by the replacement of older energy-conversion technologies with newer options (Dirks et al., 2014). However, it is for this reason that the MLP's applications and wider ETs literature has been criticized for being technologically biased (Hargreaves et al., 2013; Fuchs and Hinderer, 2016) and focused on technological substitutions (Geels, 2006).

Developing innovations is a non-linear process (Dirks et al., 2014) as are ETs (Geels and Schot, 2007; Fouquet, 2016; Andrews-Speed, 2016). Developing innovations is also like the mainstream and technological changes that are part of ETs in that it is incremental, cumulative and assimilative (Beerepoot and Beerepoot, 2007).

When a niche-innovation enters the regime, it reconfigures the incumbent regime. This reconfiguration realigns heterogeneous attributes (Geels, 2002) and should be considered in light of alignment suggesting stability (Greenhalgh and Stones, 2010). The annotation just beneath Figure 15's left regime-polygon on page 57 shows this as dynamic stability, and the annotation in the middle-right of the cascade of upward arrows between the niche and regime planes captures the realignment-stability relationship.

The MLP is a theoretical framework that approaches the nature of systems-level change through the interactions between a landscape, regime and niche planes. Geels (2006; 2018) outlines four key processes unfolding in the MLP but Geels (2018) lays them out in Figure 15's Phases (see page 57) which summarize ETs: innovations emerge in Phase 1; niches are stabilized and innovations enter small niches in Phase 2; innovations break into the regime in Phase 3 through the landscape's influence and supporting developments in the niches and regime; and Phase 4 marks the regime's transformation.

The thesis frames an ET as a change in regime-state brought on by the integration of distributed residential solar energy technologies (photovoltaics and solar water heating) as niche-innovations into Trinidad's incumbent residential electricity regime that is based on centralized, fossil fuel-powered systems and a monopolized electricity grid.

Whilst the wider electricity regime which includes other sectors beyond the residential sector is serviced by the same electricity utility network and centralized power generation units, there are several elements that define the residential sector as a specific regime (see section 1.3. in Chapter 1). For example when compared to the commercial or industrial sectors, the residential sector has a different electricity tariff structure; does not benefit from economies of scale; has more potential independent solar power generators; does not have a corporate culture; and distributed solar energy technologies are best suited for the smaller-scaled energy needs.

2.1.3. Linking Energy Transition Timeframes to Islandic Residential Electricity Regimes

The incumbent global energy system is based on fossil fuels and includes the largest and most expensive anthropogenic infrastructure so even if alternative energy resources are more widely available, the scale of the incumbent system should not be taken for granted (Smil, 2016). This means that the legacy of fossil fuels has given its regime(s) inherent structural advantages over incoming renewable alternatives (Dumas et al., 2016).

However, where fossil energy has not been fully accessed or adopted, its lock-in effect has been limited and suggests that renewables can rapidly take off (Bridge et al., 2013). But based on Lacey's (2010) conversation with Vaclav Smil, the amount of today's hydrocarbon energy consumption that needs to be substituted by renewables amongst other frictional factors would mean that the transition to renewables is a prolonged one and not sudden and revolutionary.

There are many studies that take an optimistic outlook towards how fast transitions can unfold (Grubler[1], 2012). But these outlooks should be considered in light of Fouquet and Pearson's (2012) analysis of historical transitions that show that market size has been a determinant of how fast it can occur because as the size of the economy increases so too does the length of time taken to transition.

There is historical evidence to support the prolonged timeframes of energy transitions (ETs) (Sovacool, 2016) and the wider academic ETs discussions focus on them as prolonged phenomena (Sovacool and Geels, 2016) e.g. Lawhon and Murphy (2011), Manning (2015), and Gates' (2015) work that state that ETs unfold over decades or longer. Fouquet and

Pearson (2012) outline that from their work there is a 40-year minimum over which an ET unfolds. Raven et al. (2012) further state that niche-level developments may unfold within 10 years, regimes within 50, and landscape developments over centuries.

The way in which an ET is defined will affect its timescales of operation (Sovacool, 2016; Fouquet, 2016) because there can be transitions that make up the holistic ET (Markard and Truffer, 2008; Fouquet, 2016). For example, Sovacool (2016) presents empirical evidence of faster transitions occurring in end-use devices and prime movers: lighting in Sweden, cooking stoves in China, air conditioning in the U.S., and liquefied petroleum gas in Indonesia.

Sovacool also gives further examples of rapid supply-oriented transitions through nuclear electricity in France, oil and electricity in Kuwait, and natural gas in the Netherlands. These examples lean on the definition of an ET as a sub-system unit under analysis e.g. end-use technology, prime movers, or energy supply versus the entire energy system.

Defining ETs in the Multi-Level Perspective (MLP) relates to defining the regime. The ETs literature focuses on national-scale geographies and conceptual developments (see Figure 16 on the next page) where niches have often been framed as local developments, regimes as national and the landscape as international relative to the spatial scales of research (Raven et al., 2012). For example, Hauff et al. (2014) define an ET as a fundamental change in the energy system of a country - country being the geographically relevant notion that speaks to the national scale.

Smith et al. (2010), and Raven et al. (2012) describe the regime as being geographically fluid in its interpretation (since the MLP's planes are not geographically bound). However, Markard and Truffer (2008; 607) state that defining the regime should be so done based on

using its conceptual strengths most effectively.

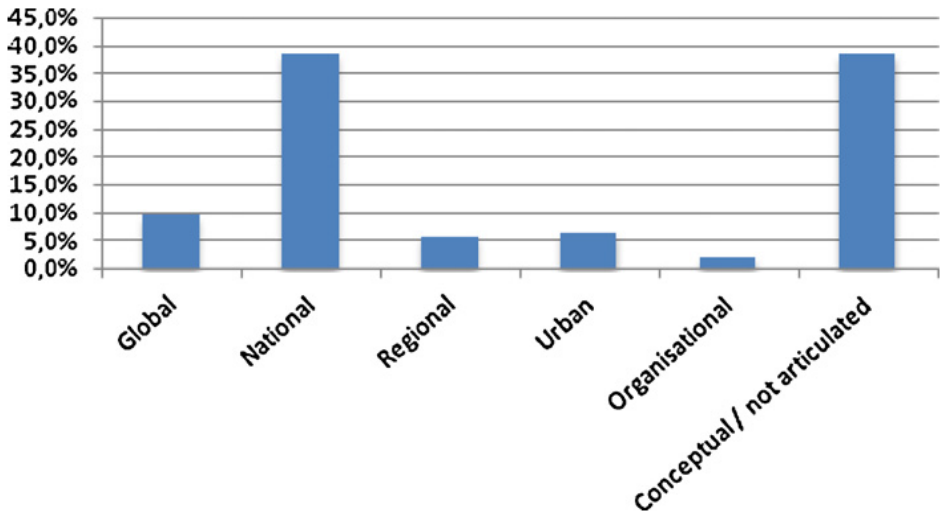


Figure 16 showing the spatial focus of the energy transitions literature from 1994 to 2011

Note: The percentages on the Y-axis refer to the proportional contributions of the different geographic scales of research seen on the X-axis.

Extracted from Raven et al. (2012; 64)

ET theories do not capture sub-national dynamics (Hiemstra-van der Horst and Hovorka, 2008) and largely overlook the role of local processes in ETs (Mattes et al., 2015); the MLP has likewise been criticized for being short on spatial considerations (Lawhon and Murphy, 2011; Truffer and Coenen, 2012; Truffer et al., 2015; Mattes et al., 2015).

In the context of a small, tropical island its geographic insularity acts as an automatic and strong framing factor for conceptualizing the regime. The thesis' design i.e. using a three-island comparison to answer ETs questions on a single island also calls for an intra-island definition of the regime. So relative to time, by defining the regime as the residential electricity sector in the case study islands, two elements stand out.

The first is related to the specificity of looking at small, tropical islands. Using such islands as the case geographies means that an ET would unfold faster here than in larger geographies; an ET should unfold faster in Oahu, Barbados and Trinidad than it would in larger islands such as Japan or even the United Kingdom for example.

The second element is the socio-technical specificity of the residential electricity regime. This means that at the intra-island level, an ET should unfold faster here than if the regime was approached as the economy-wide energy system of the island which would include other sectors such as commercial and industrial sectors, and systems beyond electricity systems such as the transport fuel sector. These other sectors would include different elements such as non-residential electricity tariff designs; markets based on economies of scale; liquefied petroleum gas, diesel and gasoline infrastructure; and vehicles which would change the nature of the regime being defined by the residential electricity sector.

2.1.4. Summaries of the Assumptions and Limitations of the Multi-Level Perspective

2.1.4.1. The assumptions

1. There are only 3 planes operating during energy transitions (ETs) i.e. niche-innovations, the socio-technical regime, and the socio-technical landscape.

2. An ET unfolds when landscape-forces affect the regime to create the space(s) for niche-innovations to enter and structurally re-orient the incumbent regime.

3. Landscape-forces take longer than the regime's to influence ETs processes and the

regime's take longer than niches'; landscape and regime-forces unfold over decadal to century timeframes whilst niche-level processes unfold within years.

2.1.4.2. The limitations

1. The 3 planes can be applied to a multiplicity of scales and contexts - the concepts are geographically fluid in their interpretation. There is therefore no concrete boundary distinguishing one plane from the other.

2. Linked to the above is the fact that the Multi-Level Perspective (MLP) falls short on spatial considerations. This refers to the conceptual geographic extents of niches, regimes, and the landscape but also to the way in which space and place influence and are influenced by transitions.

3. The MLP's application in the literature is largely technologically oriented though the MLP is not technologically biased.

2.2. Defining Mainstreaming in the Multi-Level Perspective of Socio-technical Energy Transitions

Authors such as Seyfang and Smith (2007), Smith et al. (2010), Coenen et al. (2010), Yanosek (2012), and Green et al. (2014) state that there is a difference between niches and the mainstream; niches are embedded within the mainstream (Egmond[1]et al. 2006). Smith et al. (2010), Shove and Walker (2010), and Coenen et al. (2010) directly identify the regime as the mainstream, and Smith et al. and Lockwood et al. (2013) further describe it as the mainstream

ways of fulfilling social functions.

The regime provides the 'selection environment' for innovations and competition selects the winning innovations (Markard and Truffer, 2008; Smith et al. 2010; Lockwood et al, 2013). Politics, culture, geography and the economy also influence the winning innovations (O'Connor, 2010). The creation and evolution of niches therefore combine 'variation' and 'selection' (Schot, 1998). This is seen in Figure 17 where the arrows begin to settle from their haphazard directional orientations in the niche-regime space.

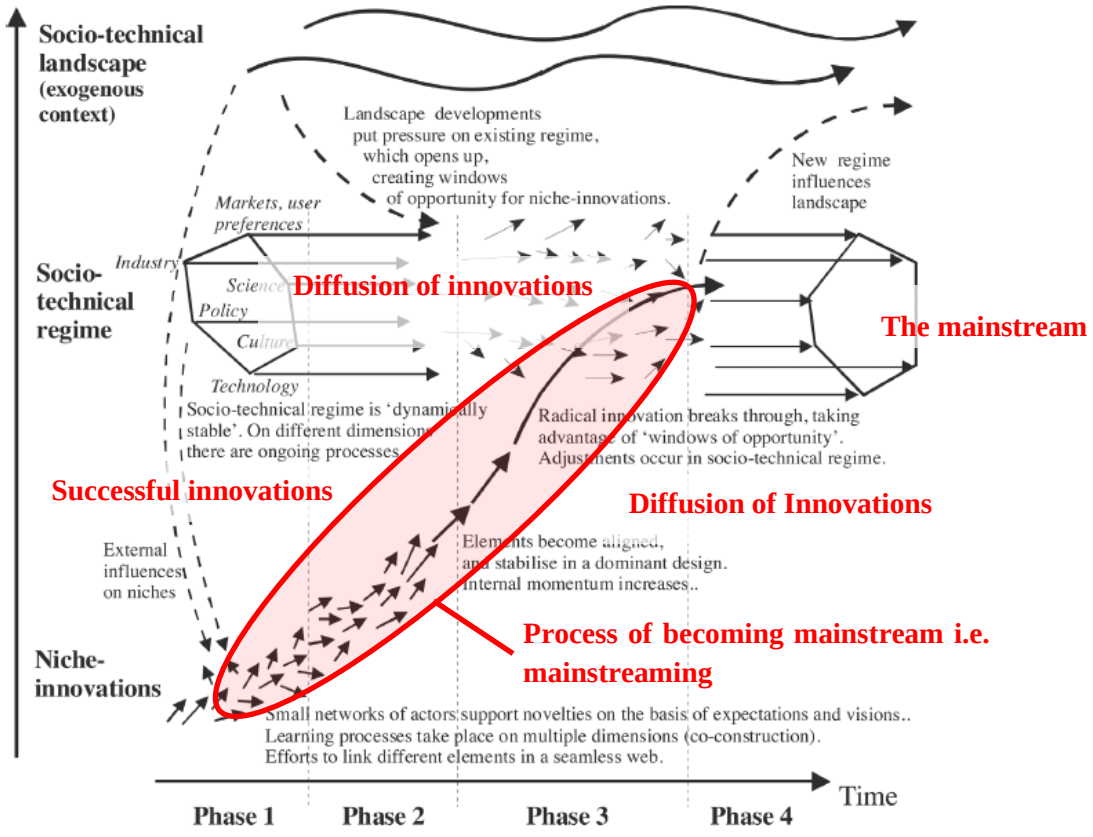


Figure 17 showing the Multi-Level Perspective and the conceptual positioning of mainstreaming

Adapted from Geels and Schot (2018; 226) using Microsoft Word

There is no formal definition of mainstreaming but an innovation's conceptual migration from

its niche and its run up to 'breaking through' into the regime in the MLP can be thought of as the process of mainstreaming i.e. phases 1 to 3 in Figure 17 (previous page). This means that the thesis' 'Implementation' in the title refers to niche-level applications, and the 'Beyond' speaks to the evolution out of these niches. Figure 17's annotation below the right regime-polygon, together with its line of symmetry on the horizontal axis of time also shows that mainstreaming is a process and not an event in time.

The diffusion of innovation theory developed by Everett Rogers is not applied in the thesis, but it is worth outlining how mainstreaming is linked to it - given the importance of adopting innovations in the MLP. Work such as Rogers (1983), Richerson et al. (2001), Robinson (2009), and Mani and Dhingra (2012) give more details on the diffusion of innovations.

An adopting market is made up of groups of adopters segmented into the innovators, early adopters, early majority, late majority and laggards, and each has their own characteristics. They make up potentially 2.5%, 13.5%, 24%, 35%, and 16% of the market respectively (see Figure 18 on the next page) (Rogers, 1983). Based on this distribution if an innovation is adopted by >2.5% the market, it enters into the early adopters' segment, >16% into the early majority's, >40% into the late majority's, and >75% into the laggards'.

The early majority is thought to be the beginning of the mainstream market (Moore, 1991; Egmond[1] et al., 2006; Goldenberg et al., 2006). Therefore, a theoretical mainstream threshold can be thought to exist at 16% adoption. A caveat however is the fact that the adoption market varies so this 16% threshold is likely not to be an absolute figure. Nevertheless, the diffusion of innovation work offers insight into what the mainstream market segments are like.

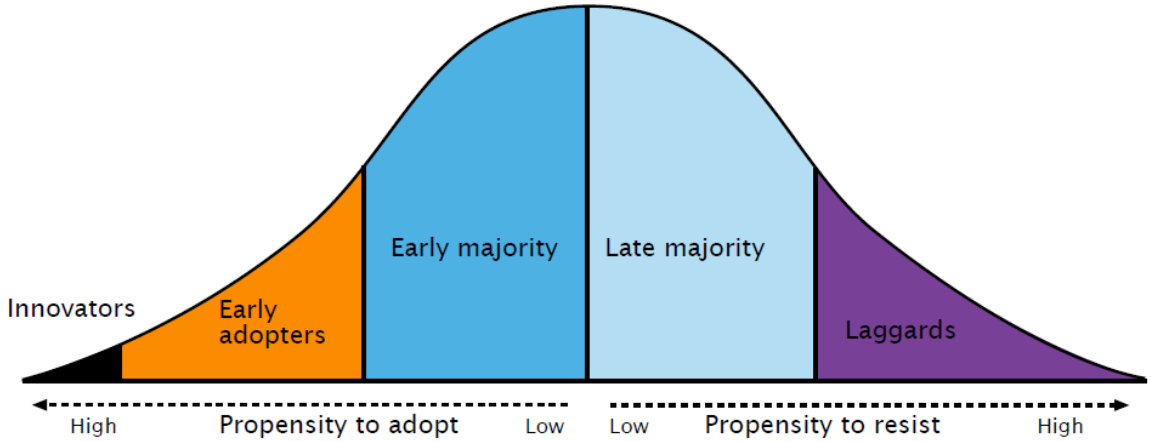


Figure 18 showing the adoption segments involved in the diffusion of innovations

Extracted from Robinson (2009; 4) (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Mainstream adopters are less willing than the early adopters to adopt innovations; are very practical and solutions-orientated; will invest in an innovation that improves the existing services they are provided with; and if they must adopt an innovation, they will usually seek out improvements that reduce the potential deviation from their norms (Egmond et al.[2], 2006).

Therefore, the mainstream can be referred to as 'average', widespread, involved in daily use and rooted in convenience (Green et al., 2014). Several of the mainstream characteristics are also consistent with the incremental development of innovations and changes in regime-states highlighted in the energy transitions (ETs) literature.

Figure 19 on the next page puts the concept of mainstreaming into the case studies' context by illustrating where the three case study islands of Trinidad, Barbados and Oahu would fit in the residential ET through solar energy based on their respective adoption of solar water heating and photovoltaics; Trinidad has only minimal solar adoption, Barbados has mainstreamed solar water heating and is now adopting photovoltaics, and Oahu has

mainstreamed both solar water heating and photovoltaics.

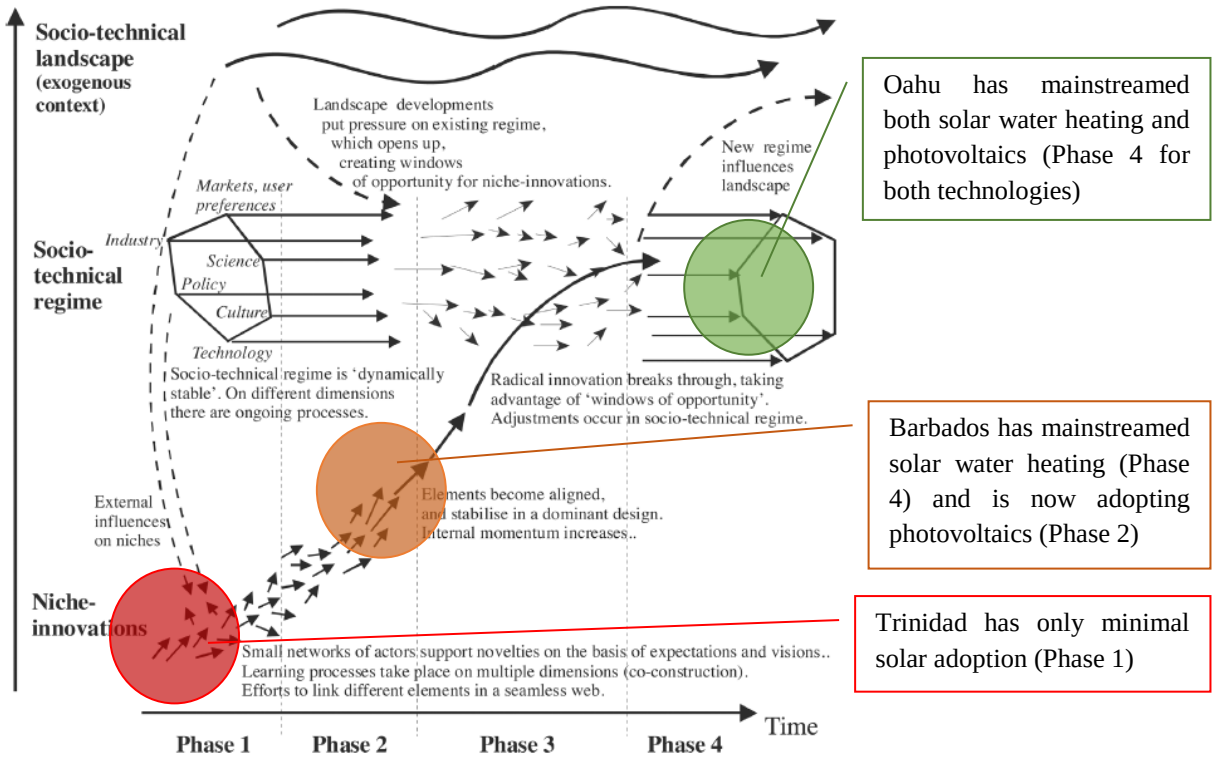


Figure 19 showing the positioning of where the case study islands would fit in the Multi-Level Perspective relative to their energy transition through residential solar energy

Note: The positioning of the 3 islands in the figure is relative to their adoption of household solar water heating and photovoltaics as well as the Phases of the Multi-Level Perspective. It is also based on the notion that there is a technological transition from the adoption of solar water heating then to photovoltaics.

Adapted from Geels (2018; 226) using Microsoft Word

Mainstreaming and an ET in the MLP are not the same conceptually. An ET is a change from one regime-orientation into another brought about by the landscape exerting change-pressures on the incumbent regime which opens spaces for niche-innovations to enter and subsequently modify this regime-state. Mainstreaming however specifically refers to the evolution of an innovation out of its niche and subsequent entry into the regime. These theoretical ideas

suggest that mainstreaming is conceptually founded on several assumptions inherited from the MLP:

- An ET is a change in regime-state.
- There are cultural, policy-based, technological, market-related, scientific, and industrial elements that affect regimes and niches.
- An ET is made up of cultural, policy-based, technological, market-related, industrial, and scientific transitions.
- A transition in one element will affect the others since they are co-evolutionary.
- Mainstreaming an innovation can catalyze a regime's cultural, policy-based, technological, market-oriented, industrial and scientific transitions. A caveat is that a technology could be mainstreamed without catalyzing an ET.

2.3. Culture and the Multi-Level Perspective of Socio-technical Energy Transitions

2.3.1. Spotlighting Policy, Technology and Culture as the Key Elements of Interest

Technology is a key element of society and energy transitions (ETs), and changing technological systems changes who we are, our behaviour, and our lifestyles (Miller et al., 2013). But the energy transition will not happen on its own (IEA and IRENA, 2017). Governments have multiple roles (Dirks et al., 2014) and they will need to support the niches

for low-carbon energy sources and technologies (Fouquet, 2011) through the appropriate policy frameworks that can support the wider transition (IEA and IRENA, 2017). Therefore, energy policies will play a key role in facilitating the technological change needed to achieve ETs that lead away from hydrocarbon lock-ins (Patwardhan et al., 2012).

Arnesen (2013) argues that policies and regulations should include interventions related to socio-cultural energy consumption because they can act as signals that influence how social priorities are expressed through norms and habits. But there is a need to understand behavioural drivers to better design policy interventions (Egmond[2] et al., 2006); policies should be humanized (Hinchliffe, 1995).

Some have argued that the transitions work is largely mechanistic (Truffer and Coenen, 2012; 12) and there is an overemphasis on technical research in relation to policy formulation and implementation (Barron and Sinnott, 2013). The academic discussion of transitions is also largely based on techno-economic models (Sovacool and Geels, 2016).

These considerations therefore argue that there is a human element missing from technological research and policymaking. There are many human dimensions that could potentially apply but culture is of particular interest. This is because the Multi-Level Perspective (see Figure 19 on page 70) explicitly includes culture as an element of its socio-technical regime.

Shove and Walker (2010) the application of transitions thinking into everyday practices and identified elements that are debated, and which are not sufficiently addressed the MLP. Culture is thought to be one such element because it has neither been concretely explored by the transitions nor wider energy literatures and has been rather implied (Stephenson et al.,

2010; Strauss et al., 2013; Arnesen, 2013). Additionally, its role and influence(s) on energy innovations or policy are not well researched relationships (Hinchliffe, 1995; Cherry et al. 2014).

This is important to consider because the policies that influence innovation-adoption can accelerate or prolong ETs (O'Connor, 2010), and culture is a barrier to but also enabler of implementation (Otte, 2014). Arnesen (2013) outlines that how energy is culturally interpreted should be a starting point for introducing innovations since generic policies being implemented in specific cultures often do not work. Likewise, innovations need to be adapted to local contexts (Geels, 2004) because introducing them into a social system where there is no grasp of its cultural background can have unexpected repercussions (Arnesen, 2013).

Based on these thoughts there are three central elements that emerge relative to the thesis' investigation of residential solar and ETs: policy, technology and culture. These three elements do not exist in isolation in the regime but there are interactions between policy and technology, culture and technology, and policy and culture.

The interactions between policy and culture are not as clear as the former two because culture's influence can be explored in the present i.e. the 'Now' in Figure 20 on the next page (short red arrows), as well as an evolutionary element that enhances the temporal sensitivity of policies (longer red arrows) since cultures change with time and in non-homogenous ways (Stephenson, 2018).

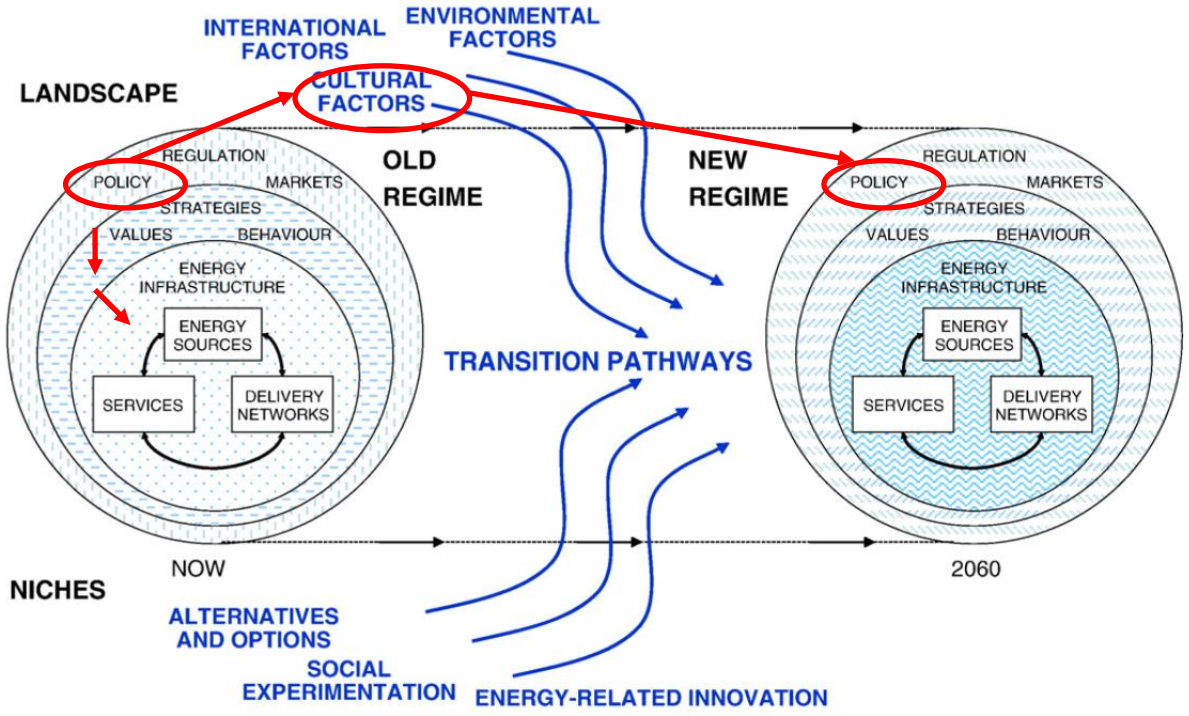


Figure 20 showing transitions pathways, their influencing factors, and positioning of policy and culture in relation to niches, the regime and the landscape

Adapted from Foxon et al. (2010; 1206) using Microsoft Word

2.3.2. Finding Culture in the Multi-Level Perspective

There is no single definition for culture (Tharp, 2012; Arnesen, 2013). It is difficult to understand and engage with scientifically because it is not directly observable (Dubois, 1972; Gallivan and Srite, 2005); is a human phenomenon that most are unaware of (Arnesen, 2013); and everyday life in its broadest sense is hard to research (Strengers, 2010).

Geels and Schot (2007) explicitly place culture in the regime (see Figure 19 on page 70). However landscape-forces, which are rather removed from the regime, are a diverse range of factors which include cultural norms (Geels and Schot, 2007; Lockwood et al. 2013); work like Foxon et al. (2010) and Smith et al. (2010) place culture in the landscape (see Figure 20

on the previous page) because of its structuration and slow rates of change (Loorbach, 2010).

This clearly shows that culture is complex because human beings are complex (Chatterton, 2011). But whilst it can exist in the landscape, one can argue that culture is not a completely exogenous element in shaping regimes nor is it as 'simple' enough to be solely a regime-level construct.

The ETs literature reviewed therefore acknowledges the existence of culture and that it spans the regime and landscape. However, it is further expected that there is also niche-level culture (as will be shown in section 2.4.). Therefore, it is reasonable to assert that one reason why culture's role in ETs is not clear is because it will co-exist in the Multi-Level Perspective's planes in different capacities.

2.3.3. Linking Culture, Islandic Residential Electricity Regimes and Geography

Spencer-Oatey (2012) and Neuliep (2015) outline that many think of culture in terms of its geography, but it is an anthropogenic product that is affected by geography not defined by it. However, Neuliep (2015) uses the term 'population' in relation to this relationship between culture and geography; 'population' and 'culture' are not synonymous since 'population' implies some degree of geographic connectivity between its members. Therefore, in the context of small, tropical islands, the population is very much defined by the land-marine border though not necessarily the cultures.

What this boundary does however is increase the probability and frequency of interactions

that occur amongst members of the population such that the island has shared traits which form the culture of the population residing on the island. These sorts of interactions create rather homogenous and close-knit collective identities in islands (King, 2009) because geographic proximity is multidimensional enough to reinforce cultural identities, communications and diffusion (Raven et al., 2012).

This subsection contextualizes culture and geography in the same way that subsection 2.1.3. did for the regime. The residential electricity regime is the conceptual regime of interest and the culture of interest is that held by its residents. The fact that both the regime and culture can conceptually extend beyond the case study islands' borders is not disputed. This understanding is acknowledged and supported since energy cannot be limited to one spatial scale of study (Mattes et al., 2015).

But the use of small-island insularity to define regimes and cultures is done on the basis of the islands' energy policies and institutional actors' jurisdictions being set within these defined geographies, the cultures of interest are shared by the respective resident populations, and the spatial fluidity of both concepts has been duly recognised.

In addition to defining the geographic extent of culture, conceptually defining it more thoroughly in relation to energy required a secondary framework/theory and the Energy Cultures Framework is used.

2.4. Literature Review on the Energy Cultures Framework

2.4.1. Characterizing the Energy Cultures Framework

Behaviour is a central feature of culture. Culture is often thought of as a 'way of life' which means that people's collective behaviours are part of it. Behaviours involve acting based on beliefs and/or perceptions using, quite often than not, tangible items - which has implications for the persons exhibiting the behaviour(s) and tangible items involved. Arnesen (2013) states that exploring culture cannot be limited to a single theory or discipline and Stephenson et al. (2010) acknowledge that microeconomics; behavioural economics; technology adoption; social and environmental psychology amongst other sociological theories are all relevant.

Behaviours can be thought of as manifestations of energy (White, 1943). Therefore studying energy and behaviours should mean exploring how energy is used and what this energy use means to consumers (Lutzenhiser, 1992). Of the literature reviewed (e.g. Wallenborn (2008), Arnesen (2013), Strauss et al. (2013) and Sheller (2014)), Stephenson et al.'s (2010; 2015) Energy Cultures Framework (ECF) was the most detailed application of 'energy' and 'culture' as linked concepts.

The aim of the ECF is to give structure to the understanding of the drivers of energy-related behaviour and potential behaviour change interventions (Stephenson et al., 2010; Mirosa et al., 2011; Barton et al., 2013; Walton et al., 2014) - by exploring how people and their energy behaviours are embedded in daily life (Ford et al., 2016). Therefore, the ECF looks at 'energy behaviours' (Stephenson et al., 2015).

It does so by approaching energy cultures as an assemblage of norms, material culture, practices and their external influences (see Figure 21 on the next page); it most recently

however more broadly addresses 'sustainability behaviours' given the model's applications to work beyond energy research (Stephenson, 2018).

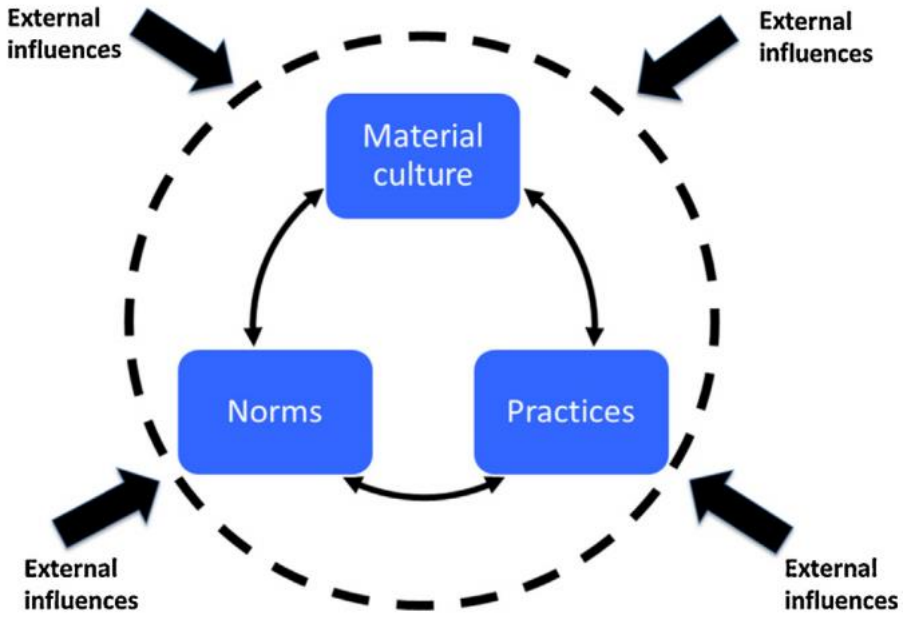


Figure 21 showing the Energy Cultures Framework

Extracted from Stephenson et al. (2015; 118)

The main alternative to using the ECF is the Social Practice Theory (SPT) and it is commonly compared to the ECF (Stephenson, 2018). Work such as Shove (2003), Shove (2010), Shove and Walker (2010), and Shove and Walker (2014) touch on the SPT and its related themes. SPT looks at competencies, materials, connections and meanings (Sovacool and Hess, 2017). It does not look at behaviour but rather the practices rooted in daily activities (Shove and Walker, 2010; Ford et al., 2017), and investigates the co-structuration between human action and social structure relative to routinized practices (Sovacool and Hess, 2017; Stephenson, 2018).

SPT focuses on a given practice and its social meaning (Shove and Walker, 2010) whilst the ECF approaches practices as a part of something larger which is more in line with the assemblage of features that would be part of a regime in the context of the Multi-Level Perspective (MLP). The ECF's consideration for the influence of an external contextual environment is another distinguishing element. According to Stephenson (2018) the ECF and SPT also differ because the latter does not consider non-routinized practices, focuses on cultural replication versus change, and is preoccupied with practices versus actors' cultural formations.

In terms of combining the MLP with a theory like SPT, Hargreaves et al. (2013) outline that the MLP is a vertically structured theory but the SPT is horizontally oriented - and as shown in subsection 2.3.2., culture transcends the planes of the MLP, so it is vertically-structured as well. Additionally, SPT treats actors as carriers of practices whilst the ECF is interested in the actors themselves and their agency - which complements the MLP since it focuses on the roles of actors in structural change (Ford et al., 2017).

Stephenson and colleagues think that a behavioural model should be versatile enough to have multi-scalar applications because culture is multi-scalar (Spencer-Oatey, 2012; Stephenson et al., 2015). The ECF is therefore useful because it is applicable to multiple analytical scales (Hopkins and Stephenson, 2014) - and this has been displayed through its empirical applications subsequent to the model's conceptualization in 2009 (Stephenson et al., 2015) (see Mirosa et al. (2011), Barton et al. (2013) and King et al. (2014) for examples).

The ECF is used to approach culture in the regime of the MLP. The ECF describes energy cultures as norms, practices and material culture together with their wider external influences;

material culture equates to the 'have', norms to the 'think', and practices to the 'do' (Stephenson, 2012). Figure 21 on page 78 illustrates the ECF. The external context will be touched on first followed by norms, material culture and practices.

Energy cultures are influenced by a wide range of external factors (Stephenson et al., 2015). These influences reside in the space beyond the pseudo-boundary (dotted perimeter) presented in Figure 21, and Stephenson et al. (2015) thought that this pseudo-boundary is particularly useful in making the theoretical distinction between the internal and external of the ECF.

External influences make up the contextual environment that energy cultures exist in (Stephenson et al., 2015). They are beyond the control of the actors' influence though external influences affect these actors' practices, norms and material culture (Stephenson et al., 2010). Stephenson et al.'s (2015) work also identify with the fact that external influences can lock-in patterns of behaviour. Ford et al. (2017) also link this to when the landscape and regime forces of the MLP support the incumbent structures. Examples of external influences are standards, subsidies, prices and social marketing campaigns (Barton et al., 2013).

Strengers (2010) describes material infrastructure as physical items such as objects, technologies, infrastructures or even systems of provision, and which make up an integral part of everyday life. Energy technologies as material culture represent physical and tangible assets that play a role in energy use (Stephenson et al., 2015); they unite the realms of doing and knowing (Drucker, 1961). Examples of material culture are heating technologies like electric heaters, furniture, housing structures, single-glazed windows, and even low income (Wallenborn, 2008; Sarrica et al., 2016; Stephenson et al., 2016).

Norms are shared beliefs about how people should behave in a given context (Stephenson et al., 2015). They are important because the beliefs about energy affect how it is used and vice versa (Strauss et al., 2013). Hopkins and Stephenson (2014), and Sarrica et al. (2016) further state that 'norms' are expectations and aspirations both of which are influential in behavioural change. Examples of norms are the expectations of comfort or even maintaining traditions learnt growing up (Sarrica et al., 2016; Stephenson et al., 2016).

Practices are analytical units that give insight into how daily life persists and are a mixture of perceptions and memories where the latter are products of and produce practices (Wallenborn and Wilhite, 2014). Practices include both routinized and non-routinized actions (Sarrica et al., 2016). Gram-Hassen (2008) distinguish between both by stating that routines are taken-for-granted, lack reflection and based on practical experience. Examples of practices are temperature settings, technology maintenance, number of heated rooms, hours of heating, or putting on more clothing when feeling cold (Sarrica et al., 2016; Stephenson et al., 2016).

Practices do not exist as isolated elements but tend to cluster of time and space (Torriti, 2017). Stephenson et al. believe that clusters of practices will emerge from a population to create energy cultures which can be used to better design policy interventions - hence the value of understanding local cultures (Wustenhagen et al., 2007).

Stephenson et al.'s use of the term 'energy cultures' targets combinations of norms, material culture, and practices within an external context that form clusters that can separate one energy culture from another. These clusters arise because cultures are not homogenous or equally distributed within a social system (Spencer-Oatey, 2012; Barton et al., 2013). Within Stephenson et al.'s work they identify nested energy cultures where the external influences of

one energy culture can be part of another energy culture at a higher scale. Figure 22 illustrates this conceptualization and shows that their model essentially extends consideration to the existence of energy subcultures because of these nested energy culture dynamics.

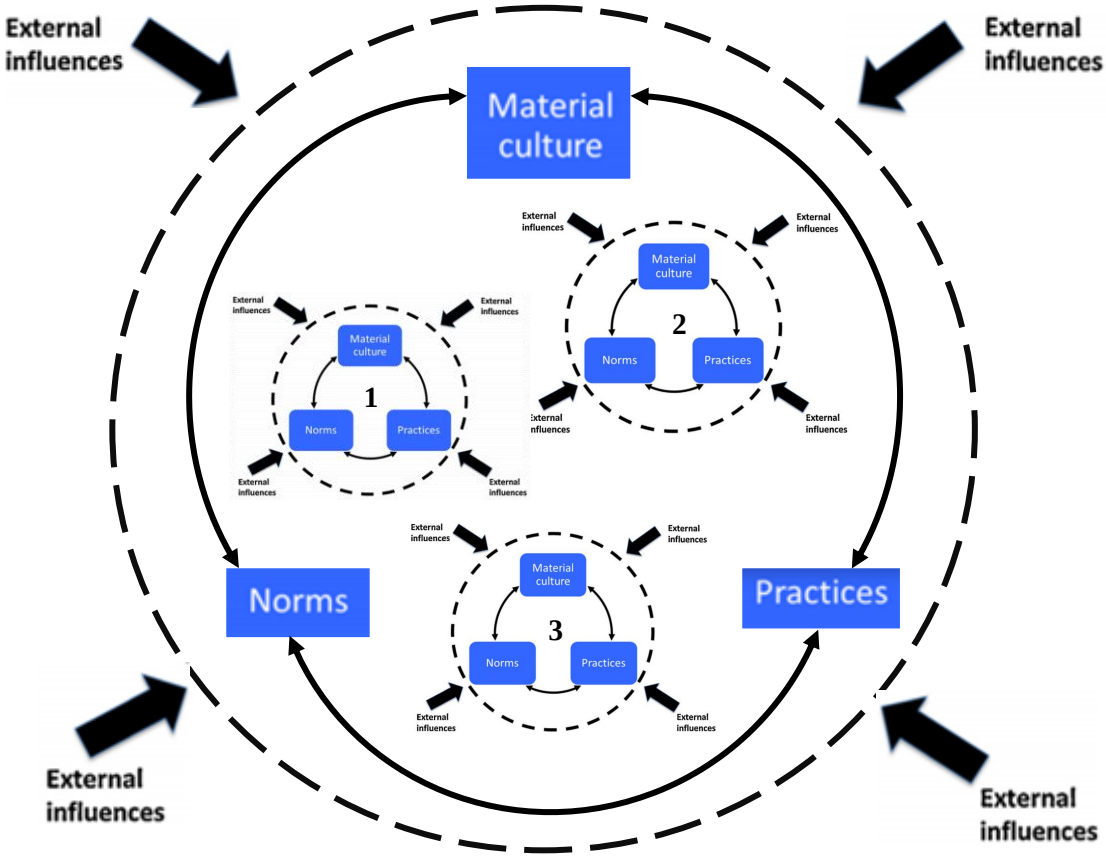


Figure 22 showing 3 arbitrary energy subcultures embedded in the wider dominant energy culture

Adapted from Stephenson et al. (2015; 118) using Microsoft Word

The formation of energy subcultures suggest that the emergence of new habits usually coincides with a shift in energy culture (Stephenson, 2012). Recalling the importance of adoption to mainstreaming (see section 2.2.), the adoption of technologies is also key process that can change material culture (as well as norms and practices) according to Stephenson et

al. (2010), and a change in one element of the ECF may create a cascade in the others (Barton et al., 2013; Hopkins and Stephenson, 2014).

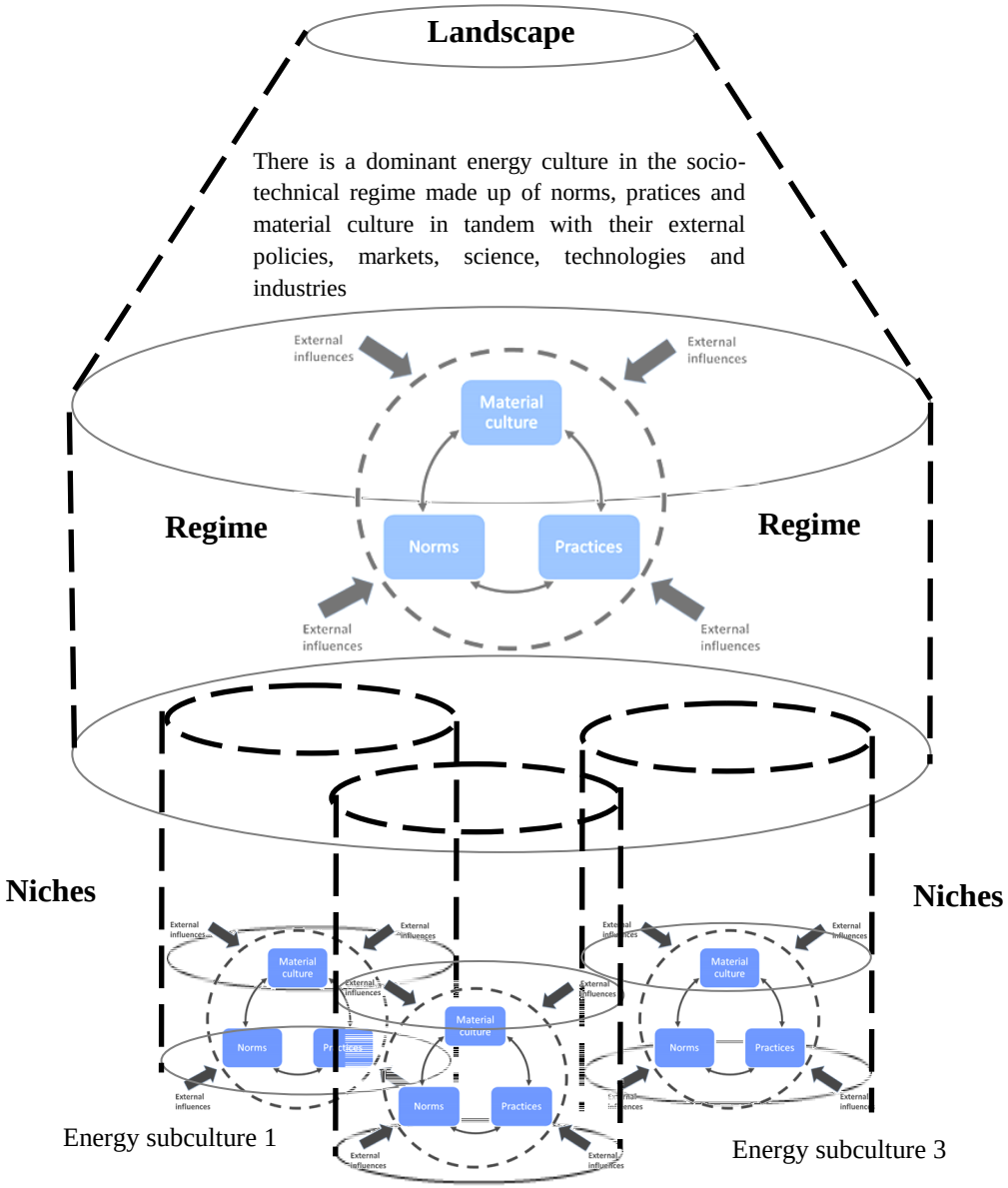
This important to consider because the ECF is used to define culture in the regime and Ford et al. (2017), one of the bodies of research that looks at the application of the MLP and ECF together, states that changes in energy cultures can reach a critical mass (perhaps linked to the 16% pseudo-mainstreaming threshold from section 2.2.) and can change the nature of the regime. This point is useful because it is strongly suggestive of an energy transition (ET), and culture's potential role in it because of the change in regime-orientation.

Based on this it is reasonable to suggest that enough adoption of a niche-innovation can catalyze an energy culture shift (and an ET). Therefore, the energy subculture notion is quite like niche-level culture in the MLP. So, by combining the MLP and ECF culture can be approached as a holistic landscape, regime, and niche-level construct.

The nature of the landscape, regimes and niches presented in subsection 2.1.2., further suggests that culture has both a proactive and reactive role in ETs. Figure 23 on the next page illustrates these dynamics and links the energy subcultures and energy culture to the landscape, regime and niche planes of the MLP.

Geels (2002) presents a diagram which shows how the various networks of actors are linked between the landscape, regime and niche planes of the MLP. This was the inspiration for Figure 23's design. The Figure shows how niches' energy subcultures are integrated into the regime's dominant energy culture, and how the landscape affects these by giving a more 3-dimensional view of Figure 22.

Landscape and regime-level factors are external influences on the dominant energy culture as well as energy subcultures' practices, norms and material culture



Niches have energy subcultures that collectively integrate into the dominant energy culture where clusters of norms, practices and material culture define the respective subcultures, and external influences on one subculture can be in another subculture

Figure 23 showing culture transcending the planes of the Multi-Level Perspective

Notes: The regime and niche-level areas of the figure gives a 3-dimensional representation of what the energy culture-subculture dynamic would look like from Figure 22.

Adapted Stephenson et al. (2015; 118) using Microsoft Word

2.4.2. Summaries of the Assumptions and Limitations of the Energy Cultures Framework

2.4.2.1. The assumptions

1. The Energy Cultures Framework assumes that a change in either norms, material culture, or practices will stimulate a change in one or more of the other elements.

2.4.2.2. The limitations

1. The model considers the effect of external influences on its core of norms, material culture and practices but the process by which this core can influence the outlying external influences is not as clear.

2. The model does not explicitly consider time but instead captures snapshots of energy cultures. This is a major limitation since its norms, practices, material culture and their external influences are products of time-sensitive processes.

3. There is the lack of consideration for the actual processes that manifest norms, practices, material culture and external influences. There is no elaborate consideration for processes such as cultural erasure, assimilation, retention or transmission.

4. The Energy Cultures Framework (ECF) does not address any differences in the strengths of expression of, and association between features that can be considered norms, material culture, practices and external influences.

5. The conceptual boundaries between norms, material culture, practices and external influences are not completely clear. For example, in the residential sector power poles

and their transformers can be perceived as material culture but can still be considered an external influence on the household's power supply because it is beyond the agency of these households.

6. A specific limitation highlighted in Ford et al. (2017), a body of work that looked at the application of the Multi-Level Perspective and ECF in the adoption of photovoltaics, is that the ECF does not adequately address how landscape and niches shape the regime within which the behaviour related to photovoltaics adoption occurs.

2.5. Nine Theoretical Linkages between the Multi-Level Perspective of Socio-technical Energy Transitions and Energy Cultures Framework for the Thesis' Investigations

Combining two distinct theories to develop a theoretical framework needs to be done considering their respective assumptions and limitations because these determine just how compatible they are. This brief subsection will show nine theoretical linkages between the Multi-Level Perspective (MLP) and Energy Cultures Framework (ECF) that are useful for the thesis' investigations.

The first link is that culture has a role in energy transitions (ETs). This creates the window to look at what it means as a socio-technical feature.

Secondly culture is explicitly included in the MLP as part of the regime. This acted as the next step in understanding culture in ETs by using the ECF's norms, material culture, practices and external influences to explore it as an energy culture in the regime.

The third theoretical link builds on the first two and is that culture transcends the landscape and regime of ETs. Given its complexity and slow rates of change, culture is a landscape-level phenomenon. However, given its explicit placement in the MLP's regime, culture is also a feature of regimes.

The fourth link relates to the existence of energy subcultures and the adoption of niche-innovations. The work on the ECF that outlined the existence of clusters of features which form an energy culture also showed that they can be nested within a wider energy culture. This therefore indicates that there may be energy subcultures relative to niches in the MLP.

So with respect to the adoption of niche-innovations, the acquisition of new technologies as material culture can be expected to have accompanying changes in norms and practices (based on the ECF's theoretical framing) to create an energy subculture (innovation-adopters) within the larger energy culture of the regime (adopters and non-adopters) for example.

A fifth link surrounds the MLP's landscape and the ECF's external influences. Given that landscape-level forces are far-removed from the regime and its actors, it is similar to the nature of external influences as being removed from the ECF's core of material culture, norms, practices, and the actors. However, regime-forces can also be external influences on an energy culture (Ford et al., 2017). This once again demonstrates the lack of a clear boundary between landscape and regime-level culture.

The sixth link is the connection that culture has with technology as part of the MLP's regime. Technology in the MLP is like the ECF's material culture (though technology in the MLP can refer to the wider construct of technological contexts). Additionally, a common representation of changes to material culture in the ECF is the adoption of new technologies and this fits

with the adoption of technological innovations that is pivotal in the MLP.

The seventh link is the focus on using the ECF to better design policy interventions, and the occurrence of policy as an explicit feature of the regime in the MLP. This means that there is an opportunity to use the ECF to explore policies in the regime which helps with looking at the potential interactions between policy and culture.

The eighth link relates to time. The MLP and ETs show consideration for time. However, the ECF as a model does not explicitly consider time as feature. Therefore, the ECF can be thought of as a tool for exploring snapshots of energy cultures during an ET; in theory comparing energy cultures snapshots at two different points in time during an ET can provide insight into the role(s) of culture in the MLP.

The ninth link is that of the interconnectedness between the elements in the MLP's regime (the plane that undergoes an ET), as well as those of the ECF. The regime's 6 elements are part of its co-evolutionary nature so a change in one element would affect one or more of the others. Likewise, in the ECF, a change in either the norms, material culture or practices of an energy culture is likely to affect the other elements. Given that the ECF was used to define culture in the regime as an energy culture, this means that a change in any of the regime's other five elements would affect the energy culture's norms, practices and material culture; Ford et al. (2017) touch on this link.

3.0. Methodology

Synopsis

The methodological literature (e.g. Burnard et al. (2008), Fox et al. (2009), Kumar (2011) and Blandford (2013)) was reviewed and it framed a qualitative approach as the most suitable for the thesis. This was also supported by similar studies e.g. McGuire et al. (2007); Winther and Bouly de Lesdain (2013); King et al. (2014); Stephenson et al. (2015); Mattes et al. (2015); Fouquet (2016); Stephenson et al. (2016); Ford et al. (2017); and Harrison and Popke (2018).

This chapter is dedicated to the types of data, their methods of collection, and how they are designed to answer the overarching research question; the main research question is: "*How could the resident population's energy culture(s) and Government's residential solar energy policies interact to mainstream distributed residential solar energy technologies in Trinidad?*"

Qualitative research places value on context rather than generalizability (Adams et al., 2007; Hancock et al., 2009). Contexts are often represented as cases (ACAPS, 2012). The study used three cases: the islands of Oahu, Barbados and Trinidad. Trinidad is the central case study and a literature review on its energy history was carried out to set the context for the island. However, the main research question has two sub-questions which are used to make two comparisons (each of which answered one of the sub-questions).

The first is: "*How could the adoption of distributed residential solar energy technologies and the residential energy culture(s) of Trinidad affect each other?*" Barbados and Trinidad are compared based on the household energy cultures of the respective samples as guided by the Energy Cultures Framework. Given that residential solar energy technologies and household

energy cultures are the focus, interviews with householders were the most appropriate way to collect the desired data.

The second is: "*What are the Government's State-level residential solar energy policy options in Trinidad?*" Oahu and Trinidad are compared based on their energy institutions and residential solar energy policies. Given that policymaking draws on specialized expertise, interviews with policy experts were the most appropriate way to collect the required data.

The chapter is structured as follows: section 3.1. overviews the literature review done on Trinidad's energy history; section 3.2. details the 33 household interviews conducted in Barbados and Trinidad which investigated the respondents' energy cultures; section 3.3. details the 22 key-informant interviews conducted in Oahu and Trinidad which focused on the policies supporting residential solar energy in each island; subsection 3.4. overviews the nature of performing thematic content analyses like those used to analyze the interview data; subsection 3.5. focuses on the study's research ethics; and subsection 3.6. provides the study's limitations.

3.1. Setting the Context for Trinidad as the Central Case Study through a Literature Review on its Energy History

Energy transitions have spatial and historical contexts (Markard and Truffer, 2008) so a literature review on Trinidad's energy history was carried out. This was facilitated by a 6-week visit to the University of the West Indies' library in Trinidad in December 2014.

History is a topic that deals with with chronology and the collective actions and beliefs over

time (Raven et al., 2012). The information from the literature review is presented in Chapter 4 and looked at the nation's energy developments surrounding the post-1700 sugarcane economy's transition to oil of the 1800s and then into natural gas during 1900s. Remshardt and Flowers (2007) describe such work as seeking to systematically understand the past by looking at verifiable records to study the present and future.

This review was therefore a form of what Harrell and Bradley (2009) describe as extraction i.e. collecting data from documents, records and archival sources. However, a caveat is that one should be aware of the extent of transferablilty of the lessons from previous energy transitions to future ones (Fouquet, 2016) given that studying past transitions are motivated by anticipating future transitions (Cherp et al. 2018).

This literature review had three objectives: 1) to gain an appreciation for the applicability of the Multi-Level Perspective (see Chapter 2) to Trinidad; 2) to create an overarching narrative on the wider energy system in Trinidad as the thesis' central case study island; and 3) to characterize the barriers to solar energy development in the island.

3.2. Conducting Residential Interviews in Barbados and Trinidad to Investigate Household Energy Cultures

3.2.1. Using Interviews and Sampling the Energy Cultures

The related academic literature on data collection methods was read to develop the research design and methodology before any data was collected. More specifically, literature related to cultural methods e.g. pile sorting, free-listing, triads, multi-dimensional scaling, and

participant observation were looked at. The pros and cons of each were then considered in the context of the available resources (time, funding and practicality). However, the various techniques looked at had their limitations.

For instance, with pile sorting (see John Hopkins University and Amy Medley (2008)), which lets respondents group similar items together, using photographic cards to represent concepts may have been used to guide the grouping activities (as is commonly applied in the technique). But in a location like Trinidad the method may not have been the most productive because residents have had no substantial contact time with solar technologies; there was a significant risk of them being unaware of what the technologies look like especially where the photographs on the cards illustrate various solar technology designs and/or components which may not necessarily fit their perceptions.

Similar reasons affected methods such as triads and multi-dimensional scaling. The time commitments involved in methods like participant observation were also not practicable for the available time and financing. These thoughts led to the use of interviews. The next step was to define the sample population.

Defining the population of interest develops the sampling frame (Fox et al., 2009). This helps with the wording of questions, response formats and persons' ability to participate in interviews (Siniscalco and Auriat, 2005). The residential interview samples in Barbados and Trinidad were defined with consideration for household member, age, gender, household size, homeownership, and geography. Appendix A provides more detail on these parameters.

They were chosen to be as inclusive as possible considering the multiplicity of subjective views that would make up energy cultures in the residential sector. Given that Trinidad is the

central case study, the sampling frame was developed with reference to the island's residents and then applied in Barbados to standardize the comparison.

The interviews were firstly trialled through two phases of pilot interviews in Trinidad and then the main study was conducted in Barbados and Trinidad. The first phase of the pilots was conducted in May 2016 and the second was conducted in June 2016. The main study was then conducted between July and September 2016.

The first phase of the pilot used written-questionnaires and after refining the approach, was trialled again using a pre-set series of open-ended questions and short questionnaire in the second phase. The main study was then undertaken based on the lessons-learnt from these pilots. The next subsections detail the development of the interviews.

3.2.2. The Early Structured Interview Design and Pilot Interviews

3.2.2.1. Written questionnaire-interviews as the early interview design

Walton et al. (2014) and Stephenson et al. (2015) outline that the Energy Cultures Framework is useful for designing methodologies and structuring analyses, so it was used to design the interview questions. The early interview design was a written questionnaire-interview and work such as Fallowfield (1995), Leung (2001), Colosi (2006), Hague (2010), and Phellas et al. (2011) offer guidance on this.

Hague (2010), Woods (2011) and Blandford (2013) outline that questionnaires and surveys are common examples of structured interviews. Alshenqueeti (2014) states that structured interviews are also quite similar to quantitative questionnaires. They have a pre-set series of

questions (Harrell and Bradley, 2009); can be self-administered or interview-administered (Leung, 2001); and are standards that interviewers can use when the questions need to be asked in the same way (Hague, 2006).

The closed structured questions used had the benefit of being quick; easy to code, record and analyze; and minimizing the discrimination against the less literate in the sample (Leung, 2001). Fallowfield (1995), Taylor-Powell (1998), Leung (2001), and Woods (2011) provide guidance on designing questions e.g. using simple, short wording and sentences; asking for only one piece of information at a time; and using mutually exclusive categories in the response options.

Another element of the design is the question's sequencing. Asking the same series of questions is known as scheduling (Phellas et al., 2011). Taylor-Powell (1998), Leung (2001), Rattray and Jones (2005), Colosi (2006), and Phellas et al. (2011) touch on the fact that the sequencing of questions is influential in retaining the respondent's interest. The questions' sequence should be general to particular; easy to difficult; impersonal to personal; most important to least important; and/or factual to abstract as one moves through the questionnaire. The design of the questions should also remain consistent in any given section to not overwhelm the respondent (Taylor-Powell, 1998).

3.2.2.2. Trials, and the structured interview design and delivery

Ares et al. (2014) state that completing exercises demonstrates a level of cognisance by interviewees and shows why work such as Leung (2001) advises researchers to ensure that their respondents have the necessary knowledge to complete the survey. Part of testing this

can be through experiments and trials; work such as Barriball and While (1994), Leung (2001), Quinlan (2005), Hague (2010), and Melson and Davies (2012) highlight the value of experimenting with pilots before conducting the main study.

Siniscalco and Auriat (2005), and Phellas et al. (2011) suggest that the pilot should target the same types of respondents as the actual study, but they should be excluded from the main study. An initial trial of face-to-face structured interviews was carried out with 6 households in the Claxton Bay community of Trinidad on the 28th May 2016 by using a local community contact to facilitate introductions and recruit participants.

A contact residing in Claxton Bay was identified and they got in touch with a community figurehead to facilitate introductions with members of the community who were willing to participate. The nature of the study and the interview parameters e.g. age and type of household were communicated to the contacts beforehand so willing participants could be identified prior to visiting the community.

During the visit respondents were given more information about the study; the time and effort spent doing this helps ensure that the right type of data is collected (Wilmot, 2005). Respondents were also allowed to ask any questions they had about the topic and were assured that their anonymity will be preserved (section 3.5. provides more details).

The respondents' reactions during the interviews led to the determination that they were not comfortable with answering some of the questions. As a result, they took too long to complete the exercise. Each questionnaire-interview took between 30 to 45 minutes to complete. It not only seemed a bit laborious to respondents but also created some awkwardness waiting for them to finish. This indicated that the written questionnaire-interview was not the most

suitable method.

One positive however was the networking through the local contact. The community contact not only aided in directly recruiting participants but their presence during the interviews created a more comfortable atmosphere for the respondents. Their introductions also acted as a pseudo-vetting of character and research intent as noted in work like Wilmot (2005), and Heri and Mosler (2008).

Considering that the interviewee does most of the work in the interview by answering a series of questions (Barriball and While, 1994) the process should be made as amiable as possible. So, based on the lessons from the trials the most productive questions were extracted and refined. The redesign developed a structured question-sheet (13 questions in Barbados and 12 in Trinidad), as well as a short questionnaire (15 core items of information in Barbados and 9 in Trinidad). Appendix B shows the Barbadians' questions as an example.

The interviews were tested again with 5 households in the Freeport community on the 27th June 2016. The former 30 to 45-minute-long interviews now averaged between 15 to 20 minutes and respondents handled the questions with increased fluency and confidence.

3.2.3. The Final Structured Interview Design and Question Structure used for the Energy Cultures Data Collection

The final residential interview design was a combination of a question-sheet together with a short questionnaire as a structured interview. Structured interviews use pre-set questions and are useful for capturing attitudes, knowledge, behaviours and facts without the researcher's

influence (van Teijlingen, 2014) - and its pre-set questions are a defining feature (Woods, 2011; Alshenqeeti, 2014).

Open-ended questions ask respondents to formulate their own answers whilst closed-ended questions are more restrictive (Siniscalco and Auriat, 2005; Hague, 2010; Phellas et al., 2011). Both types of questions were used but the questionnaire relied more heavily on the latter and the question-sheet on the former.

Taylor-Powell (1998) and Colosi (2006) suggest that questions which address similar domains should be grouped together since it allows for a more logical and organized interpretation of the domain. The questions were separated into the 5 themes shown in Table 2 (next page). The structured nature of the interviews meant that the same questions were asked of each of the respondents and Table 2 also provides examples.

Asking questions in the same way is known as standardizing (Phellas et al., 2011). However, Gordon (2011) notes that words have subjective meanings. This could affect the interpretation of questions. But Barriball and While (1994) suggest that wording will not hamper standardization so long as the meaning of what is being asked is not altered.

Questions being asked across a group should be standardized so that comparisons can be made (Barriball and While, 1994). Standardizing questions also allows quantifiable data to be collected; increases the replicability; allows for a degree of generalization from the results; and enhances the data's reliability (Woods, 2011).

THEME	REASON FOR INCLUSION	EXAMPLES
Energy Supply	These three themes are framed by the fundamental interactions between electricity utility companies and households. The company transmits and distributes electricity (energy supply) to households, and households consume (energy demand) and pay (energy costs) for this electricity.	How does your household get energy? (Barbados and Trinidad)
Energy Costs		In your opinion what specific factors influence how much you pay for energy? (Barbados and Trinidad)
Energy Demand		In your opinion what specific factors influence how much energy is used in your home? (Barbados and Trinidad)
Considering Solar	These themes were included to look for any differences in the understanding of the resource and technology due to its adoption; the Barbadians adopted solar water heating and the Trinidadians were non-adopters.	Can you define what solar energy is? (Barbados and Trinidad)
Solar Water Heating		How did you go about getting your solar water heater? (Barbados) How do you heat your water? (Trinidad) How do you think a solar water heater works? (Barbados and Trinidad)

Table 2 showing the main themes investigated through the residential interviews conducted in Barbados and Trinidad

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Cross-referencing responses to a given question asked across respondents can produce interesting comparative perspectives on the same issue and build a systems-level narrative on the processes operating (N.Y.S. State Office of Alcoholism and Substance Abuse Services, 2008). Melson and Davies (2012) add that by designing impersonal questions which target issues that represent the 'typical' or 'average' state of some social element, the inquiry may have better chances of persuading the respondent to use their own personal convictions in their response.

Therefore, any overlapping responses between respondents' answers are elements of the 'typical' state being explored which is ideal for comparing the mainstream energy cultures (see Chapter 2 for more about the mainstream).

3.2.4. Recruiting and Accessing the Energy Cultures Respondents

The Barbadian interviews were undertaken in July 2016 followed by the Trinidadian interviews during August to September 2016. The data collection followed the snowball approach used in the trials but Table 3 (next page) provides a summary of the various forms of sampling that were part of data collection.

Face-to-face and over-the-phone interviews were used to collect the data. Telephone interviews are often considered to be methodological compromises (Irvine, 2011) and a secondary data collection method to face-to-face interviews (van Teijlingen, 2014). But using telephone interviews is dependent on many factors such as budgets, time constraints, safety, and physical/visual context (Irvine, 2011).

2 interviews were done face-to-face and 15 were conducted over-the-phone in Barbados, and in Trinidad 5 were over-the-phone and 11 were face-to-face. The mix maximized participant-inclusion and mitigated any trust-related perceptions held by participants related to hosting a 'stranger' in their home. Tables 4 and 5 (pages 101 and 102) show the respondents' basic details.

TYPES OF SAMPLING	DESCRIPTION	APPLICABILITY
Convenience	Research is conducted on cases/participants that are readily available and 'convenient' sources of data; most research involves some level of convenience sampling (van de Vijver and Leung, 1997; Frederick, 2006; Hancock et al., 2009; Elmusharaf, 2012; Blandford, 2013).	1) Selecting Trinidad as a case study because I am Trinidadian. 2) Facilitating both face-to-face and over-the-phone interviews. 3) Establishing community contacts in each region. 4) Selecting several respondents directly.
Purposive / Purposeful	Defining a sample group through purposeful sampling means that the cases/participants selected are good sources of information relative to the topic being investigated (Sandelowski, 1995; Tuckett, 2004; Brikci, 2007; Kumar, 2011; Barnett et al., 2015).	1) Selecting Trinidad and Barbados as case studies was purposeful in that they are both small, tropical islands; one has widespread solar deployment and the other does not. 2) Selecting the sampling parameters for the householders represented a specific energy culture of interest (see Appendix A).
Critical case	Critical case sampling involves the selection of cases/participants that are particularly significant (Hancock et al., 2009).	1) Selecting Trinidad represented some element of critical case sampling because it is a small, tropical island that has a unique energy system; Trinidad is one of the only, if not the only, small island that has globally significant reserves of oil and natural gas.
Strategic	Strategic sampling involves a pre-planned sampling frame (Hancock et al., 2009).	1) Trying to get different perspectives from various municipalities/parishes in Trinidad and Barbados.
Typical case	Typical case sampling selects a case study that represents a normal or average case that is not atypical or extreme (Elmusharaf, 2012).	1) Using Barbados as a case study represented a typical small, tropical island from an energy standpoint.
Snowball	Snowball sampling involves contacting a few respondents then asking them to recommend other respondents of similar standing (Frederick, 2006; Family Health International, 2006; Elmusharaf, 2012; Blandford, 2013).	1) Using the community contact to recruit interviewees and also using interviewees to recommend other respondents.

Table 3 showing the broad types of sampling that were used to collect the energy cultures data through the residential interviews conducted in Barbados and Trinidad

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TRINIDAD (TTD)					
INTERVIEW NUMBER	**GENDER (M / F)**	**AGE (years)**	**HOUSEHOLD SIZE (persons)**	**MUNICIPALITY**	**IDENTITY CODE**
01	F	31	1	City of San Fernando	Respondent 01FTTD
02	M	62	1	Diego Martin	Respondent 02MTTD
03	F	56	2	Diego Martin	Respondent 03FTTD
04	F	65	2	City of San Fernando	Respondent 04FTTD
05	F	27	1	Sangre Grande	Respondent 05FTTD
06	M	32	2	Sangre Grande	Respondent 06MTTD
07	M	62	3	Sangre Grande	Respondent 07MTTD
08	F	67	4	Sangre Grande	Respondent 08FTTD
09	M	45	1	Couva/Tabaquite/Talparo	Respondent 09MTTD
10	M	45	2	Couva/Tabaquite/Talparo	Respondent 10MTTD
11	M	46	3	Couva/Tabaquite/Talparo	Respondent 11MTTD
12	F	47	4	Couva/Tabaquite/Talparo	Respondent 12FTTD
13	M	63	1	Tunapuna/Piarco	Respondent 13MTTD
14	M	46	3	City of San Fernando	Respondent 14MTTD
15	M	36	2	Tunapuna/Piarco	Respondent 15MTTD
16	F	63	4	City of San Fernando	Respondent 16FTTD

Table 4 showing the anonymous identifiers and basic demographics of the residential respondents in Trinidad

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BARBADOS (BDS)					
INTERVIEW NUMBER	**GENDER (M / F)**	**AGE (years)**	**HOUSEHOLD SIZE (persons)**	**PARISH**	**IDENTITY CODE**
01	M	55	8	Christ Church	Respondent 01MBDS
02	M	68	2	Christ Church	Respondent 02MBDS
03	M	43	1	St. Michael	Respondent 03MBDS
04	F	>50	4	St. Michael	Respondent 04FBDS
05	M	50	4	Christ Church	Respondent 05MBDS
06	M	58	1	St. Michael	Respondent 06MBDS
07	F	40	4	St. Andrew	Respondent 07FBDS
08	F	49	3	St. Thomas	Respondent 08FBDS
09	M	63	4	St. Lucy	Respondent 09MBDS
10	F	30	3	St. Lucy	Respondent 10FBDS
11	F	63	3	St. Andrew	Respondent 11FBDS
12	M	36	2	St. Michael	Respondent 12MBDS
13	M	52	4	St. Michael	Respondent 13MBDS
14	M	>60	4	Christ Church	Respondent 14MBDS
15	F	61	1	St. Lucy	Respondent 15FBDS
16	F	50	3	Christ Church	Respondent 16FBDS
17	F	40's	1	Christ Church	Respondent 17FBDS

Table 5 showing the anonymous identifiers and basic demographics of the residential respondents in Barbados

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3.2.5. Sample Size Considerations

In qualitative work sample sizes are dependent on the study's purpose, quality of information, resources available, and sampling approach (Remshardt and Flowers, 2007; Blandford, 2013)

i.e. it is context-dependent (Marshall et al., 2013). Every study has a purpose (Blandford, 2013) and the appropriate sample size is the one that sufficiently answers its research question(s) (Marshall, 1996; Frederick, 2006). Large datasets are not necessary in qualitative sampling (Family Health International, 2006) since small samples can answer the research question depending on what it is (Elmusharaf, 2012).

Small sample sizes are valid in qualitative work because the goal is not statistical verification but rather documenting response variation since every response has value (Blair et al., 2006). Marshall et al. (2013) caveat however that too large a sample may lose the in-depth subjectivity of the interviews whilst too small may not capture the core views sought.

Most qualitative studies do not offer justification for their sample sizes (Marshall et al., 2013; Barnett et al., 2015). But some of the common methods for doing so are citing recommendations from qualitative methodologists, citing samples sizes from similar studies, and using internal justifications like data saturation (Marshall et al., 2013).

3.2.5.1. Sample size justification from the literature

Previous qualitative, ethnographic and cultural research have used the literature to justify sample sizes. The literature (e.g. Hague (2006), Schrauf and Sanchez (2010), Baker and Edwards (2012), Vardar et al. (2012), and Marshall et al. (2013)) connects with sample sizes roughly ranging from 20 to 60.

Energy studies such as Morris et al. (2016) investigated peak electricity demand reduction interventions in Magnetic Island, Australia and used 30 household interviews to collect their

data. Gram-Hassen (2008) was another example of work that used 30 interviews and they looked at electricity consumption in relation to information and communication technology. By comparison there were a total of 33 interviews conducted in Barbados (17 interviews) and Trinidad (16 interviews).

Relative to the intra-island sample sizes, King et al. (2014), one of the works that used the Energy Cultures Framework, undertook a related project in the Blueskin area near Dunedin, in New Zealand in 2013 and explored the underlying drivers of residents' interest in adopting photovoltaics. Their work used 18 residential interviews. Ford et al. (2017) is another example of work that used similar interviews and analytical approaches to look at photovoltaics adoption in this same area of New Zealand.

Winther and Bouly de Lesdain (2013) conducted a similar study that compared French and Norwegian electricity cultures and used 20 and 11 interviews respectively. Grieve et al. (2012) looked at the non-adoption of energy efficient hot water systems and conducted 13 household interviews but also stopped their data collection once there was no new information emerging. The last example shows that data saturation was a sample size determinant.

3.2.5.2. Sample size justification through data saturation

Qualitative samples are small, so generalizability is not the aim and data saturation is often used as a determinant of adequate sample sizes (Marshall, 1996; Brikci, 2007; Hancock et al., 2009; Holton, 2010). Brikci (2007) states that short-term studies across homogenous groups can become saturated around 15 respondents. However, Marshall et al. (2013) state that many

studies use data saturation but few describe it.

Saturation represents the point at which any addition of new items to the list of interview codes does not substantially contribute to new knowledge (Frederick, 2006; Schrauf and Sanchez, 2010; Elmusharaf, 2012; Blandford, 2013). So, saturation is the point at which it is unlikely that conducting more interviews yields new information (Ramsden, 2016). In relation to Brikci's sample size of 15 mentioned earlier, Thomson's work outlines that saturation tends to occur between 10 and 30 interviews though more interviews should be done to test it once the researcher believes it has been achieved (Marshall et al., 2013).

Weller and Romney's work advises researchers to trace the frequencies of interview codes to identify the point of saturation. Data saturation then is essentially the recognition of what Willis (1999) calls dominant trends across survey groups. Data saturation was determined by open coding each interview's transcript whilst in the field and monitoring the emergence of codes.

Figure 24 (next page) shows the trends of the codes generated in the field during data collection. As will be outlined in section 3.4, the residential interviews' data were analysed through an inductive thematic content analysis and this open coding is part of it because the researcher reviews the material, makes notes and assigns textual labels, and later groups these labels into broader categories (Hall, 2018).

Figure 24 shows the interviews' cumulative codes, number of new codes, percentage of pre-existing codes, and percentage of new codes observed after each interview. The 17 Barbadian interviews produced 365 different codes where ≈95% of the codes generated after the 17th interview existed in a previous interview. By comparison, 377 different codes were generated

from the Trinidadians and ≈94% of the codes generated after the 16th interview existed in earlier interviews.

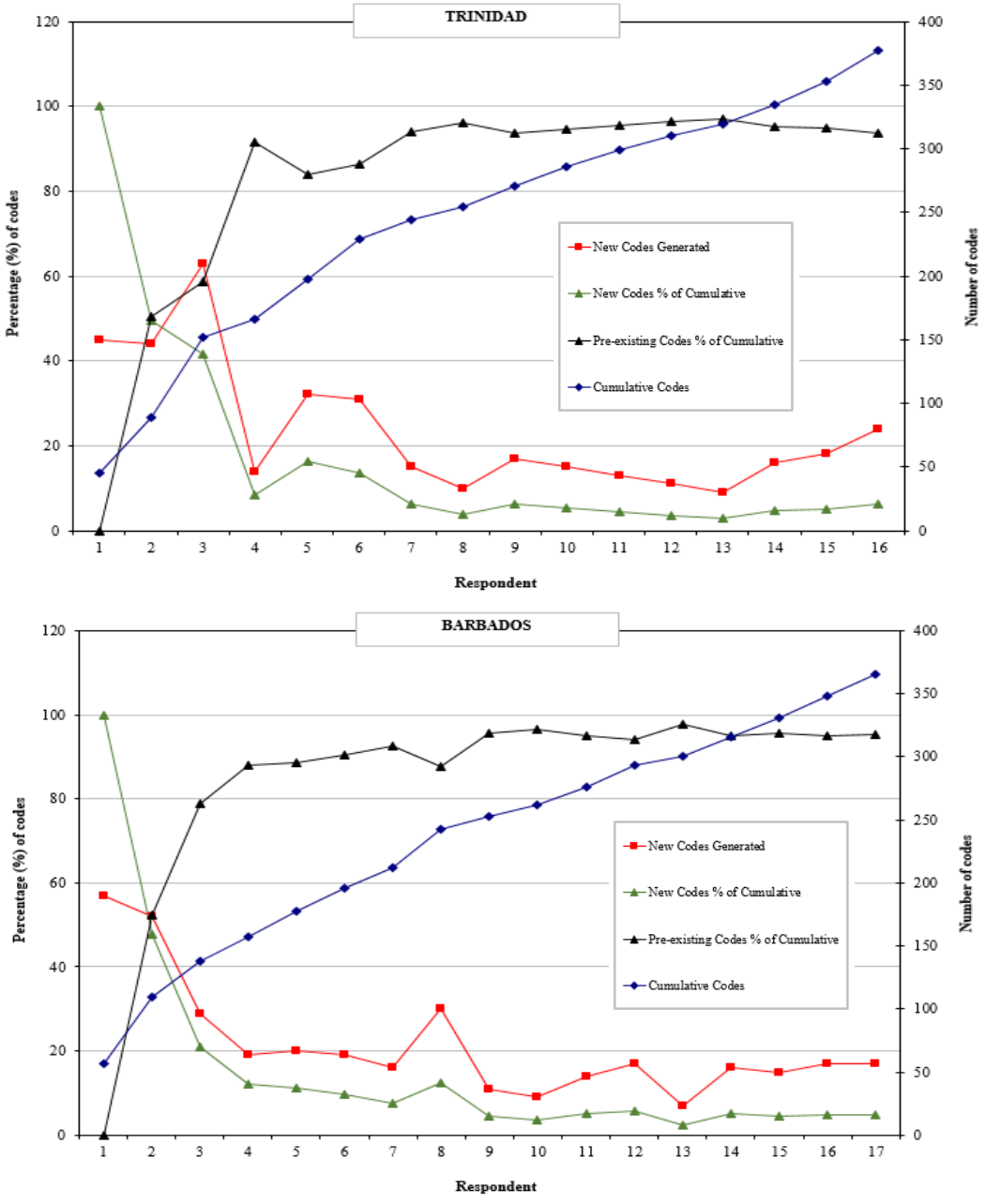


Figure 24 showing the patterns of the open-codes generated during the energy cultures data collection in Trinidad (top graph), and Barbados (bottom graph)

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Theoretically saturation can be thought of as Figure 24's (previous page) black lines being consistently recorded at '100%' whilst all others are at '0' over the course of the interviews. However, given the multiplicity of individual perceptions, such observations would be rare unless the entire population was sampled which is a logistical impossibility.

The most important line in Figure 24 is the black one. The black line specifically shows that the codes which emerged in previous interviews were making up greater proportions of the cumulative code count (blue line). The graphs show that fewer new codes were likely to emerge if more interviews were done i.e. diminishing returns from conducting more interviews.

Culture is shared by at least two people (Spencer-Oatey, 2012). So, considering that ≈52% of the codes were generated after 2 interviews in Barbados and ≈59% in Trinidad, the data collected has cultural potential. The aim was to conduct as many interviews as possible within the allotted time in the field. But this code-monitoring suggested that the intra-island sample sizes were sufficient to capture the core of the respective energy cultures though individual responses that reside outside the samples' norms exist as what Wills (1999) calls 'discoveries' e.g. the 8th Barbadian interview in Figure 24.

Following the pattern of emerging codes in the field had two objectives: 1) to help with the sample size determination and 2) to begin understanding the data in-situ.

3.3. Conducting Institutional Interviews in Oahu and Trinidad to Investigate Residential Solar Energy Policy Implementation

3.3.1. Developing a Comparative Foundation through Institutional Concept Diagrams

There is room to explore the more local energy transition processes relative to the multipilicty of actors involved (Mattes et al., 2015). Considering this, Geels (2002) and Geels' (2004) work on multi-actor networks was the inspiration for looking at the institutions involved in residential electrification in Oahu and Trinidad.

Reviewing the literature on each island's energy policies identified the institutions, their functions and their potential interactions with each other. This information was used to develop network diagrams that characterize where different institutions fit in relation to others (see Chapter 7). They are not multi-actor networks but rather institutional concept diagrams. It is important to make that distinction because the sole purpose of these diagrams is to act as supporting illustrations for the thesis' policy discussions. They are also not products of more explicit actor-network methods or analytical metrics such as actor-density or strengths of association.

Institutional actors like those in the diagrams are usually observed from within the researcher's context (Harrell and Bradley, 2009). The diagrams have no concrete boundaries because the researcher defines the scope for institutions' inclusion/exclusion (Bots et al., 1999). This is also set in the wider academic understanding of actors in energy transitions not being arranged in set arrangements (Mattes et al., 2015).

Such subjective diagrams therefore assume that only the linked institutions interact (Reagans and Zukerman, 2008) which is not the case. Nevertheless, conceptualizations like these diagrams allow researchers to produce a well-defined system to reference as a temporal snapshot of institutional relationships (Lucas and Mayne, 2013).

3.3.2. Adding Depth to the Institutional Concept Diagrams through Semi-Structured, Key-Informant Interviews

Interviews allow for in-depth discussions of topical interests where informants' knowledge is a rich resource for learning (Sociology Central, 2002; Harrell and Bradley, 2009; Soiferman, 2010). Semi-structured interviews are commonly used in policy-based research (Harrell et al., 2009) and use open-ended questions that address topical interests (Cohen and Crabtree, 2006; Hancock et al., 2009).

Semi-structured interviews were the most effective and efficient way to collect data from busy high-level policymakers. This also comes with the fact that the policy data collected was more strongly coupled with literature resources (compared to the cultural data); it put the literature's secondary data into the context of the current policy situation in the respective islands based on the policy narratives developed from the primary interview data.

Myers and Newman (2007), and van Teijlingen (2014) outline that semi-structured interviews make use of an incomplete script which combines improvisation and pre-prepared questions. This makes semi-structured interviews conversational which affords the interviewee the freedom to express their views (Cohen and Crabtree, 2006; Global Research Team and Policy and Practice Communications Team, 2012).

Zhang and Wildemuth (2009) state that semi-structured interviews usually have preconceived theoretical framings - like the Multi-Level Perspective being used in the thesis (see Chapter 2). Laforest (2009) also adds that such interviews supplement other sources of data quite well - like the islands' energy policy literature reviews used to design the institutional concept diagrams.

Mattes et al. (2015) undertook a similar study and state that semi-structured interviews are the most appropriate means of collecting data on the complex and multifaceted nature of local change processes. So, conducting face-to-face, key-informant, semi-structured interviews with the officials of institutions represented in the diagrams gives the comparative analysis depth.

Sources such as Barriball and While (1994), Boyce and Neale (2006), Kumar (2011), Elmusharaf (2012), and ACAPS (2012) offer guidance on undertaking key-informant interviews and outline that they are qualitative interviews that target a rather small but select group of participants because of their knowledge on and/or experience in a topic.

Key-informant interviews are useful for looking at specialzed systems (NECAPT, 2004; N.Y.S. Office of Alcoholism and Substance Abuse Services, 2008) like the residential electricity systems of Oahu and Trinidad. They are however hard to generalize beyond a given sample (UCLA Center for Health Policy Research, 2005; Boyce and Neale, 2006) and island-specific interviews were conducted in Oahu and Trinidad.

3.3.3. Sample Sizes, and Selecting, Recruiting and Accessing the Institutional Key-Informants

3.3.3.1. Selecting the institutions and key-informant sample sizes

Key-informant interviews capture the views of diverse groups to field more balanced perspectives (USAID Center for Information Development and Evaluation, 1996; UCLA Center for Health Policy Research, 2005; Mattes et al., 2005). The answer to how many interviews is enough is subjective and contextual (Ramsden, 2016). But key-informant interviews are well-suited for small samples (Boyce and Neale, 2006; Laforest, 2009; ACAPS, 2012).

Blandford (2013) outlines that semi-structured studies commonly use sample sizes between 10 and 20. The USAID Center for Information Development and Evaluation (1996), and UCLA Center for Health Policy Research (2005) outline that key-informant interview sample sizes can range from 15 to 35. Kumar (1989) however states that less than 15 may make the data's validity questionable whilst Frederick (2006) suggests that as few as 5 are acceptable.

A related study on the energy metabolisms of Caribbean islands undergoing energy transitions was done in Harrison and Popke (2018) and they used 35 interviews like those conducted here. But ensuring that most or all of the perspectives are captured is an important part of qualitative research (ACAPS, 2012) so the right size is the one that provides a range of perspectives that answer the study's research question(s).

The number of interviews was guided by each island's institutional concept diagrams, informed judgement in selecting institutions, and more practically the informants' availability and organizations' willingness to facilitate interviews. Table 6 (next page) summarizes the

types of sampling that were part of the data collection.

TYPE OF SAMPLING	DESCRIPTION	APPLICABILITY
Convenience / Opportunistic	Research is conducted on cases/participants that are readily available and 'convenient' sources of data; most research involves some level of convenience sampling (Frederick, 2006; Hancock et al., 2009; Elmusharaf, 2012; Blandford, 2013). Opportunistic sampling is related to convenience sampling and is based on a first-come, first-served premise (Luborsky and Rubinstein, 1995) - and as the name implies, the data is collected as the opportunity arises (Elmusharaf, 2012).	1) Selecting Trinidad as a case study given that I am Trinidadian. 2) The facilitating officials in each institution were subject to the organizations' gatekeepers. 3) Some interviews were conducted as the chance presented itself whilst in the field.
Purposive / Purposeful	Defining a sample group through purposeful sampling means that the cases/participants selected are good sources of information relative to the topic being investigated (Sandelowski, 1995; Brikci, 2007; Tuckett, 2004; Kumar, 2011; Barnett et al., 2015).	1) Selecting Trinidad and Oahu as case studies was purposeful in that they are both small, tropical islands; one has widespread solar deployment and the other does not, it represented a contrasting case study comparison. 2) Selecting the various organizations and by extension the officials facilitating the interview was so done so as to capture perspectives from more than one actor in the residential electricity system.
Critical case	Critical case sampling involves selecting cases/participants that are particularly significant (Hancock et al., 2009).	1) Selecting Trinidad and Oahu represented some element of critical case sampling because both are small, tropical islands that are unique energy systems in their own right - Oahu has widespread deployment of residential solar energy, whilst Trinidad is one of the only, if not the only, small island that has globally significant reserves of oil and natural gas.
Strategic	Strategic sampling involves a pre-planned sampling frame (Hancock et al., 2009).	1) Using Trinidad and Oahu's institutional concept diagrams to identify institutions that should be interviewed.
Judgemental	Wilmot (2005) stresses the importance of having prior knowledge about a sample group. This knowledge can be used to make decisions on which cases/participants should be in the sample. Judgemental sampling is guided by the research's purpose but also by what happens as the data is collected (Tuckett, 2004) to select the most productive sample that answers the research question(s) (Blandford, 2013).	1) Using the institutional concept diagrams and energy policy literature review on Oahu and Trinidad enabled informed decisions about which institutions would provide the best narratives on each residential electricity system.

Table 6 showing the broad types of sampling that were used to collect the policy data through the institutional interviews conducted in Oahu and Trinidad

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14 organizations were contacted in Oahu and 13 in Trinidad. Of these, 11 facilitated interviews in Oahu and 11 in Trinidad. Using guidance from Dapeng and Weiwei (2009; 2422), Tables 7 and 8 (next page) show the types of institutions that facilitated interviews, the number of informants present in each interview, and the informant-identifiers used to preserve anonymity.

TYPE OF INSTITUTION	NUMBER OF INFORMANTS IN INTERVIEW	INFORMANT IDENTITY CODE
Government / State Office	1	OH01
Innovation Financing	1	OH02
Solar Energy Retailer	1	OH03
Solar Energy Retailer	1	OH04
Non-Governmental Organization	1	OH05
Research / Academic	1	OH06
Research / Academic	1	OH07
Government /State Office	1	OH08
Energy Industry	1	OH09
Solar Energy Retailer	1	OH10
Independent Agency	1	OH11

Table 7 showing the anonymous identifiers for the institutional informants in Oahu

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Oahu's interviews were begun before Trinidad's and were separated into two visits - each just short of 2 weeks (in June 2015 and March 2016). Interviews were conducted with the Hawaii State Energy Office; Energy Excelerator; Distributed Energy Partners; Island Pacific Energy; Blue Planet Foundation; Hawaii Natural Energy Institute; and University of Hawaii on the 1st visit, and the Hawaii State Legislature, Hawaiian Electric Company, RevoluSun, and Public

Utilities Commission on the 2nd.

Trinidad's interviews were conducted during late December 2015 to May 2016. The Environmental Policy and Planning Division; Multilateral Environmental Agreements Unit; Green Fund Executing Unit; National Institute for Higher Education, Research, Science and Technology; Trinidad and Tobago Electricity Commission; Smart Energy Limited; University of Trinidad and Tobago; University of the West Indies; Regulated Industries Commission; Solaris Energy; and Sustain T&T facilitated interviews. It is worth noting that a key institution unable to facilitate an interview was the Ministry of Energy and Energy Industries.

TYPE OF INSTITUTION	NUMBER OF INFORMANTS IN INTERVIEW	INFORMANT IDENTITY CODE
Government / State Office	1	TD01
Government / State Office	1	TD02
Government / Financing Office	1	TD03
Government / State Office	4	TD04 / TD05 / TD06 / TD07
Energy Industry	2	TD08 / TD09
Solar Energy Retailer	1	TD10
Research / Academic	1	TD011
Research / Academic	1	TD12
Independent Agency	2	TD13 / TD14
Solar Energy Retailer	1	TD15
Non-Governmental Organization	1	TD16

Table 8 showing the anonymous identifiers for the institutional informants in Trinidad

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3.3.3.2. Recruiting and accessing the key-informants

Gaining access to research participants is unique to each study (Wanat, 2008). The various

organizations were contacted (via email and phone as appropriate) to set up a rapport and determine who in the organization would be the most suited to accommodate an interview (if at all).

In many instances this initial contact was made through a gatekeeper i.e. a person within the organization who regulates access to potential interview participants and sources of information (McAreavey and Das, 2013); work such as Myers and Newman (2007), Heath et al. (2007), Wanat (2008), and McAreavey and Das (2013) touch on the interactions between researchers and gatekeepers.

These gatekeepers were able to either contact the most appropriate personnel in the organization or forward these personnel's contact information. Once the internal contacts were identified further discussions took place to directly inform them about the study, gauge their willingness to participate, and explore their schedules and availability.

So far as logistically possible the interview question ideas and draft institutional concept diagrams were sent to these contacts before the interview. Though this exposed the interviews to potentially pre-prepared answers, the interviews' semi-structured nature and open-ended questions mitigated this. In some instances, sending the question ideas was a means of ensuring that the topics did not target 'off-limits' issues as part of acquiring their informed consent (section 3.5. provides more information on informed consent).

3.3.4. The Institutional Interviews' Structure and Delivery

Sources like the University of Illinois Extension Service-Office of Program Planning and

Assessment (2000), the N.Y.S. Office of Alcoholism and Substance Abuse Services (2008), and the Oklahoma Department of Mental Health and Substance Abuse Services (2011) offer useful practical interview tips. The interviews had four integrated segments.

The first was to introduce not only myself and work but to explain why Hawaii and Trinidad were being featured, the expected outcomes of the field-visits and structure of the interview. This pre-interview dialogue was also used to get their informed consent to carry on with the interview and to record the interview via notes and/or audio recording.

The second segment required the informants to comment on their respective draft institutional concept diagram and suggest/identify changes, add-ons and/or misrepresented information (as advised by Daley (2004)). In addition, they were also asked to identify which of the institutions and/or relationships they thought were the most influential. This is important because each institution will see the network from a different perspective (Bots et al., 1999). Comparing the responses across a broad range of sources also increases the reliability of the data (Brikci, 2007). So, having the diversity of commentary enhanced the diagrams' accuracy.

The third segment involved the topic guides i.e. the list of leading question prompts (Boyce and Neale, 2006; Brikci, 2007; Hancock et al., 2009), and interview questions to elicit responses from participants. Analyzing objective knowledge helps develop the interview questions for semi-structured interviews (McIntosh and Morse, 2015) so the Multi-Level Perspective (see Chapter 2) and the respective islands' energy policy literature informed the questions that were asked.

There were a few questions that were posed across informants but each of the organizations which facilitated interviews had a unique series of questions that were prepared because each

plays a different role in each island. Appendix C shows an example of the topic guides used for the Hawaii State Legislature in Oahu and Sustain T&T in Trinidad. Table 9 provides more details on the interview themes discussed together with question examples.

THEME	REASON FOR INCLUSION	EXAMPLES
Institutional network	The socio-technical regime is made up of multiple actors interacting which each other (Markard and Truffer, 2008; Lockwood et al., 2013). The regime's actors interact at the socio-technical level rather than separate and distinct agglomerations of regimes (Geels, 2004). But within the regime are smaller financial, supplier, user, producer, research, societal and public actor-clusters (Geels, 2002).	Which actors do you think are the most influential in the network? (Oahu and Trinidad)
General	Adds contextual information to the themes that were developed from the Multi-Level Perspective of socio-technical energy transitions.	What are some of the challenges/opportunities that the inter-island grid connections or lack thereof present for the solar industry? (Oahu) How would you describe the government's response to sustainable energy issues? (Trinidad)
Niche to regime migration of innovations	When an innovation evolves out of its niche and enters the regime it has been mainstreamed. The regime is the Multi-Level Perspective's mainstream structure (Smith et al., 2010; Shove and Walker, 2010; Coenen et al., 2010).	What are the State's main residential solar energy strategies that have been implemented? (Oahu) What are some of the State's residential solar strategies that should be implemented? (Trinidad)
Resistance during transitions	Socio-technical regimes exhibit an adaptive capacity to change-pressures and this capacity includes resistance to change i.e. resistance to the landscape's pressures and the entry of innovations into the regime (Smith et al. 2005; Markard and Truffer, 2008; Smith et al., 2010).	What are some of the hurdles associated with making legislations? (Oahu) What are some of the barriers to solar energy in Trinidad? (Trinidad)
Transition vision	Energy transitions are long-term phenomena that unfold over decades to centuries (Lawhon and Murphy, 2011; Manning, 2015; Gates, 2015).	How does the '100% renewables' ambition by 2045 affect the initiatives that sit on the energy drawing board? (Oahu) Is the 10% renewables target a legislated standard or a quantitative guide for the energy sector? (Trinidad)

Table 9 showing the main themes investigated through the institutional interviews conducted in Oahu and Trinidad

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The ultimate goal of the interviews was not a cross-comparison between each island's interview responses but rather building a collective systems-level narrative for each island that could then be compared. The questions followed an inverted funnel interview protocol where narrower questions were asked first followed by broader ones (Siniscalco and Auriat, 2005); interview protocols are the rules that guide interviews to maintain the reliability and consistency of the sample (Boyce and Neale, 2006). This led to wider discussions and was advantageous because it put the informant in the context of the topic and allowed a more interactive discourse (Harrell et al., 2009).

The institutional concept diagrams were also used as visuals which proved effective in stimulating a fluent rapport during the interviews. Combining this with probing questions further enhanced the fluidity of the dialogue by motivating the interviewee to give more information as necessary (Willis, 1999; Harrell and Bradley, 2009; Hancock et al., 2009; Hague, 2010; van Teijlingen, 2014).

The fourth and last segment was used to summarize the main points, clarify uncertainties that were flagged during the interview, and to facilitate informal conversation. This included expressing thanks for the interview, a chance for informants to ask any questions they had, and to reassure them of their anonymity - a practice that Hague (2010) and Oxfam's Global Research Team and Policy and Practice Communications Team (2012) value because interviews should be treated courteously, professionally, and as mutual information exchanges and learning experiences.

Wills (1999) and the NECAPT (2004) outline that an interview on average should take about an hour and methodological research from Irvine (2011) state that their interviews took just

over 1.5 hours on average. The institutional interviews ranged between 45 minutes to 1.5 hours and were comparable to those in a similar study by Mattes et al. (2015) that lasted between 40 minutes and just over 2 hours.

These inter-island interviews produced two institutionally vetted concept diagrams and associated institutional narratives that formed the basis for comparing Oahu and Trinidad.

3.4. Data Analysis

3.4.1. An Overview of Thematic Content Analyses

Collecting data should be done considering the overall aim of its theoretical analysis (Woods, 2011). Brikci (2007) and Vaismoradi et al. (2016) outline that qualitative data can be analysed using thematic or descriptive techniques. They further note that the thematic approach is the most common since it identifies the main themes that summarize the collected perspectives. Blandford (2013) adds that thematic analyses assume that the dataset already exists, and it focuses on how it can be analysed.

Qualitative data should undergo content analyses (Mathers et al., 1998). Content analyses use a series of codes to reduce and manage the amount of text data so that it can be used to identify patterns and give insight (Hall, 2018). Thematic content analyses focus on the frequency of occurrence of themes and content based on specific analytical rules and guidelines for generating these themes (Hancock et al., 2009; Vaismoradi et al., 2016). Literature reviews tend to also be a large part of the pre-data analysis of thematic analyses (College of Humanities and Social Sciences, 2011) - hence Chapter 2's density. The

methodological literature (e.g. Thomas (2003), Hsieh and Shannon (2005), Schadewitz and Jachna (2007), van Wyk (2012) and Hall (2018)) shows that there are largely deductive and inductive qualitative thematic content analyses.

In deductive analyses the researcher applies existing theories to analyze the data. It is particularly useful in instances where the researcher is aware of interviewees' possible responses and helps in confirming answers. These analyses are used to answer a particular question by looking at what all the informants said and using the question itself as a guide to the predetermined theme(s) being analyzed. This analytical approach has been described as one that moves from the general to the specific in terms of its coding.

Inductive analyses explore the data to reveal emergent themes, relationships or theories. It uses the data to drive the analytical structure and is particularly useful when there is relatively little known about the phenomenon being studied. Unlike its deductive counterpart the analysis moves from the specific to the general.

The energy cultures data collected through the 33 residential interviews in Barbados and Trinidad was analyzed inductively whilst the institutional perspectives from the 22 interviews with energy officials in Oahu and Trinidad were analyzed deductively.

3.4.2. Transcribing and Coding the Interviews

3.4.2.1. Transcribing the interviews

Sociology Central (2002) outlines that the results of interviews are often hard to generalize amidst deciding which items of information are relevant to the study's analysis. Burnard

(1994) advises to clean the data for unnecessary information before analyzing and this begins with the extent of transcription. Transcribing is the process of producing a text document from an interview (Hancock et al., 2009; Davidson, 2009).

Remshardt and Flowers (2007) state that since interviews involve discussions a complete transcript is useful but the additional value it adds compared to the time taken to produce it may not be worth undertaking - provided that the research does not depend on complete transcriptions (Zhang and Wildemuth, 2009).

Elo and Kyngäs (2008) point out that transcription involves latent and manifest interview content. The latent content refers to non-verbal interview content such as body language or tone of voice whilst manifest content refers to the explicit commentary from the interview. The thesis focused on transcribing the manifest content as is consistent with the focus of thematic content analyses (Vaismoradi et al., 2016).

The residential interviews in Barbados and Trinidad were conducted over-the-phone as well as face-to-face and note-taking was used to record the data. The data recorded was largely not verbatim though there were many quotes, statements and comments that were recorded as such. All the transcripts for the residential interviews were originally in the form of these notes (in a notebook) and each transcript was produced immediately following the interview given that this was a key process in the open coding that gave insight into data saturation (see subsection 3.2.5.2.).

The institutional interviews were recorded via notes and audio-recording where agreed. The transcripts for the institutional interviews were verbatim because of the audio recordings (except for those that were solely recorded by taking notes). Each interview was transcribed

immediately after it was conducted to minimize the loss of data. Given the formal nature of these interviews, the final transcripts were sent back to the informants via email so that they could have vetted them i.e. member-checking (Thomas, 2003; Blandford, 2013; Penn, 2014).

3.4.2.2. The theoretical context for coding the thesis' data

Decoding deciphers the core meaning of excerpts whilst encoding assigns codes to text (Saldana, 2009). The latter applied to the thesis' transcripts and will be referred to simply as coding. Qualitative coding may seem to have few set guidelines (Stalp and Grant, 2001) but work like Zhang and Wildemuth (2009), Hesse-Biber (2010), Penn (2014), Morris et al., (2016) and Vaismoradi et al. (2016) outline it. Coding is a process (Adair and Pastori, 2011) and a systematic means of recording data (Kumar, 1989). It should fit the data as opposed to data fitting the coding (Tobacco Control Evaluation Center, 2012).

The primary analytical unit for coding is a label assigned to text (Thomas, 2003; Evaluation Control Team, 2009). Many studies use the term 'code' to refer to different analytical units. But there are many units of coding. As the name 'thematic content analysis' implies, themes are involved. Themes are products of codifying and analysis (not something to be coded) (Saldana, 2009; Vaismoradi et al., 2016) and meanings are embedded within them (Vaismoradi et al., 2016).

It is important to make the distinction between themes and other coding labels (Vaismoradi et al., 2016). Saldana (2009) gives guidance on the distinctions where the analytical hierarchy is as follows: sub-codes, codes, sub-categories, categories, themes/concepts, and theories. Sub-codes are the most specific coding units and theories are the broadest. These coding units can

be arranged in tree diagrams during the analysis and is a useful way of organizing the coded data hierarchically (Daley, 2004; Hsieh and Shannon, 2005; Penn, 2014).

Irvine (2011), Penn (2014), and Vaismoradi et al. (2016) outline coding as a data reduction process. Tree diagrams are also useful in data reduction because they take multi-page transcripts and convert them into one page and this especially helps in cross-analyses (Daley, 2004; Learning Strategies Center, 2009) - such as the inter-island comparisons in the thesis.

Though preparing the data for inductive and deductive analyses are similar (Elo and Kyngäs, 2008), Thomas (2003), Schadewitz and Jachna (2007) and van Wyk (2012) state that coding usually employs an inductive-deductive mix. Combining both approaches is useful for looking at patterns spanning more than one context (Schadewitz and Jachna, 2007) and has been a recommended approach for researchers (Tobacco Control Evaluation Center, 2012). So, this fits well with the thesis' inter-island comparisons.

The College of Humanities and Social Sciences (2011), and Vaismordi et al. (2016) outline the phases of thematic analyses as familiarization with the data; generating initial codes; identifying themes; aggregating these codes into the themes; reviewing and defining these themes; and finally producing the narrative. Reviewing the information at each stage of the process also grounds it in the original data (Fereday and Muir-Cochrane, 2006).

Remshardt and Flowers (2007), Elo and Kyngäs (2008), Hahn (2008), Holton (2010), and the Tobacco Control Evaluation Center (2012) detail the coding process by stating that it begins with initial/open coding, then focused coding and category development followed by axial/thematic coding, and finally searching for the theoretical concepts that emerge from saturated categories. After initial coding, duplicate codes can be omitted to create much

shorter code-lists which can then be analyzed for patterns (Remshardt and Flowers, 2007). This is also part of cleaning the data as noted by Thomas (2003) and Meurer et al. (2007).

Coded data can be arranged according to chronology, major events or any other themes that are relevant to the area of study (College of Humanities and Social Sciences, 2011). Patterns in the data can also be identified by looking for similarities, differences, frequencies, correspondences, causations, or even sequences (Saldana, 2009).

Looking for such patterns enables the construction of the larger conceptual units through code-sorting (Woods, 2011). During this analytical scaling, memoing is a useful practice that summarizes emergent theoretical explanations and hypotheses about relationships (Holton, 2010; Woods, 2011). Another good practice is referencing a coding matrix i.e. a coding framework that contains a list of codes and sub-codes (Adair and Pastori, 2011).

During coding the inter-code connections should be identified in reference to a coding matrix (Adams et al., 2007; Hesse-Biber, 2010) because this helps justify why specific categories were chosen and can act as a template that provides a credibility trail for the study (Fereday and Muir-Cochran, 2006) - an important consideration for researchers (College of Humanities and Social Sciences, 2011). Appendix D provides the thesis' coding matrices.

However coding often occurs simultaneously with data collection so there is room for modifying the process as data collection continues since new themes will emerge directly from the texts as they are analyzed (Hsieh and Shannon, 2005; Schadewitz and Jachna, 2007; Zhang and Wildemuth, 2009; Woods, 2011; Tobacco Control Evaluation center, 2012); in qualitative data analyses, the transcripts are read and re-read to search for emergent themes (Daley, 2004).

Saldana (2009) and van Teijlingen (2014) acknowledge that analyzing interviews are iterative processes and researchers should go through one interviewees' data at a time since it is expected that after the first transcript is coded, subsequent transcripts will influence the coding of the first. Coding is therefore not a discrete process and like the larger thematic analysis that it is a part of, it is cyclic (Fereday and Muir-Cochrane, 2006; Holton, 2010; Vaismoradi et al., 2016).

In addition, the data was triangulated where appropriate to validate and further support any emergent observations that arose from the respective content analyses. Work such as Oliver-Hoyo and Allen (2006), O'Cathain et al. (2010), Mertens and Hesse-Biber (2012), Blandford (2013) and Penn (2014) touch on the nature of triangulation but in essence triangulation compares information to determine if there are elements which can be supported by a consensus (Oliver-Hoyo and Allen, 2006).

The primary data collected through the interviews were largely corroborated by referring to literature-based sources of information such as energy policy documents and datasets where appropriate. The results of the residential interviews, institutional interviews as well as policy-based literature were compared in some cases.

3.5. Research Ethics

The interviews were granted approval by the Central University Research Ethics Committee prior to the data collection. But practically there are ethical considerations worth highlighting i.e. informed consent; confidentiality and anonymity; data ownership and reporting; and research integrity and quality.

3.5.1. Informed Consent

Gaining informed consent is central to ethical social science research (Heath et al., 2007) and the terms of the consent must be clearly agreed on however informal the arrangements (Global Research Team and Policy and Practice Communications Team, 2012; Blandford, 2013).

With the residential interviews, though the community contact would have briefed the respondents about the interview, before proceeding with asking questions the nature of the study and structure of the interview were outlined in more depth. This was followed by asking for their permission to conduct the interview. For the institutional interviews, the organizations and where possible the informants themselves were contacted prior to making the respective field-visits. There was an initial email (and where practicable face-to-face) rapport surrounding facilitating the interview.

Both sets of interviews obtained informal informed consent that was largely word-of-mouth. In the case of the residential interviews, this was due cultural and practical reasons e.g. over-the-phone consent. With respect to the institutional interviews, email threads served as an electronic form of consent, but it was still obtained during each of the interviews.

Contacting the interviewees in this way to get their informed consent ensured that they were made aware of the nature of the study and understood what was to be expected so that a conscious decision to participate could have been made (NECAPT, 2004; Family Health International, 2006; Adams et al., 2007; Brikci, 2007; Blandford, 2013).

Another issue was seeking permission to record (audio and note-taking) the interviews as appropriate since this should only be done with their permission (van Teijlingen, 2014) - and

this was agreed upon with each interviewee and where consent was not given for audio recordings, this was adhered to.

3.5.2. Confidentiality and Anonymity

Where confidentiality and anonymity have been promised, researchers should be cautious so that any quotes or identifiers included in the text are not easily traceable (Boyce and Neale, 2006) to help preserve anonymity (NECAPT, 2004; Adams et al., 2007; Sugarhood et al., 2014). Both the residential and institutional interviewees were assured that their statements would remain anonymous - and in keeping with this mutual understanding the responses were analyzed in isolation from any identifiers, and their names were not mentioned in the thesis' discussions and reporting. The interviewees were assigned identifiers as shown in Tables 4, 5, 7, and 8 on pages 101, 102, 113 and 114 respectively.

An added consideration for the institutional interviews was the fact that the research was conducted in a highly specific sector on small islands. This meant that the chances of one informant knowing another based on their institutional affiliation were rather high, so their institutions were not included in their identifiers.

3.5.3. Data ownership and Reporting

There is no contention regarding the ownership of the data collected. However relative to the reporting, only one institutional informant stated that as part of the agreement to accommodate an interview, their company would like to review the relevant work before its

publishing and this was adhered to (a copy of the relevant chapters were forwarded prior to submitting the thesis for examination).

3.5.4. Research Integrity and Quality

Given that there is neither a set methodology for qualitative research nor standards for evaluating validity and authenticity, a researcher tends to 'makes up' the method for a particular study rather than applying a preset series of investigative techniques and/or adhering to predetermined procedures (Adams et al., 2012). Adams et al. (2007), Hancock et al. (2009) and Blandford (2013) further outline that displaying reflexivity through an honest, clear and detailed account of how the data was collected, the issues that arose, and how they were addressed is a fundamental part of gauging the confidence that can be placed in the study's conclusions.

These thoughts also apply to interviews where internal self-reflection questions such as those concerning interviewee credibility, or even concerning the context of an interviewee's response are asked for example (Adams et al., 2007). Barriball and While (1994) also present several guidelines that help researchers identify a good respondent which ultimately gives an idea as to the reliability of the information recorded: good respondents give solid answers that are usually well-developed; they tend to stay on a topic of interest to fully engage with it; are willing to reflect on what was said; and display mannerisms that seem open and truthful.

This guidance was strongly considered, and this methodology clearly outlined how the data was collected, and the analysis and reporting considered the appropriate self-reflective elements. This is also important for gauging the thesis' overall validity i.e. the degree to

which a study reflects the aims it sought to investigate (Sinsicalco and Auriat, 2005; Alshenqueeti, 2014). External validity applies to data that is generalizable and internal validity deals with whether the data was collected without confounding variables (Blandford, 2013). So, recalling that qualitative research is by in large not generalizable, the thesis' interviews relied on their internal validity - and this was reported in this methodology.

3.6. Summary of the Limitations

As was the case for the thesis' interviews, using the same interviewer to conduct the interviews reduces the impact of having different personal interview styles playing out in the research (Irvine, 2011; Irvine et al., 2012); using the same researcher is more consistent because different researchers would see the data and analyze it differently (Thomas, 2003). But there are several limitations that still warrant acknowledgement.

3.6.1. Practical Limitations

Firstly, toggling between recording the institutional interviews via notes and audio (when given consent) meant that the transcripts were not as equally in-depth since audio-recording captures more information. In some instances, the audio-recorder cut off so this meant that the notes taken would have had to fill the gaps in the transcripts where appropriate.

Secondly, given that the institutional informants are speaking under the umbrella of the organization that they are affiliated to, this meant that some of the interviews had the risk of being based on pre-prepared responses - especially in cases where question samples needed to

be sent as a means of gaining informed consent. However, the semi-structured nature of the interviews helped add some dynamism and organic content to the dialogue.

Thirdly, the institutional interviews conducted in Oahu were separated into two visits. This was primarily due to the funding supporting the visits. This is a limitation because some of the issues discussed during the 2nd visit to the island were not able to be discussed during the first e.g. the policy transition away from net energy metering.

The fourth particularly applied to the residential interviews. Toggling between over-the-phone and face-to-face interviews meant that the data collection via 'the interview' was not consistent. However, the benefits of practicality outweighed those of methodological consistency. Even further the structured format of the interview mitigated any potential impact of inconsistency whilst the focus on explicitly recording and analyzing the manifest content of the interview i.e. responses and not behaviour or mannerisms also moderated the over-the-phone versus face-to-face differences.

Fifthly, the residential interviewees' responses were vulnerable to a lack of understanding of what the question(s) meant. Whilst the interviews were structured, the way a given question needed to be asked had to be varied in a given interview so that the respondent understood what it meant. Whilst the use of different words can prompt different responses, the cultural context of the residential respondents was well-understood so this wordplay was not as problematic as it would have been in unfamiliar cultural contexts.

3.6.2. Data Limitations

Firstly, the institutional concept diagrams are subjective though the scope of institution and relationship inclusions were guided by Oahu and Trinidad's energy policy literature.

Secondly, not all the institutions in the diagrams facilitated interviews. The sampling included making informed judgements on which institutions should facilitate interviews, so this gave preference to some institutions over others. Additionally, some organizations such as the Ministry of Energy and Energy Industries in Trinidad were contacted but were unable to facilitate an interview.

Thirdly, the residential interviewees' responses were prone to inaccuracies since respondents were required to recall events in the distant past. Though probing during the interviews somewhat mitigated this and was able to stir memories, several of the interviews were affected by respondents' simply being unable to recall details e.g. several of the Trinidadians had trouble recalling if their electric water heaters had a warranty. This was however still important because it showed that this information may not be culturally salient.

Fourth is that several of the residential respondents were not within the anticipated sampling frame for parameters such as age, homeownership and housing type - this was a result of practicality in the field. Also noteworthy is the fact that 1 Trinidadian respondent owned solar water heating, and this was an unexpected observation during the interview.

Fifth is the subjectivity of the interviews' coding since determining how to classify text is a potential source of error (Hague, 2010). Whilst having one researcher made the coding and analysis more consistent, it lacked having multiple perspectives which may have reinforced or disagreed with code-assignments. However, the coding matrices used to guide the inductive

and deductive coding offered the rationale behind why the higher tiers of coding labels were used e.g. themes and categories (see Appendix D).

4.0. Characterizing Trinidad's Economic Transition History & Barriers to Solar Energy Implementation

Synopsis

This chapter sets the context for Trinidad as the central case study by highlighting its major historical economic transitions. The chapter does not explicitly help answer the thesis' research questions but it was important to include because Trinidad is a small island that many may not know much about (if at all) let alone its rich oil and gas legacy - the latter of which is particularly important to acknowledge in any renewable energy study concerning the island given that renewables will be facing a historical energy subsidy that artificially lowers the costs of the incumbent fossil fuels used on the island.

The chapter gives the background on the wider economic system that solar energy technologies will be entering during a potential residential energy transition (ET). It therefore sets the stage for the 'regime' which is a key theoretical concept to both mainstreaming and ETs (see Chapter 2). The chapter also gives insight into the path dependency, lock-ins and resistance that would be a part of Trinidad's regime relative to solar energy deployment (with particular reference to the subsidy's effect on solar energy technologies' competitiveness).

This chapter's discussions are based on the review of Trinidad's historical energy policy literature conducted and the deductive thematic analysis of the 11 key-informant interviews conducted with energy officials on the island. The chapter is structured as follows: section 4.1. describes the major economic transitions the economy experienced using the post-1700 sugarcane economy, oil economy from the late 1800s, and natural gas economy from the early

1900s; section 4.2. outlines Trinidad's uniqueness as a small-island energy case study and the impact of the energy subsidy on energy prices; and section 4.3. presents the chapter's conclusions and characterizes mainstreaming based on the chapter's findings.

4.1. Characterizing Trinidad's Economic Transition History

4.1.1. Energy in the post-1700 Sugarcane Economy

The chapter's discussions will start from the post-1700 sugarcane economy since it is arguably the country's economic foundation. Sugarcane originated in New Guinea (Crosby, 2006) and the Dutch planted it in the Caribbean from 1630 (Sugar Heritage Village[1], 2012). Subsequent years brought changes in Spanish, French and British colonial rules (Artana et al., 2007). One reason for this diversity of sovereignty is that island geographies were much easier to colonize and control when compared to continental locations (Bass and Dalal-Clayton, 1995).

Besson (2011) outlines that Tobago was a sugar-producing colony long before Trinidad's production started and that by the time the industry had been well established on the islands, Tobago had almost exhausted its soil resources. This catalyzed an economic downturn which led the British to geopolitically join Tobago to Trinidad in 1898 (Artana et al., 2007).

The sugarcane industry had several energy resources associated with it. Bagasse is the fibrous remnants left from squeezing the sucrose out of sugarcane and is an effective boiler fuel (Shupe, 1982). Ethanol may have been another fuel since molasses, another sugar industry

by-product, can be used as feedstock for ethanol production (Holland, 2015) - though it is rather uneconomical to do so and more readily used as livestock feed (Shupe, 1982).

Elias and Victor (2005), Crosby (2006) and Chivers (2015) outline that the metabolic power of draft animals was an energy resource in agrarian economies i.e. the power of muscle as the first prime mover. For example, Crosby (2006) states that animals like horses massively improved the speed and power available for human activities. But highlighting metabolic energy in the Caribbean sugar economy also includes its humans because sugarcane cultivation was labour-intensive.

The Caribbean is one of the best direct reflections of the various phases of colonialism in the world (Japtok, 2000). Trinidad's sugarcane economy had many human resource inputs through colonial policies such as the African slave trade from the late 1700s until 1838; East Indian indentureship from 1845 until 1915; and European and Chinese immigrants throughout its history (Paria Publishing Company Limited, 2000; Artana et. al., 2007; Sugar Heritage Village[1], 2012; Sugar Heritage Village[2], 2012; NALIS, 2015).

Another energy resource was charcoal. It became prominent in the 1800s (Bissessarsingh, 2014) and is created by slowly burning wood in almost airless conditions (Crosby, 2006). Eckelmann and Joseph (2003) describe it as a widespread cooking fuel and Wartluft (1984) documents its application. Imbert (2011) outlines that the best quality charcoal comes from the Mora and other hardwood species that are particularly common in the rural, Eastern regions of Trinidad. Charcoal was a popular cooking fuel until the 1960s when liquefied petroleum gas became the most widespread cooking fuel in the Caribbean (Wartluft, 1984).

The sugar economy's growth was sustained well into the 1900s and two major developments

marked a new era of sugar production: the consolidation of a sugar workers' trade union and the establishment of Caroni 1975 Limited as the nation's sugar-producing conglomerate (Sugar Heritage Village[2], 2012). However, oil slowly shifted Trinidad's economy and culminated with the end of the sugar industry in 2003 (Thomas, 2009; Sugar Heritage Village[2], 2012); the sugar economy of the 19th century began transitioning into the oil economy of the 20th (Artana et al., 2007).

4.1.2. Energy in the Oil Economy of the late 1800s and early 1900s

Trinidad has one of the oldest oil industries in the world (Sergeant et al., 2003; Marzolf et al., 2015). The nation's petroleum developments had their beginnings in 1595 when Sir Walter Raleigh caulked his ships with asphalt (Mining Maven, 2013). The world's largest asphalt deposit is found in the Pitch Lake in the Southern part of Trinidad (Mining Maven, 2013) (see Figure 25 on the next page) so the use of pitch as a resource positioned it as a rudimentary precursor to oil.

Raleigh took samples back to Britain and this can be thought of as a metaphor for the petroleum export industry that was to come in the future; there was British interest in the lake and it would eventually become a foundation of the island's future economy (Mining Maven, 2013).

The data from a geological survey of Trinidad in 1855 led to interest in extracting the oil from pitch, and there were attempts to distil its oil in 1857 (Mining Maven, 2013). The Petroleum Association of Trinidad (1952), Ministry of Energy and Energy-Based Industries (1979), Besson (2011), Shaw (2011), and Bissessarsingh (2014) suggest that this pitch together with

paraffin and some lignite were amongst the first hydrocarbon-based energy resources in Trinidad.

The image showing the base map of Trinidad and Tobago originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Ezilon.com[1]. 2009. Trinidad and Tobago Mao- Physical Map of Trinidad and Tobago. Website: http://www.ezilon.com/maps/north-america/trinidad-and-tobago-physical-maps.html (accessed 17th March, 2017)

Figure 25 showing the locations of several of Trinidad's early petroleum developments: the Pitch Lake, Point Fortin, Barrackpore and Tabaquite

Adapted from Ezilon.com[1] (2009) using Microsoft Word

The first oil well was drilled in 1857 (though unproductive) but oil was discovered in 1866 (Sergeant et al., 2003; McGuire et al., 2007; Besson, 2011; Mining Maven, 2013; Espinasa and Humpert, 2016). The Ministry of Energy and Energy-Based Industries (1979) asserts that this was the 1st phase of the nation's petroleum history. The Ministry of Energy and Energy-Based Industries (1979) continues by stating that 1901 to 1907 was the 2nd phase where South Trinidad became the exploratory target of the first oil companies.

The 3rd phase ended in 1914 and brought commercial success where the Southern explorations resulted in oil exportation to Great Britain. This period also solidified the Barrackpore, Tabaquite and Point Fortin areas of Southern Trinidad as the earliest production sites (Ministry of Energy and Natural Resources, 1984) (see Figure 25 on the previous page).

During this 3rd phase commercial oil production began in 1907/1908, was first refined in 1912, and shipped in 1913 (McGuire et al., 2007; Thomas, 2009; Braveboy-Wagner, 2010; Jobity, 2013; Espinasa and Humpert, 2016). After this 3rd phase, the nation's economic vulnerability to external shocks was shown through the World Wars (WW).

Between 1914 and 1919, WW1's global impact marked a 4th phase of the nation's petroleum history (Ministry of Energy and Energy-Based Industries, 1979). During WW1 Trinidad's petroleum economy was a central part of the British Empire's military effort since it was a valuable refuelling station for the Royal Navy - and Thomas (2009) outlines that local oil production was ramped up when the Navy converted from coal to oil.

In 1916 pipelines were constructed to connect the 3 aforementioned Southern production sites (analogous to the industry's consolidation) (Ministry of Energy and Energy-Based Industries, 1979). But this was not enough to mitigate the War's economic repercussions because it limited the industry's exploratory activity and shifted the focus to oil-refining and maximizing existing wells' production (Ministry of Energy and Energy-Based Industries, 1979). The Ministry of Energy and Energy-Based Industries' account of the energy history continues with the 1919 to 1924 post-war growth and the industry's stability thereafter until 1930 due to drilling innovations and industrial learning.

In the 1930s and 1940s the nation experienced economic repercussions when the global price

of oil dropped due to significant finds in Texas and Oklahoma (Ministry of Energy and Natural Resources, 1984). Gately (1986), Mining Maven (2013), Baumeister and Kilian (2016), and Baffes et al. (2015) outline that the price-plummet continued until 1973 and resulted in an industrial contraction (globally and locally). But more optimistically, this period marked the exploration of Northern Trinidad.

After 1940 the industry hit another major stumbling block with WW2. As with WW1, oil-refining was prioritized due to its military importance and oil exploration was once again limited. However, this time so too was oil production (Ministry of Energy and Energy-Based Industries, 1979). Though the Ministry of Energy and Natural Resources (1984) asserts that a marginal amount of the nation's reserves were exploited at this stage, Trinidad and Tobago was experiencing a decline in hydrocarbon production during the late 1900s (Ministry of Energy and Natural Resources, 1984; Ministry of Energy, 1987; Mining Maven, 2013).

Local oil-refining capacity has historically outstripped oil production (McGuire et al., 2007). So, the war's impact on oil production together with this refining-production gap opened the gates for oil importation and by 1950 the nation imported over 10 million barrels of oil (Ministry of Energy and Energy-Based Industries, 1979). This importation continued well into the 1960s (Krausmann et al., 2014).

4.1.3. Energy in the Natural Gas Economy of the 1900s and 2000s

Natural gas was traditionally viewed as the poorer relative of oil (Brinkworth, 1985) and both are usually found in association with each other (McMullan et al., 1977). Trinidad's gas was inadvertently found during searches to boost oil production in the exploration of the Herrera

Sands (Homer, 2011); Figure 26 shows the Sands' location.

The image showing the base map outline of Trinidad and Tobago and details of the location of the Herrera Sands originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Worldatlas.com. 2016. Trinidad and Tobago- Outline Map. Website: http://www.worldatlas.com/webimage/countrys/namerica/caribb/outline/ttout.htm (accessed 12th April, 2017)

Mining Maven. 2013. Trinidad Oil Report. Website: http://www.miningmaven.com/pdf/Trinidad-OilReport.pdf (accessed 26th October, 2016)

Figure 26 showing the general location of the Herrera Sands in Southern Trinidad

Generated by the Author but adapted from Mining Maven (2013; 7) (for map information), and Worldatlas.com (2016) (for map outline) using Microsoft Word

Commercial gas production began from 1946 (McGuire et al., 2007). The declining production from the terrestrial fields that carried the industry in the early 1900's led the existing oil companies to invest in offshore strategies in Western Trinidad after 1950, and significant commercial discoveries were made in 1955 (Ministry of Energy and Energy-Based Industries, 1979; McGuire et al., 2007; Russell and Bududass, 2012).

Gas which was originally flared was also diverted and used for downstream activity (Homer,

2011; Espinasa and Humpert, 2016). This gave shape to the gas economy and a classic example was the introduction of gas for power generation in 1953 (Espinasa and Humpert, 2016) which marked the beginning of a gas-powered electricity sector.

The downstream energy sector developed on this 'new' energy resource and industrialization led to petrochemical industries that used natural gas as a feedstock (Thomas, 2009); the advent of the petrochemical sector started the nation's 2nd phase of industrialization (after petroleum refining) (Ministry of Energy and Natural Resources, 1984).

The offshore gas search expanded to the East coast of Trinidad in the 1960s but most notably the nation gained independence from the British in 1962 and the Ministry of Petroleum and Mines was formed (Espinasa and Humpert, 2016). A modified energy system was established in the 1970 to 1979 post-independence period through an oil boom in the 1970s (Artana et al., 2007; Moya et al. 2010) due to an increase in hydrocarbon prices (Dorf, 1984) as well as the discovery of significant gas reserves off Trinidad's Northern coast in 1971 (Espinasa and Humpert, 2016).

The high hydrocarbon prices were a result of the Organization of Petroleum Exporting Countries' (OPEC) activity from 1975. The OPEC is a group of prominent oil-exporting countries that seeks to co-ordinate petroleum policies amongst its member countries, in order to negotiate equitable and stable prices for petroleum producers; efficient, economic and uninterrupted supplies to consumers; and an equitable return on capital for investors (OPEC, 2016).

McVeigh (1984) and the OPEC (2016) state that during this period (the 1970's), the OPEC became more internationally prominent as its members (countries like Venezuela and Saudi

Arabia amongst others) consolidated their domestic oil economies and events such as the Arab oil embargo in 1973, and the Iranian Revolution of 1979 caused prices to rise. The OPEC is a cartel, so its policies strongly affect oil markets and the 1979 oil price high was maintained by the OPEC reducing its supply for the next six years (Baffes et al., 2015; Baumeister and Kilian, 2016).

A major local development in the 1970s was the institution of the Petroleum Production Subsidy and Levy Act (Li and Canetti, 2016; Khan and Khan, 2017). This detailed the national legislative protection for consumer-prices so that residents could have the benefits of low and stable prices from the local hydrocarbon wealth (Solaun et al., 2015). The oil companies producing more than 3,500 barrels of oil per day are responsible for bearing the cost of the subsidy by contributing 4% of their gross income (Solaun et al., 2015; Khan and Khan, 2017). Solaun et al. go on to state that any amount of the subsidy bill greater than these companies' 4% contributions is paid by the government; Appendix E details the subsidy.

The State's industrialization directive to use natural gas led to an increased gas consumption of nearly 8% per annum from 1975 to 1995 (McGuire et al., 2007). The increasing economic prominence of gas led to the consolidation of the State-owned National Gas Company of Trinidad and Tobago (NGC) responsible for purchasing, selling and transporting gas (McGuire et al., 2007; Espinasa and Humpert, 2013; Samuel, 2013; Espinasa and Humpert, 2016).

In 1996 natural gas output surpassed that of oil (on an energy equivalent basis) for the first time (see Figure 27); 142,600 barrels of oil equivalent per day (boe/day) of natural gas were produced versus 141,000 barrels of oil (McGuire et al., 2007; Espinasa and Humpert, 2016).

The image showing the crude oil and natural gas production in Trinidad and Tobago from 1965 to 2012 originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Figure 27 showing Trinidad's crude oil and natural gas production from 1965 to 2012 in barrels of oil equivalent per day (boe/day)

Adapted from Espinasa and Humpert (2016; 8) using Microsoft Word

McGuire et al. (2007), and Russell and Bududass (2012) additionally state that the gap between the commodities increased even further when the country entered the liquefied natural gas (LNG) industry in 1998/1999. Figure 28 on the next page shows the effect of LNG on gas consumption around this time and it is worth noting that Trinidad's LNG capacity was such that in 2012, 56.6% of the nation's gas was used for LNG production and Trinidad was the world's 6th largest exporter of the commodity (Marzolf et al., 2015).

The image showing the natural gas usage in Trinidad and Tobago from 1990 to 2013 and the 2012 gas consumption breakdown originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Marzolf, N. C., F. C. Cañeque and D. Loy. 2015. A Unique Approach for Sustainable Energy in Trinidad and Tobago. Inter-American Development Bank. Website: http://www.energy.gov.tt/wp-content/uploads/2016/08/A-Unique-Approach-for-Sustainable-Energy-in-Trinidad-and-Tobago.pdf (accessed 12th January, 2017)

Figure 28 showing Trinidad's natural gas utilization from 1990 to 2013 in million barrels of oil equivalent, and the natural gas consumption breakdown for 2012 as the inset

Adapted from Marzolf et al. (2015; 8 and 9) using Microsoft Word

To further contextualize the natural gas impact during this time, Espinasa and Humpert (2016) outline that between 1995 and 2006 natural gas production's annual growth rate of 16% took it from 126,600 boe/day to 669,400. Production remained stable near these levels and peaked at 746,700 boe/day in 2010 (versus peak oil production of 240,000 barrels in 1978). Marzolf et al. (2015) also state that in the wider 1990 to 2013 period shown in Figure 28 annual gas

consumption grew by 359%.

Between 1999 and 2002 the energy sector was being restructured from oil to gas (Espinasa and Humpert, 2016). However, natural gas has been the central resource since 1975 (Moya et al., 2010) because oil production was slowly declining around that time (Espinasa, 2008; Espinasa and Humpert, 2013).

From the legacy of oil in the pre-independence and early post-independence years, natural gas became the more important part of the economy as the primary energy supply dominated by oil in the 1960s to 1980s shifted to gas (Espinasa and Humpert, 2016). The shift can be seen in the size of the blue bars highlighted in Figures 29 to 32 on pages 146 to 149 as they increased over time. The key elements are the growth in gas as an energy input and its consequent consumption, and the rise of natural gas-related export due to the LNG developments.

Artana et al. (2007) state that Trinidad's economy transitioned from oil to oil and gas (which is quite true resource-wise). However, the gas trends continued and matured into today's present state where many such as Thomas (2009) and Khan and Khan (2017) describe the nation as a gas-based economy. This is perhaps because of its share of the nation's primary energy consumption (McGuire et al., 2007).

The image showing the primary energy mix of Trinidad and Tobago from 1971 to 1974 originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Figure 29 showing Trinidad and Tobago's primary energy mix (excluding exports) in thousand barrels of oil equivalent per day from 1971 to 1974

Note: The highlighted bars are the natural gas contributions.
Adapted from Espinasa and Humpert (2016; 44) using Microsoft Word

The image showing the primary energy mix of Trinidad and Tobago from 1984 to 1987 originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Figure 30 showing Trinidad and Tobago's primary energy mix (excluding exports) in thousand barrels of oil equivalent per day from 1984 to 1987

Note: The highlighted bars are the natural gas contributions.
Adapted from Espinasa and Humpert (2016; 45) using Microsoft Word

The image showing the primary energy mix of Trinidad and Tobago from 1992 to 2002 originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Figure 31 showing Trinidad and Tobago's primary energy mix (excluding exports) in thousand barrels of oil equivalent per day from 1992 to 2002

Note: The highlighted bars are the natural gas contributions.
Adapted from Espinasa and Humpert (2016; 46) using Microsoft Word

The image showing the primary energy mix of Trinidad and Tobago from 2005 to 2008 originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Figure 32 showing Trinidad and Tobago's primary energy mix (excluding exports) in thousand barrels of oil equivalent per day from 2005 to 2008

Note: The highlighted bars are the natural gas contributions.
Adapted from Espinasa and Humpert (2016; 47) using Microsoft Word

4.2. Trinidad's Economic Transition History and its Uniqueness as a Small-Island Energy Case Study

Figure 29 to 32's (pages 146 to 149) blue bars show that natural gas became the most significant energy resource in Trinidad. Figure 33 (next page) completes this series and shows that of the nation's production of 494,000 barrels of oil equivalent per day, 356,000 came from natural gas and 138,000 came from crude oil (Espinasa and Humpert, 2016). Jobity (2013) states that the industry has come a long way since its inception due to specific policy decisions, and these have enabled the nation's natural gas to accrue increased market value.

The image showing the primary energy mix of Trinidad and Tobago in 2012 and primary energy breakdown percentages originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Figure 33 showing Trinidad and Tobago's primary energy mix (excluding exports) in thousand barrels of oil equivalent per day for 2012, and the percentage primary energy breakdown as the inset

Adapted from Espinasa and Humpert (2016; 6 and 7) using Microsoft Word

Shaw (2011) asserts that the energy industry is the driver of Trinidad and Tobago's economy in the new century regardless of upstream or downstream industrial development. Trinidad's

petroleum industry accounts for 39% of the national Gross Domestic Product, and this is made up of extraction and production (22%); refining (10%); petrochemicals (4%); distribution (2%); and service contracts (1%) (Solaun et al., 2015). Trinidad's economic history and natural gas economy have made the island an atypical energy case study from a small-island point of view.

There are four defining characteristics worth reiterating from the discussions so far:

- Trinidad has one of the oldest and most mature hydrocarbon economies in the world - the industry is over a century old.
- Trinidad is one of the world's leading liquefied natural gas exporters, and it is the most significant export product.
- Trinidad is one of the world's leading exporters of ammonia, methanol and urea which are energy-intense, downstream industries that use natural gas as a production feedstock.
- Trinidad's hydrocarbon wealth finances an energy subsidy that is funded by oil companies and the Government, and it is supported by national legislation (see Appendix E).

Figure 34 (next page) presents a useful visual narrative of the earlier historic accounts and its energy transitions (ETs) timeframes are based on major energy events as proxies. This however does not mean that major energy events determine when an ET occurs - they were simply the most convenient way to illustrate them in this historical account. The economies have been shaped over decadal to century timeframes as seen by the 387, 151 and 71-year

reigns of the sugar, oil, and natural gas economies respectively (in line with the ETs literature's timeframes from Chapter 2).

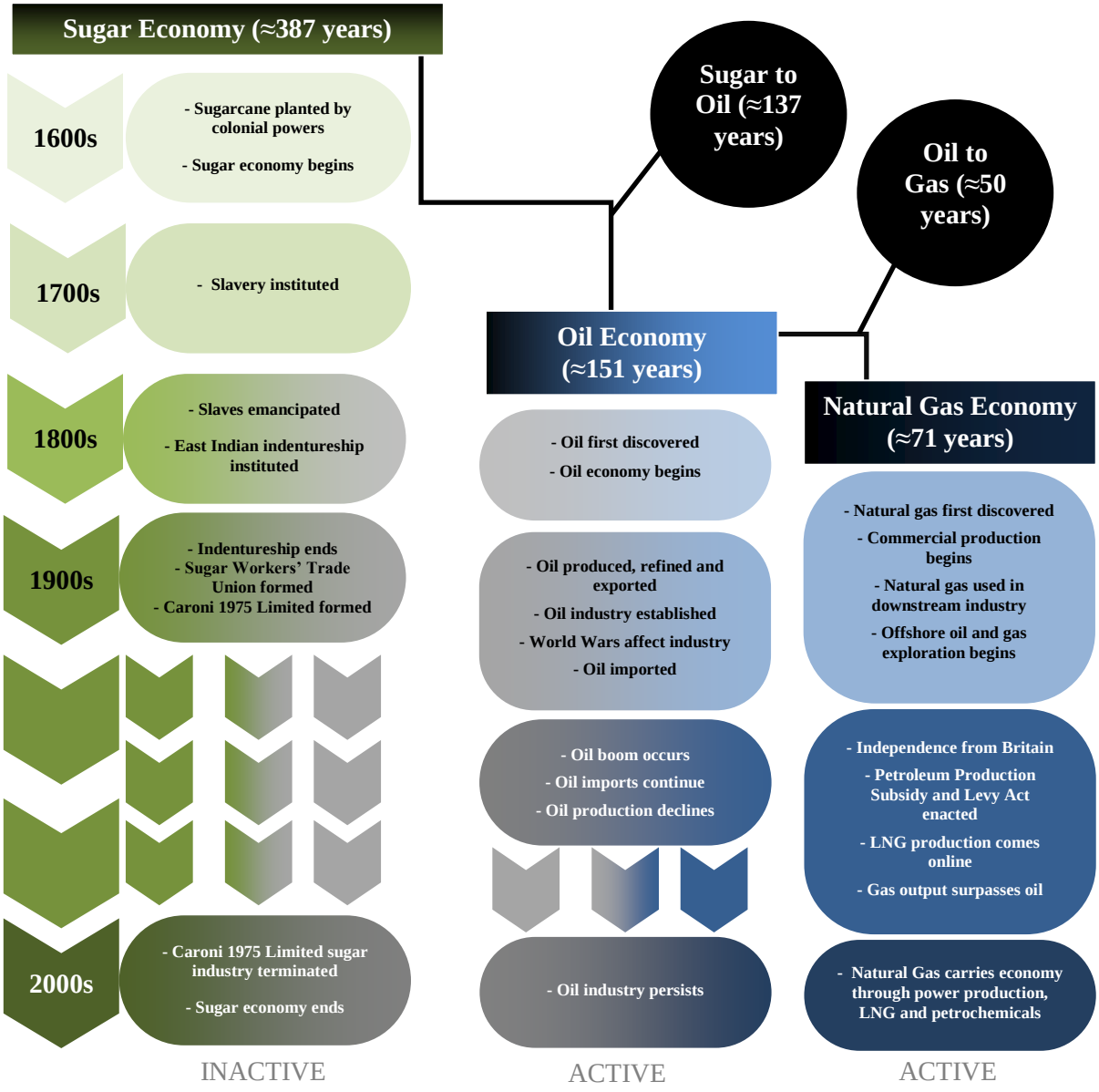


Figure 34 showing Trinidad's major historical economic transitions and events

Generated by the Author using Microsoft Word

The gaps between the economies also mark potential lag times of disruption the national

system may have experienced during the transition. Notably the change from oil and natural gas is thought to have been smoother than the transition from sugarcane to oil; the transition from sugarcane to oil may have taken at least 137 years whilst the transition from oil to gas may have lasted around 50.

These notions are important because they suggest that an ET away from the current natural gas-based system will be a prolonged process due to path dependency, lock-ins and resistance to change. The chapter has thus far focused on the energy resources of Trinidad and Tobago's economy in which its electricity sector is set in. But the historical accounts show that natural gas rose to be the most dominant energy resource in the island's economy (Espinasa and Humpert, 2013).

It is the sole energy resource used for power generation in Trinidad (Marzolf et al., 2015; Espinasa and Humpert, 2016) and electricity is provided by three independent power producers that operate 6 centralized power plants (Marzolf et al., 2015; Espinasa and Humpert, 2016); Chapter 7 provides more technical descriptions on the residential electricity regime. Trinidad's natural gas-based power generation legacy has created several barriers to renewable energy many of which have long historical legacies intertwined in the historical accounts presented earlier in the chapter.

Rogers et al. (2012) state that the most significant barriers to renewable energy implementation on small islands are usually financial, institutional and/or political in nature. In Trinidad they include limited electric utility experience with renewables; different ministries coordinating power generation and electricity distribution; lack of renewable energy research and development; lack of fiscal support for energy conservation and

alternatives; low public awareness and information access; lack of capital, information and skilled labour; limited technology transfer opportunities; and subsidized electricity (Haraksingh, 2001; Espinasa, 2008; Sharma and Aiyejina, 2010; MEEA, 2012; Solaun et al., 2015; Espinasa and Humpert, 2016; Marzolf et al., 2015; Khan and Khan, 2017).

The 11 Trinidadian key-informants were asked '*What are some of the barriers to solar energy?*' to give in-situ context to the literature's barriers. This was important to explore the potential resistance that the incumbent residential electricity regime may exhibit towards solar energy technologies as well as any lock-ins present (based on the nature of regimes as described in Chapter 2). 4 different categories emerged from 11 codes and Table 10 (next page) shows the coding relationships.

Based on Table 10 and the policy-oriented literature, cost is the key barrier. Informants provided supporting statements such as:

"once the cost of electricity here [in Trinidad] is cheap and the cost to deploy the [solar] technology for a residential consumer is preventative, nobody's going to put the technology in - because you could have all the legislation and policy frameworks for it to happen, and if the cost is a barrier to it being deployed by the individual homeowners, it's never going to be done." (*Informant TD01*)

"…the bottom-line is cost. Does it cost more and what is the cost-benefit." (*Informant TD02*)

"…too expensive for Trinidadians…Nationals aren't spending that kind of money on solar." (*Informant TD10*)

The driving reason for these perceptions was highlighted earlier in this section as the last of the four main takeaways on the uniqueness of Trinidad i.e. the heavily subsidized energy.

CODING STRUCTURE			FREQUENCY
THEME / CONCEPT	**CATEGORY**	**CODE**	
Barriers to solar energy in the incumbent socio-technical regime	Economics	Expensive costs	22
		Import-export design of the energy system	6
	Institutions	Lack of policy frameworks and interventions	4
		Lack of supporting legislative instruments	6
		Governmental bureaucracy	13
	Cultural acceptance	Conflicting personal preferences	2
		Lack of public awareness and education	13
		Business as usual culture	7
		Low public engagement	1
	Other	Lack of technical and industrial capacity	5
		Lack of funding opportunities	6

Table 10 showing the basic deductive coding structure relating to the 'Barriers to solar energy' theme/concept as derived from the coding of the 11 energy officials' transcripts in Trinidad

Note: The frequency is defined as the number of times each code was flagged during the analysis.

Generated by the Author using Microsoft Word

The subsidy is detailed in Appendix E but it was instituted in the 1970s and is financed by a levy on the oil and gas companies operating in the country that produce more than 3,500 barrels of oil per day under the provisions of the Petroleum Production Levy and Subsidy Act (Solaun et al., 2015). The companies contribute 4% of their gross income and any amount of the subsidy that is greater that these companies' contribution is paid by the Government (Solaun et al., 2015).

The subsidy was instituted for two main reasons: to attract industries by offering cheap energy as part of industrialization by invitation, and to allow nationals to benefit from the

country's hydrocarbon wealth. The subsidy on the costs of the natural gas used for power generation is not the most institutionally visible element of the overall energy subsidy but the electricity sector does benefit from preferential low prices (see Appendix E); the subsidy makes the Trinidad and Tobago Electricity Commission's (T&TEC) rates artificially low.

The retail rates are currently USD $0.04 per kilowatt-hour (kWh) for the first 400 kWh, $0.05 per kWh for the next 600 kWh, and $0.06 per kWh for any amount above this 1000 kWh threshold (Espinasa and Humpert, 2016). By comparison distributed residential photovoltaics system costs in the Caribbean average USD $3.85, and ranges from $1.50 per Watt in Antigua to $8.00 in Jamaica (GTM Research and Meister Consultants Group, 2015).

These figures show that Trinidad`s electricity rates make residential solar energy not as competitive as it could be. However, these rates are not readily seen by adopters because it is the upfront capital costs that they face when purchasing systems. There is no readily available data for the capital costs of residential solar in Trinidad because the industry has not been consolidated and the costs of residential installations vary by project. But it would be fair to say due to the subsidized electricity from the T&TEC (see Appendix E) and low technical capacity of the local solar energy industry (see Chapter 7) which would affect installation and maintenance costs, the capital costs are expected to be quite high.

4.3. Chapter Conclusions

Trinidad's economy shifted from the colonial legacy of sugarcane into oil and then natural gas. These shifts were industrial transitions centered on sugar refining, petroleum refining, gas processing, and then petrochemical production. The island's economy transitioned from a

diversified, low quality mix of resources into a few high-quality resources that brought increased economic profitability.

The economic transitions outlined in the chapter also showed geographic energy sourcing shifts as Trinidad's hydrocarbon production started onshore, then moved offshore and is now in the deep-water geography. All these geographies are still operating and so contribute to the resources' historic longevity. There are over 150 years of institutional legacy behind Trinidad's hydrocarbon economy and about 70 of those years support the economy that coevolved around the use of natural gas.

The residential electricity sector is but a small sub-system of the larger energy system that powers the economy. It has evolved on natural gas as its primary energy input for centralized power generation. The structures that have been built around the use of natural gas for electricity production have resisted the integration of renewables like solar energy because of economics; political agendas; archaic legislation; bureaucracy; lack of renewable energy financing; lack of public education on renewables; and an inherent socio-cultural disconnection from energy issues. The nation's subsidized electricity however is the most the most restrictive barrier to renewables (see Appendix E).

4.3.1. Characterizing Mainstreaming

The thesis focuses on the mainstreaming of residential solar energy in Trinidad. Mainstreaming in the Multi-Level Perspective of socio-technical energy transitions is the process by which a niche-innovation (like residential solar energy technologies in Trinidad) evolves out of niches and into the regime.

As shown in the chapter, fossil fuels and their supporting structures constitute the incumbent regime. But they were not always part of it. Therefore, there are lessons to be learnt about mainstreaming by looking at the historical evolution of the incumbent. Several tenets emerged from this chapter's discussions to begin the thesis' characterization of mainstreaming:

i. Mainstreaming is a time-sensitive process.

ii. Mainstreaming is a systems-level process.

iii. Mainstreaming does not always have complete systems-level resource substitutions, but resource substitutions are involved e.g. hydrocarbons replacing metabolic energy and biomass.

iv. Mainstreaming is most easily facilitated when the resource fits non-disruptively into the incumbent system e.g. natural gas superseding oil

v. Mainstreaming can be inhibited by the incumbent system's structures that have been locked-in.

5.0. Household Energy Usage, Costs & Supply in Barbados & Trinidad's Energy Cultures

Synopsis

This chapter compares energy usage, costs and supply as cultural domains of Barbados and Trinidad's household respondents' energy cultures. It is based on the inductive thematic content analysis of the 33 household interviews conducted with residents in the islands.

The thesis' research questions are framed around exploring the way in which culture interacts with the adoption of residential solar energy technologies during an energy transition (ET), and also specifically with these technologies' supporting policies. But it was important to firstly understand the underlying structure of the energy cultures that exist in Barbados and Trinidad's regimes since there was no prior research on this.

The three aforementioned cultural domains were used to explore the underlying structure of the respondents' energy cultures based on interview questions pertaining to the fundamental interactions between the residents and the monopolized electricity systems existing in each island i.e. the distribution of electricity to homes (supply), consumption in homes (usage), and the payments to the sole utility company for providing it (costs).

The chapter's findings help address the first research sub-question, "*How could the adoption of distributed residential solar energy technologies and the residential energy culture(s) of Trinidad affect each other?*" by predominantly looking at the impact of adoption on the respondents' energy culture.

There are both proactive and reactive roles for culture during an ET as presented in Chapter 2.

This chapter's characterization of the respondents' incumbent energy cultures in the two islands particularly provides insight into the reactive role - which specifically refers to an energy culture reacting to the adoption of solar energy technologies as was the case with Barbados' respondents. This helps fulfil the aim of the thesis i.e. to explore the role(s) of culture in ETs.

The chapter is structured as follows: section 5.1. gives the context for looking at energy usage, costs and supply as cultural domains; section 5.2. describes the respondents' usage and costs domains in each island; section 5.3. outlines the impact of solar water heating in the Barbadian respondents' energy culture; section 5.4. describes the supply domains in each island; and section 5.5. presents the chapter's conclusions and how they answer the cultural research sub-question, gives the conclusions' policy implications, and characterizes mainstreaming based on the chapter's findings.

5.1. Domains in Energy Cultures

Chapter 2 outlined the theoretical background of the Energy Cultures Framework and the meaning of energy cultures i.e. an assemblage of norms, practices and material culture affected by external influences. The thesis' energy cultures investigations are framed by the socio-technical relationships between utility companies and households; these companies provide electricity and households consume and pay for it.

This energy production and consumption has set a context for society's relations with its human and non-human elements (Horta et al., 2014) such that the centralized power generation that typifies most of the world is mirrored in the energy economics, socio-

economic values, behaviours and governance of any given country (Nolden[1], 2012).

The introduction of electricity as well as its presence and usage are culture-specific (Winther, 2013). Therefore it is reasonable to suggest that people's interactions with their energy supply, consumption and payment systems have developed practices, norms, material culture and external influences because users' habits have been locked-in through their interactions within the culture, over history and with their material environments (Wallenborn and Wilhite, 2014).

Cultural models are formed when cultural information groups around a specific domain (Broesch and Hadley, 2012). Domains help individuals understand and organize their social world (Fryberg and Rhys, 2009) and energy usage, energy costs, and energy supply are the domains analysed in this chapter. This is because the interactions between the utility companies in Trinidad and Barbados and their respective residential customers are primarily based on the distribution of electricity to these customers, and their consumption of and payments for it.

The inter-island comparison was specifically done to identify any differences that may have been attributable to the adoption of residential solar energy in Barbados since the Barbadians adopted solar water heating.

5.2. Energy Usage and Costs as Domains

5.2.1. A Descriptive Overview of Energy Usage as a Domain

The Energy Cultures Framework (ECF) was originally based on energy consumption

behaviour (Stephenson et al., 2010; 2015). Therefore, an interesting question to ask respondents directly was: '*In your opinion, what specific factors influence how much energy is used in your home?*' This was asked to give respondents the chance to specifically point out norms, material culture, practices and external influences that they believed affect the amount of energy their household uses.

This question complements the one that will be outlined in the next subsection surrounding household energy costs. They were important to ask because the questions are based on the technical and institutional design of the residential electricity regime that the respondents' energy cultures are set in in each respective island. In Trinidad's case, households get their electricity from the Trinidad and Tobago Electricity Commission and in Barbados, from the Barbados Light and Power Company.

Whilst the question is based on the electricity network the phrasing is important to consider because the term 'energy' is used versus 'electricity'. This was so done so that any electricity-related answers would have come organically, and respondents could include other non-electrical energy uses such as the liquefied petroleum gas used for cooking for instance. An important point to highlight is that the question does not have a temporal dimension as phrased. However, Appendix F looks at the respondents' perceived peak energy demand and its driving factors so this puts the features in this domain into the context of routines.

The respondents stated multiple factors they believed to affect their energy usage. In Trinidad only 3 of the 16 respondents stated one factor whilst Barbados' 17 respondents listed multiple. This means that 30 of the 33 respondents acknowledged a diversity of factors affecting their energy usage. In Trinidad the least number of factors listed by a respondent

was 1 and the most was 9 whilst in Barbados the least was 2 and most was 7.

There were explicit similarities noted in both energy cultures. There were 12 different sub-codes out of a total of 46 that were recorded in both islands. Figure 35 shows these sub-codes and their frequencies. A caveat is that some sub-codes may not have been explicitly tagged in both islands, but they would have been eventually subsumed in a similar yet broader coding class like code or category.

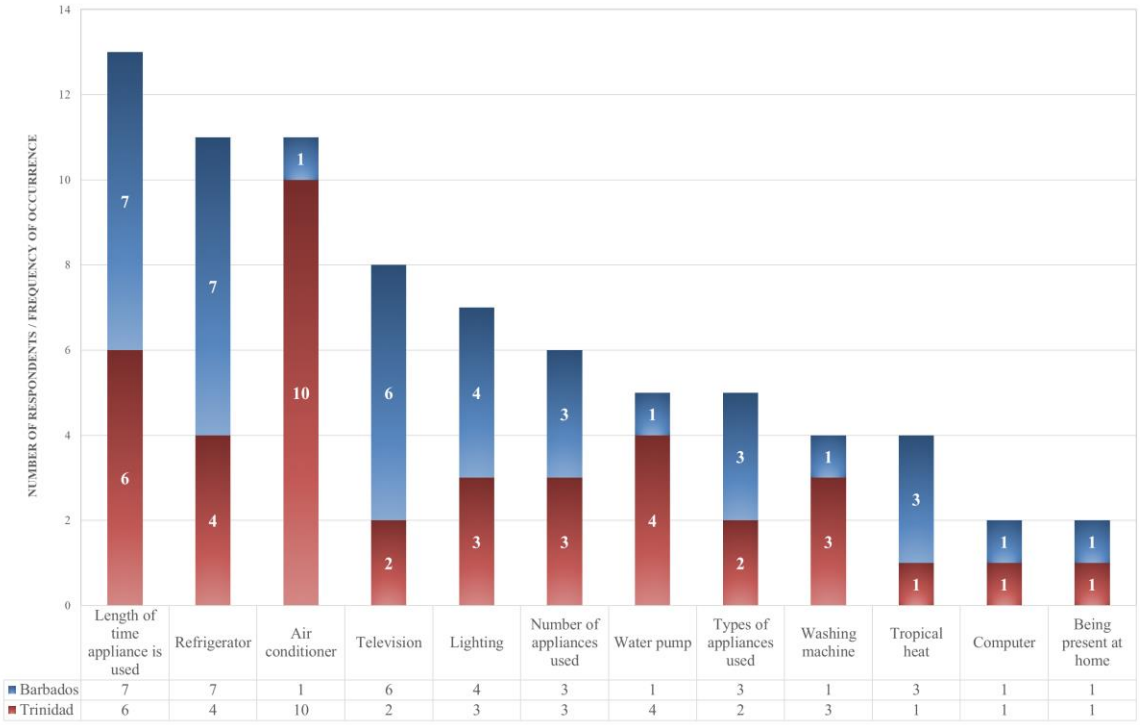


Figure 35 showing the explicit sub-codes common to both the Barbadians and Trinidadians' energy usage domains

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As can be seen from Figure 35 (previous page) there were sub-codes mentioned more frequently in one energy culture than the other e.g. of the 8 responses highlighting televisions

as a factor influencing energy usage, 6 were Barbadians' and 2 were Trinidadians'. Other examples are water pumps (mentioned in 4 Barbadians' responses and 1 Trinidadian's) and air conditioners (mentioned in 10 Trinidadians' responses and 1 Barbadian's).

To put these similarities into context, Tables 11 and 12 (next two pages) show the all sub-codes generated from the inductive coding in Trinidad and Barbados respectively. There are then brief descriptions of the recorded material culture followed by the norms and practices as well as their external influences.

Residential energy consumption is not as tangible as other forms of consumption (Buys et al., 2015) especially in modern energy systems. Sovacool (2009) and Mazur-Stommen (2013) describe the physical invisibility of energy technologies and energy use, and Sovacool suggests that technologies that are highly visible are often believed to be more consumptive by its users; Attari et al. (2015) gives insight into these sorts of observations relative to energy conservation. This is because energy in homes is connected to energy-using appliances and no longer to the fuels that power them (Rüdiger, 2008).

Respondents acknowledged that specific appliances i.e. material culture have substantial impacts on energy consumption. Examples of statements provided which led to sub-codes for the different material culture items are:

"The appliances that use a lot of energy like the air conditioner, hot iron for ironing clothes and [the] washer-dryer - so any heating or cooling appliances." (*Respondent 10MTTD*)

"As a retiree, we are home all day so the fridge [refrigerator], TV [television] and radio are on all day long." (*Respondent 02MBDS*)

FREQUENCY	SUB-CODE
10	Air conditioner
6	Length of time appliance is used
4	Refrigerator
4	Water pump
3	Lighting
3	Washing machine
3	Appliance isn't owned but they are aware it can affect energy demand
3	Number of appliances used
2	Electric water heater
2	Freezer
2	Hot iron
2	Television
2	Types of appliances used
2	Different energy user lifestyles
1	Arc welding plant
1	Computer
1	Electric Stove
1	Microwave
1	Heating or cooling appliances
1	Being present at home
1	Wasting energy
1	Energy efficiency
1	Tropical heat
1	Energy demand underestimation by household
1	Utility cost recovery
1	Utility reliability
1	Costs of electricity

Table 11 showing the sub-codes that emerged from the inductive coding of the 16 Trinidadian respondents' answers within the energy usage domain

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.

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The quotes on the previous page also include norms, practices and external influences. But they are useful to show how the material culture references were integrated in the responses; in these examples the material culture listed was the air conditioner, hot iron, washer-dryer, refrigerator, television and radio. In Trinidad air conditioners were the standout (mentioned in

10 responses) whilst refrigerators were the most significant in Barbados (mentioned in 7 responses). These were also the most frequent sub-codes recorded (see Tables 11 (previous page) and 12).

FREQUENCY	SUB-CODE
7	Refrigerator
7	Length of time appliance is used
6	Television
4	Lighting
3	Number of appliances used
3	Types of appliances used
3	Type of energy user
3	Faulty appliances waste energy
3	Wasteful energy practices
3	Tropical heat
2	Clothes dryer
2	Lifestyle lock-ins
1	Air conditioner
1	Cable box for the television
1	Compressor
1	Computer
1	Fan
1	Gas stove
1	Radio
1	Washing machine
1	Water pump
1	Ways in which appliance is used
1	Energy conscious appliance installation location
1	Being present at home
1	Wasting energy is costly
1	Lack of education
1	Energy consumption misconceptions
1	Water availability
1	Appliances being always plugged in
1	Climate change

Table 12 showing the sub-codes that emerged from the inductive coding of the 17 Barbadian respondents' answers within the energy usage domain

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.

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The best way to present the norms and practices which emerged would be to discuss both together but to make the distinction between them clear. From the *Respondent 10MTTD*'s quote on page 164, an example of a norm is the belief that switching on and using (the practice) heating and cooling appliances (the material culture) will increase the amount of energy used in the home. Another example emerged from statements like:

"If it's [the appliance] not running all the time then the bill would not go up." (*Respondent 01FTTD*)

"Certain appliances constantly being used - you can't shy away from them." (*Respondent 05MBDS*)

As hinted by *Respondent 01FTTD*'s above quote, the length of time an appliance is used was a practice. However, by using appliances (the material culture and practice) for longer periods of time, the respondents believe and expect that more energy will be used (the norm). This particular observation plays on the fundamental technical relationship between the power rating of an appliance and its energy consumption where the length of time it is used for is the variable factor.

The length of time an appliance is used for was the second most frequent sub-code in Tables 11 and 12 (previous two pages); it was flagged in 6 Trinidadians' responses and 7 Barbadians'. From the description of the norms and practices which emerged, there is a general question arising as to why the material culture is used in the way that it is. Looking at the respondents' external influences on their energy cultures helps answer this question.

The external influences that emerged were the tropical heat (both island's respondents), climate change (Barbados' respondents), water availability (Barbados' respondents), and the utility company's influence (Trinidad's respondents).

There are environmental influences in both islands and respondents reported the main factor to be the tropical heat (3 Barbadians' responses and 1 Trinidadian's response), and the subsequent need for cooling e.g.:

"The heat - we have 4 air conditioners which are being used much more than expected since they're used day and night." (*Respondent 16FTTD*)

"…fans to try to keep the place cool…" (*Respondent 12MBDS*)

This illustrates that weather directly affects thermal load and energy use (Hong et al., 2013), and that the prime driver of cooling demand is the climate (DeForest et al., 2014). As shown by *Respondent 16FTTD*'s quote above, the tropical heat is an external influence which causes householders to switch on (the practice) their air conditioners (the material culture) during the day and night and by using the air conditioners in this way, there is an aspiration to cool the home and the expectation that it will be cooler (the norm) - this exemplifies how all the features of the ECF interact to drive energy demand.

Respondent 09MBDS understood that global warming was another influential factor on their energy use by saying that:

"with climate change and the heat, air conditioning use is key." (*Respondent 09MBDS*)

This presented climate change as another external influence. *Respondent 07BDS* also outlined water availability as another. They said that they recently installed a tank and water pump because they live in a water scarce region of Barbados.

A final point on the analysis' external influences came from the Trinidadians where the utility's cost recovery, reliability and electricity costs emerged as sub-codes. In terms of the

electricity costs, *Respondent 07MTTD* simply stated that the costs influenced their energy usage. But relative to the utility's reliability, *Respondent 03FTTD* thought that good, quality service is not always provided by utilities and:

"companies [referring to utility companies] abuse customers to some extent." *(Respondent 03FTTD)*

They also stated that earlier that week there were several power cuts to their home over a short period of time and went on to say that those sorts of occurrences damage appliances and they are not compensated for any damages incurred. Relative to the utility's cost recovery this same respondent also thought that the company's expenses are:

"thrown-off on consumers." *(Respondent 03FTTD)*

5.2.2. A Descriptive Overview of Energy Costs as a Domain

As stated at the start of the last subsection, the question being asked in both subsections complement each other and are based on the technical and institutional residential electricity system of the islands where a sole electricity utility company distributes power to households, and these households consume and pay for it in the respective islands.

The energy costs domain was explored by asking respondents: '*In your opinion, what specific factors influence how much you pay for energy?*' This was asked to give respondents the chance to specifically point out norms, material culture, practices and external influences that they believe affect the costs of the energy their household uses.

Again, the term 'energy' is used over 'electricity' to keep the questioning consistent with the

energy usage domain, to let any electricity-related responses emerge organically, and to ensure that there was still scope for the inclusion of other non-electrical factors such as the costs associated with liquefied petroleum gas for instance.

As with the energy usage domain described in the previous subsection the cost domain question does not have an explicit temporal dimension. However, Appendix F looks at the respondents' perceived peak energy demand and its driving factors so this puts some of the features listed into the context of the respondents' routines - which is useful because this domain was defined by energy consumption and its retail electricity costs as broad themes/concepts.

The respondents mentioned more than one factor influencing their household energy costs. However, there was 1 Trinidadian that described only one factor. So, 32 of the total 33 inter-island respondents mentioned more than one influencing factor. In Trinidad the least number of factors given by any respondent was 1 and the most was 6 whilst in Barbados 2 was the least and 10 was the most.

Relative to the explicit similarities between the respondents' energy cultures, of Trinidad's 27 different sub-codes and Barbados' 33, there were a total of 48 different sub-codes. This means that there were 12 that were observed across both islands. Figure 36 (next page) shows these sub-codes. Similarlyto the energy usage domain, there were factors that were mentioned more frequently in one energy culture than another.

Examples included air conditioners being mentioned in 5 Trinidadians' responses versus 1 Barbadian's; refrigerators being mentioned by 3 Trinidadians' responses and 6 Barbadians'; the number of appliances used being mentioned by 1 Trinidadian's response versus 5

Barbadians'; and 3 Trinidadians' responses flagged washing machines compared to 7 Barbadians'.

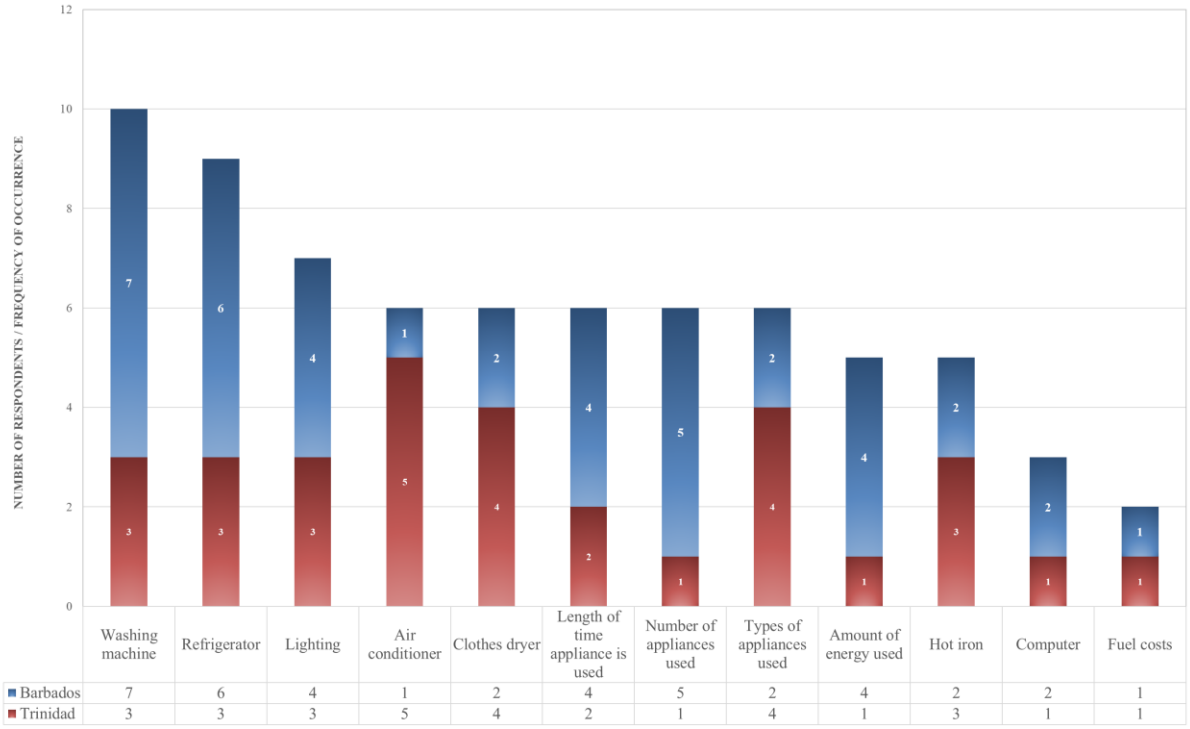


Figure 36 showing the explicit sub-codes common to the Barbadians and Trinidadians' energy costs domains

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To put these sub-codes into the context of the energy cultures, Tables 13 and 14 (next two pages) show all the sub-codes generated from the inductive coding in Trinidad and Barbados respectively. There are then brief descriptions of the recorded material culture followed by the norms and practices as well as their external influences.

As seen in the energy usage domain, air conditioners were the most frequently referenced material culture in Trinidad (mentioned in 5 responses) whilst in Barbados washing machines

were the most frequent (mentioned in 7 responses). Examples of responses which led to material culture sub-codes are:

"Washer; dryer; refrigerator; lights at night." (*Respondent 07MTTD*)

"Energy use from appliances like the [clothes] dryer, washing machine, and refrigerator." (*Respondent 01MBDS*)

FREQUENCY	SUB-CODE
5	Air conditioner
4	Clothes dryer
4	Types of appliances used
4	Number of energy users
3	Hot iron
3	Lighting
3	Refrigerator
3	Washing machine
2	Length of time appliance is used
2	Retail electricity tariff rate
1	Computer
1	Microwave
1	Power tools
1	Steel cutter
1	Electric water heater
1	Water pump
1	Gas stove
1	Heating or cooling appliances
1	Number of appliances used
1	Amount of energy used
1	Rainy season
1	Dry season
1	Institutional cost recoveries
1	Institutional policies
1	Fuel costs
1	Other customer charges
1	Utility's geographic billing method

Table 13 showing the sub-codes that emerged from the inductive coding of the 16 Trinidadian respondents' answers within the energy costs domain

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.

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FREQUENCY	SUB-CODE
7	Washing machine
6	Refrigerator
5	Number of appliances used
4	Lighting
4	Television
4	Amount of energy used
4	Length of time appliance is used
2	Clothes dryer
2	Computer
2	Fan
2	Freezer
2	Hot iron
2	Types of appliances used
2	Different energy user lifestyles
2	Switching off appliances
2	Leaving appliances plugged in
2	International oil market
1	Air conditioner
1	Phone
1	Radio
1	Tablet
1	Appliance efficiency
1	Type of energy user
1	Cloud cover
1	Unplugging appliances
1	Energy-saving appliances
1	Energy-efficient appliances
1	Fixed costs
1	Fuel costs
1	Government taxes
1	Electricity utility injustice
1	Fuel adjustment legislation
1	Solar water heater electrical backup

Table 14 showing the sub-codes that emerged from the inductive coding of the 17 Barbadian respondents' answers within the energy costs domain

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.

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As indicated by the sub-codes presented in Figure 36 (page 171) and Tables 13 and 14 (previous two pages) there were similar norms and practices which arose e.g. those related to the length of time an appliance is used for based on statements such as:

"…frequency of use of the different energy-consuming things in the house." (*Respondent 16FTTD)*

An example of a related statement from a respondent in Barbados is:

"The amount of usage - meaning the amount of appliances used and how long they are used for*."* (*Respondent 04FBDS*)

Where responses like the above were given, in addition to the norms, practices and material culture related to the 'how long they are used for' phrase from the quote, the respondent is saying that by using more appliances (the practice and material culture) they believe and expect their energy costs to increase (the norm). The quote from *Respondent 04FBDS* reflects the retail electricity tariff design where the bill is determined as a function of the kilowatt-hour consumption and the cost per kilowatt-hour over the billing cycle.

There were some key practices noted in the Barbadians' responses. In the coding of their responses, a sub-category concerning energy conscientiousness emerged. This sub-category was linked to a sub-code related to energy-efficient appliances as well as a code related to energy conservation. With respect to the latter, the practices related to unplugging appliances when not in use, switching-off appliances when not needed, and using energy-saving appliances e.g. turning-off fans when not in use, installing timed fluorescent lighting and comparing electricity bills before and after getting into the habit of unplugging appliances that are not in use.

Examples of quotes that identified several of the aforementioned practices are:

"I tried a test by unplugging everything when I leave [my] home and the bill has dropped e.g. unplugging the cell phone['s] charger, fan, microwave, [and] electric kettle." (*Respondent 07FBDS*)

"Turning off the fans however, that decreases it [the electricity bill]. Leaving appliances plugged-in also increases the bill." (*Respondent 10FBDS*)

The external influences were largely environmental and institutional-industrial. Examples of environmental influences were given by *Respondent 11MTTD*: they stated that their air conditioning might be used more frequently during the dry season whilst their clothes dryer may be used more frequently in the rainy season.

The dry season extends from January to May (Narinesingh et al., 2013) and is the drier part of the year with higher temperatures which therefore create increased cooling demands. On the other hand, the rainy season's (June to December) impact on drying clothing was presumably due to less sunshine (due to more cloud cover) that would have otherwise been used for drying clothing outdoors, and the rainfall.

Another example came from *Respondent 05MBDS* who stated that their solar hot water supply is affected by cloud cover during December and January when they believed that cloud cover is at its highest; high cloud cover reduces the amount of incident solar energy on the solar water heater's collector surface and consequently reduces the quality of the hot water service (Curry, 2007; Goss, 2010). This observation is important because this was the only time that any sub-code relating to solar energy emerged organically in the energy usage and costs domains.

Cloud cover in Barbados, and the dry and rainy seasons in Trinidad were the only environmental external influences that emerged during the coding. With respect to the other external influences, their sub-codes were subsumed in the retail electricity costs' theme/concept that emerged during the coding.

This sensitivity to the retail costs of electricity was driven by industrial costs and the electricity bill - where the latter is the most significant means of communication between suppliers and consumers because of its cost and consumption information (Winther and Bouly de Lesdain, 2013), and is also one of the only correspondences between both parties (Morris et al., 2016).

The common element in both islands was the impact of the fuel costs; 1 response in Trinidad connected with the natural gas prices whilst another in Barbados acknowledged the influences of generic fuel prices. Trinidad's respondents identified with the retail tariff rate as a factor, and in Barbados 1 response highlighted the international oil market and specifically noted the fluctuant oil price's impact on their electricity costs.

Respondents also highlighted cost recoveries based on the policies of local energy authorities, government tax regimes, fuel adjustment legislation, and the fixed costs of power generation through responses like:

"…government taxes on electricity which are passed on to the consumer." (*Respondent 03MBDS*)

"…the relevant mark-ups in the line agencies, [the] T&TEC [Trinidad and Tobago Electricity Commission], and [the] PowerGen [Power Generation Company of Trinidad and Tobago] in providing the service." (*Respondent 15MTTD*)

Additionally, *Respondent 14MBDS* believed that pricing injustices spurred by the electric

company's rate-setting affects their electricity costs. They believed that there are loopholes in the utility's fuel adjustment clause which enable the company to have a significant amount of institutional control that makes the electricity prices:

"artificially high [and] manufactured by these people [referring to the electricity industry]." (*Respondent 14MBDS*)

Respondent 14MTTD described another external influence as what they perceived to be their utility's billing methodology. They believed that the utility uses the average consumption for a given area in the island to determine individual households' electricity bills and does not necessarily use homes' actual electricity meter measurements; the meter measurements are rated at $0.04 USD for the first 400 kWh, $0.05 per kWh for the next 600 kWh, and anything over 1000 kWh is charged at $ 0.06 per kWh (Espinasa and Humpert, 2016).

Respondent 14MTTD stated that after speaking to friends living in urban areas, they found that their friends' bills were near USD $330, others in the more rural areas were closer to $70 whilst the respondent quoted their own bill as being closer to $180. They acknowledged that appliance usage can account for such disparities but believed that their urban friends tried reducing their consumption, yet the bills were perceivably high. However, they were not able to give any figure for the cost of the bills after this consumption reduction experiment.

The aforementioned factors also came with the belief that:

"we don't have control over the rates since they are fixed prices" *(Respondent 16FTTD)*

Appendix G provides the respondents' perceived average electricity bills and puts the above observations into the context of their electricity bills as being either too high, affordable or

too low by describing the drivers of these perceptions. Examples of drivers which emerged are the international oil market and the utility company's billing methodology outlined earlier.

5.2.3. General Takeaways from the Energy Usage and Costs Domains

The Trinidadians' energy usage and costs domains each had 27 different sub-codes. The Barbadians' had 30 and 33 respectively. Out of these domain counts, the Trinidadians had a total of 41 different sub-codes and the Barbadians had 49. These latter counts for each island can be seen in Appendix H's tables. Based on these tables there are sub-codes that were mentioned more frequently than others.

Air conditioners were the most frequently mentioned across the Trinidadians' domains and had a frequency (number of responses tagged with the sub-code) of 15. There was no single feature that was least significant but rather 20 that had a frequency of 1. In Barbados, refrigerators were the most significant with a frequency of 13, and as observed in Trinidad, there was no single feature that emerged as least significant - 28 features were recorded with a frequency of 1.

From the tables' colour-coding there are several sub-codes assigned to factors that affect both energy usage and costs (pink rows); features affecting either usage or costs but mentioned more than once (yellow rows); and features that affect one or the other as well but have a frequency of 1 (grey rows). There are three key takeaways from the data in the tables.

Firstly, the data from the respondents' energy usage and costs domains suggest that there is

no fixed number or arrangement of features. Therefore, it is likely that features can increase and decrease in salience over time. A caveat is that the most consumptive material culture is not necessarily the most salient (see Appendix F). Appendix F shows that technological transitions (as explained through household lighting) is one process that can cause changes in the salience of factors that affect energy usage and its costs, and the changes would be dependent on the salience of the material culture involved in the transition.

Secondly, the energy costs domain was the most sensitive to external influences based on the data in Appendix H. This suggests that the usage domain is predominantly influenced by features that are internal to the home as an infrastructural energy space.

Thirdly, both regime and landscape-level elements were observed as external influences. The regime and landscape are two of the three planes of the Multi-Level Perspective (MLP) of socio-technical energy transitions used to study energy transitions (ETs) in the thesis (see Chapter 2). The regime is an endogenous, co-evolutionary structure that is the plane undergoing the ET and the landscape is an exogenous plane made up of complex factors that affect regime and niche-level processes over prolonged timeframes.

The theory and data therefore show that there is no exclusive theoretical synonymity between external influences and a given plane of the MLP. For example, fuel costs are an institutional part of Trinidad's residential electricity regime but exist as an external influence to the energy culture studied whilst the tropical heat is landscape-level and exists as an external influence.

5.3. The Cultural Impact of Solar Water Heating

Recalling that *Respondent 05MBDS* flagged cloud cover as an external influence on their solar hot water supply (page 175), more explicit questions were asked in Barbados to gauge solar hot water's impact. The respondents were asked: *'How does having solar water heating affect your energy usage in the home?'* and *'How does having solar water heating affect the cost of your energy bill(s)?'* This was a useful question to ask because as shown in the previous subsections, there were no strong references related to solar hot water. It also specifically gives insight into the way in which the respondents' energy culture may have reacted to the adoption of solar water heating.

There was one response which showed that a respondent was completely unsure about the technology's impact, but the other 16 were split between there being no perceived impact on their energy usage and costs (8 responses), and there being an impact on both (8 responses).

Interestingly, only 2 responses outright did not perceive an impact. The other 6 all had norms and practices which pointed towards there being an energy change that was attributable to using solar hot water e.g.:

"No real impact on the home's energy use really. Although I would add that when there's no sun and you switch to electrical [via the solar water heater's backup booster] to heat water, because it ties into the electrical panel, it would increase the bill and ultimately consumption as well." (*Respondent 01MBDS*)

"It has no impact on the bill. [I] Never really used the booster [referring to the solar water heater's electrical backup] since in Barbados…it is always sunny and getting 2 cloudy days is rare." (*Respondent 09MBDS*)

There were three possible reasons as to why there may have initially been no perceived impact by solar water heating.

Firstly, in Barbados the global oil price's fluctuations are reflected in the retail electricity rates (NREL[2], 2015: Hohmeyer, 2015) so there may not have been a consistent cognitive baseline for what solar water heating's impact on electricity bills at the household level was; the bills' fluctuations are subject to landscape-level factors beyond the home's energy consumption.

Secondly, since solar water heaters are generation technologies this means that they could have been perceived as being outside the conventional consumptive framing of household energy. As will be shown later, solar water heaters were believed to reduce several respondents' household energy consumption. Therefore, the systems were believed to conserve energy. However, recalling that material culture like household appliances are the most salient type of material culture in the energy cultures looked at, household appliances are energy-consuming. But solar water heaters are generators so this can be a reason why some did not perceive any impact on their energy usage or costs.

Thirdly, as the respondents became more familiar with the technology it became less 'observable' (Labay and Kinnear, 1981). Cressman (2009) states that because a technical element is functioning as it should the complexities of it get lost - similarly to electricity infrastructure which was once socially contested but is now invisible because of its passive infrastructure (Richerson et al., 2001; Namias, 2008; Sovacool, 2009; Schelly[1], 2014; Wallenborn and Wilhite, 2014).

From the earlier quotes (previous page), the impact-stimulus alluded to is the use of the system's electrical auxiliary heater which enabled the water to be heated by electrical energy instead of solar by flipping the associated switch (the practice). The respondents who outright

connected with an impact thought that their solar water heaters affected the households' use of, and costs of using liquefied petroleum gas (LPG) and electricity (the norms).

LPG is used as a cooking fuel (McIntyre et al., 2016) and is usually connected to a stove like the one shown in Figure 37. There is usually a steel cylinder, a pressure regulator, a hose that connects the regulator to a burner, and a burner like the one shown in the Figure (Sepp, 2014). Relative to the impact on LPG, 2 examples of responses given are:

"No real impact. If I didn't have it [referring to the solar water heater], I'd be using gas [to heat water on the stove] to wash the dishes." (*Respondent 02MBDS*)

"Well for sure…if I was using an electric [water] heater the electricity bill would go up and the same would go for using a gas stove in terms of the costs of buying more gas." (*Respondent 12MBDS*)



Figure 37 showing water being heated on a stove by combusting liquefied petroleum gas

Photograph taken by the Author

The respondents therefore referred to the use of LPG to heat water on their stoves where its costs and consumption would have been higher if not for solar water heating. Combusting LPG for heat energy was substituted for solar energy, and work such as Headley (1998), Perlack and Hinds (2003), Milton and Kaufman (2005), and Marzolf et al. (2015) touch on the LPG to solar substitution. This is important to consider for Trinidad's transition since the most widely used cooking fuel in Trinidad is LPG (Marzolf et al., 2015). Appendix I looks at the Trinidadians' incumbent water heating methods and it shows that the LPG to solar substitution will be a likely one.

In terms of solar hot water's impact on electricity, examples of responses are:

"It keeps it [referring to the electricity bill] lower because the switch [for the electrical backup booster] isn't used at all since it doesn't get cold enough to require using the switch to enable electrical heating of the water when solar energy is limited." (*Respondent 08FBDS*)

"During rainy months, when the booster [referring to the solar water heater's electrical backup] is turned on, it increases the bill - especially if you forget it on." (*Respondent 11FBDS*)

What this means is that solar hot water was perceived to have either reduced energy bills and consumption because of its adoption and subsequent usage i.e. electrical energy was substituted for solar energy, or the home's energy consumption and bills increased because the water heater's electrical auxiliary heater was used i.e. solar energy was substituted for electricity.

As shown by the respondents' accounts, using domestic solar water heating displaces the need for other heating fuels and electricity (NREL, 1996; Milton and Kaufman, 2005; Del Chiaro and Telleen-Lawton, 2007; Research and Economic Analysis Division, 2014). It saves households money and energy by reducing the consumption of energy supplied by the

incumbent system(s) and so too the costs of consumption (Headley, 1998; Milton and Kaufman, 2005; Hill et al., 2011; Kakaza and Folly, 2015).

This subsection illustrates that solar water heaters have been integrated into the energy culture's material culture; acquiring the solar water heater and flipping its electrical backup switch are practices; and associated norms are the perceived energy costs and consumption reductions that follow from adopting and using solar hot water, and vice versa when the electrical auxiliary heater is used. The emergence of new habits is thought to indicate energy culture shifts (Stephenson, 2012) so from comparing the Trinidadians and Barbadians' energy cultures it is likely that Barbados' underwent a cultural shift.

The awareness of solar's substitution for LPG and electricity also points to a cultural transition because the respondents' energy input norms have changed to include solar; producing electricity is also a way of developing a new culture of energy according to Wallenborn's (2008) take on the intersection of 'culture' and 'energy'. This point however is more fully looked at in the next section.

Since the energy usage and costs domains were dominated by electric-oriented features, the practice of flipping the electrical auxiliary switch means that the water heater is positioned outside of this main electrical cultural construct - much like the way in which distributed solar has tended to play a disruptive role outside the conventional, technical energy system (Manning, 2015). Therefore, electricity acts as a connector across the cultural transition space.

5.4. A Descriptive Overview of Energy Supply as a Domain

Modern industries and societies are linked through energy production, delivery and consumption (WEF, 2018). But energy supply and demand have often been treated as separate elements (Sovacool, 2009; Strengers, 2012) and they should instead be connected especially in the energy policy arena (Barton, 2013).

Therefore, investigating the energy supply will build a more holistic understanding of respondents' energy cultures because all cultures are dependent on sources of energy (Ruotsalainen et al., 2017).

Like the previous cultural domains, the energy supply domain also had a lead question: *'How does your household get energy?'* This was interesting to ask because it would give insight into what people believe are their energy (re)sources and where it comes from. It is further useful to consider because Chapter 2 showed that a popular metric from looking at energy transitions is the technical energy mix. This question was asked to explore the cultural side of this mix considering that the Barbadians use solar hot water in their homes which should diversify their household energy inputs.

The responses to this question also directly give insight into the norms that relate to the respondents' household energy inputs which complements their norms, material culture, practices and the external influences from the earlier sections to help detail what the incumbent energy cultures are like.

What is interesting to mention is that many respondents answered this domain's question with little to no elaboration. Notwithstanding their unwillingness to respond in detail as a limitation, this is worth stating because where one-word or one-phrase responses were

recorded, it could demonstrate how detailed their knowledge of their supply system needs to be.

Domain-wise there were 12 different sub-codes that emerged from the Trinidadians' energy culture and a total of 20 in the Barbadians'. However, there were a total of 30 different sub-codes observed across the islands which meant that only 2 sub-codes were common in both Trinidad and Barbados. Relative to the frequency of each sub-code recorded (i.e. the number of responses tagged with the given sub-code) the Trinidadians' 12 different sub-codes' frequency counts added up to 30 whilst the Barbadians' 30 different sub-codes amounted to 53.

Figures 38 and 39 (next two pages) show the households' energy inputs based on the respondents' accounts and frequency of sub-codes. Trinidad's showed only electricity and liquefied petroleum gas (LPG) as household energy inputs but in Barbados, electricity, LPG, batteries, and solar energy were recorded. In Trinidad 26 out of the 30 total sub-codes' frequencies related to electricity, 2 were associated with LPG, and 2 were other notions of the energy supply (*Respondent 03FTTD* viewed light and sound as forms of energy).

In Barbados 23 were associated with electricity, 4 with LPG, 1 with batteries, and 25 were linked to solar energy. Solar water heating therefore had a cultural impact on the household perception of where respondents get their energy from in Barbados. These findings also support the deductions in section 5.3. which suggest that Barbados likely experienced an energy culture shift due to the adoption and use of solar hot water.

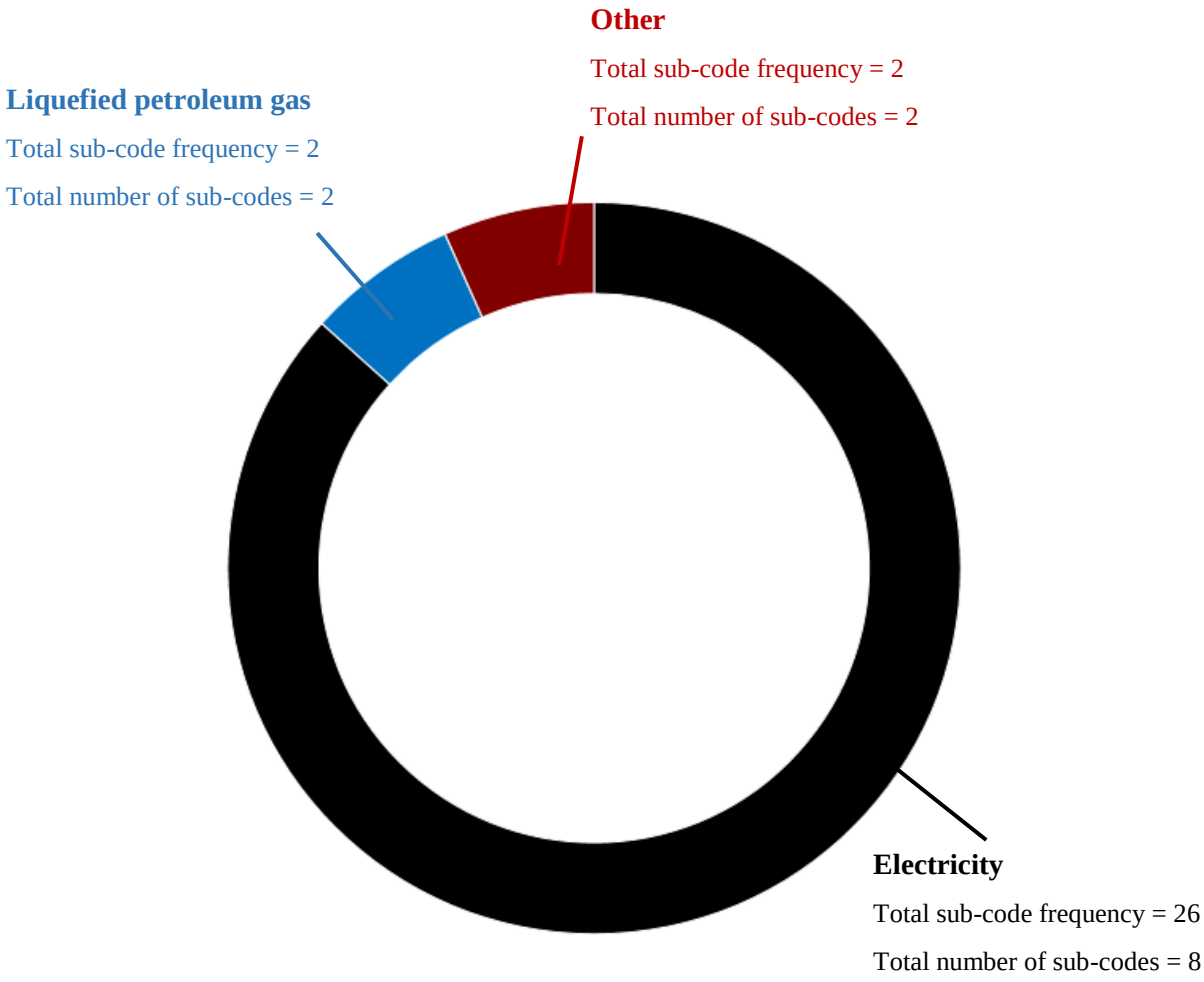


Figure 38 showing the breakdown of the Trinidadian household energy inputs that emerged from the inductive coding of the 16 respondents' answers within the energy supply domain

Note: The divisions are based on the total frequencies of the sub-codes that constitute each category of energy input and the frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
Generated by Author using Microsoft Excel

Table 15 (page 189) shows the combined distribution of the coding data for the electricity category in Barbados and Trinidad for convenience. At the island level, electricity had 8 different sub-codes in Trinidad and 5 in Barbados. These sub-codes' frequencies also accounted for 26 of the total 30 in Trinidad, and 23 of the total 53 in Barbados. The sub-codes

were subsumed in the understanding of electricity as a domestic energy input and hydrocarbons as its fuel source as sub-categories which consequently made up the electricity category (see Table 15 on the next page).

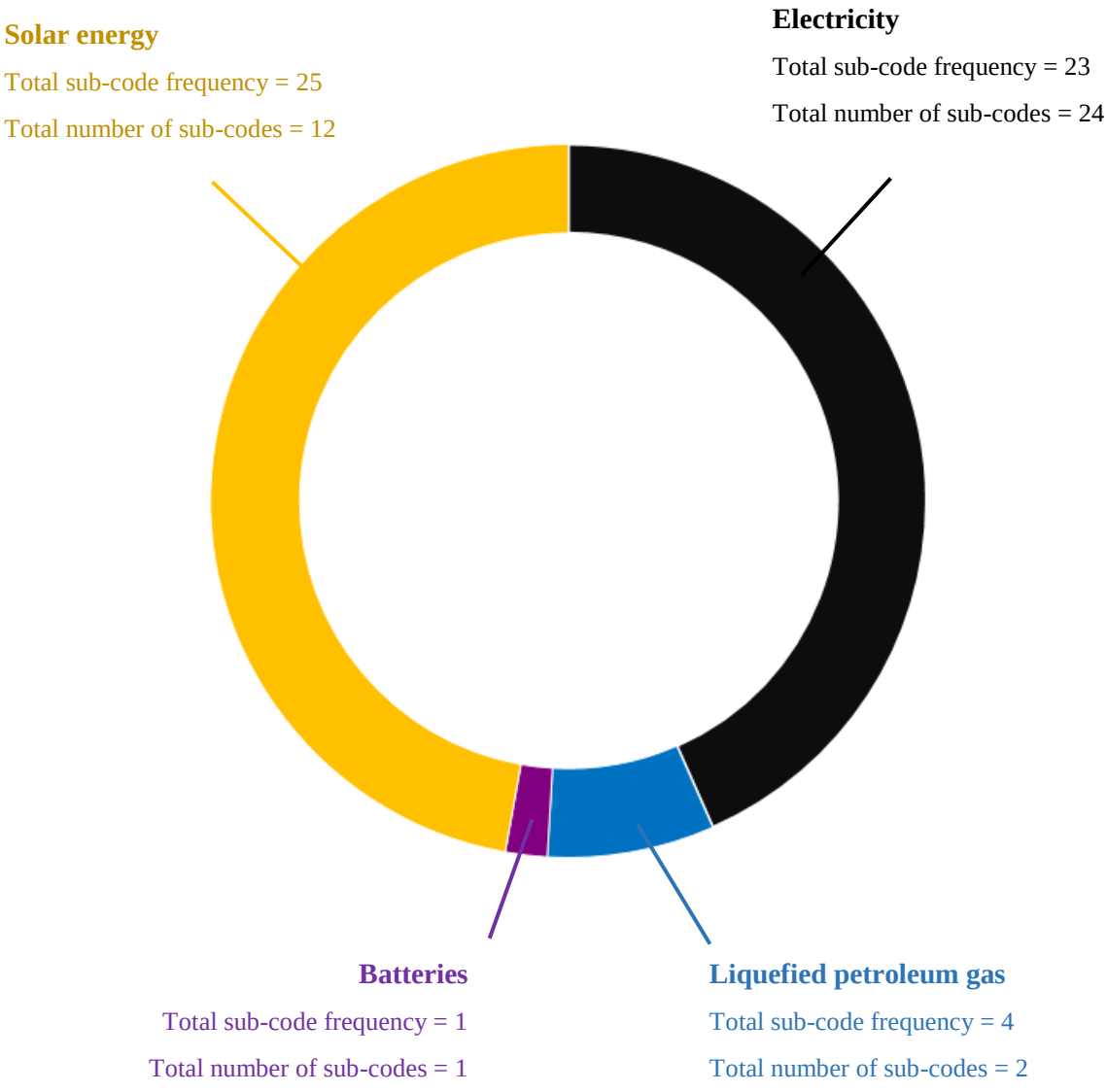


Figure 39 showing the breakdown of the Barbadians' household energy inputs that emerged from the inductive coding of the 17 respondents' answers within the energy supply domain

Note: The divisions are based on the total frequencies of the sub-codes that constitute each category of energy input and the frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.

Generated by Author using Microsoft Excel

CODING STRUCTURE				SUB-CODE FREQUENCY	
				BARBADOS	TRINIDAD
Electricity	Electricity is a domestic energy input	Homes use electrical energy		12	12
		Transmission and distribution infrastructure		0	2
		A single electric utility company provides electricity to homes	T&TEC provides energy	0	6
			BLP provides energy	7	0
			Electric utility provides electricity	2	0
			There is only 1 electric utility	1	0
	Hydrocarbons fuel electricity production	Fossil fuel is used as the power generation feedstock		1	0
		Natural gas fuels electricity production	Natural gas is used as the power generation feedstock	0	2
			Natural gas is sourced from offshore hydrocarbon reserves	0	1
		Power generation plants generate electricity through turbines	Power generation plant produces electricity	0	1
			Natural gas-powered turbines generate power	0	1
			Power generation plant location is known	0	1
CATEGORY	SUB-CATEGORY	CODE	SUB-CODE		

Table 15 showing the electricity-oriented sub-codes that emerged from the inductive coding of the 17 Barbadian and 16 Trinidadian respondents' answers within the energy supply domains

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
Generated by the Author using Microsoft Word

With respect to the hydrocarbons there were 5 sub-codes in Trinidad and 1 in Barbados. Table 15 shows that these were not amongst the most significant in the electricity category but were still important analytical considerations. The Barbadian response (from *Respondent 01MBDS*) outlined that energy comes from the utility which uses fossil fuels for power generation whilst in Trinidad 2 responses connected with hydrocarbons' role in providing their homes with energy. These 2 responses identified with natural gas use and is important to mention because oil could have been easily misconceived as the power generation feedstock:

"energy comes from electricity, which comes from [the] T&TEC [the utility company], which comes from [natural] gas." (*Respondent 14MTTD*)

The other, *Respondent 02MTTD*, stated that the natural gas resources come from offshore and drive gas turbines that generate power at a plant in Southern Trinidad. Table 16 provides the power production energy mix in each island for reference.

The table's columns showing the power production energy mixes for Barbados and Trinidad originally presented here cannot be made freely available via ORA because of copyright. The information were respectively sourced from:

Ince, D. 2017. Final Draft of the Energy Policy (2017 – 2037). Presented to the Division of Energy and Telecommunications at the Prime Minister's Office. Website: http://www.energy.gov.bb/web/component/docman/doc_download/76-final-draft-of-national-energy-policy (accessed 21st November, 2017)

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Table 16 showing the technical power production energy mixes of Barbados and Trinidad

Generated by the Author but adapted from Ince (2017; 26) (for Barbados) and Espinasa and Humpert (2016) (for Trinidad) using Microsoft Word

The most significant part of electricity's cultural framing was its direct reference during the interviews. 24 of the total 33 respondents outright connected with its usage as the prime domestic energy input. The sub-code associated with homes using electrical energy was the most significant of all the sub-codes in the analysis (see Table 15 on the previous page). It had a frequency of 12 in Trinidad as well as Barbados. Respondents provided answers like:

"Well electricity." (*Respondent 12FTTD*)

"Well from electricity from the sole electric company." (*Respondent 02MBDS*)

In Barbados electricity makes up nearly 14% of the demand in the energy mix (Ince, 2017) and around 3.6% in Trinidad (Espinasa and Humpert, 2016). Barbados' residential electricity consumption makes up nearly 33% of the island's electricity usage (Ince, 2017), and nearly 29% in Trinidad (Espinasa and Humpert, 2016). Data on the energy consumption breakdown in an average household was not available but electricity is expected to be the most widely consumed. These considerations show why it is so culturally important.

In Trinidad 2 responses showed that respondents were aware (however generically) of the existence of the technical network that supplies electricity to their homes as their household energy was perceived to come:

"from the grid." (*Respondent 15MTTD*)

The grid refers to the infrastructure used to generate, transmit and distribute electricity (Lofthouse et al., 2015; Citizens Advice, 2016) and is the external network that households are set within where energy generation and transformation connects energy and homes (Wallenborn, 2008); households are a part of a wider material infrastructure system including wires, power stations, appliances and even switches (Strengers, 2010).

Additionally, residents gave responses such as:

"Through T&TEC [the utility company, the Trinidad and Tobago Electricity Commission]." (*Respondent 01FTTD*)

"From the electric company, Barbados Light and Power." (*Respondent 09MBDS*)

The Trinidad and Tobago Electricity Commission (T&EC), and the Barbados Light and Power Company (BLP) are the electric utility companies on the islands of Trinidad and

Barbados respectively. Not only was the identification of the specific companies a unique trait in each energy culture, it fundamentally meant that the respondents connected with the fact that their supply of electricity comes from a sole electricity utility company. The sub-codes associated with the utilities in each island were the second most significant sub-codes to consider in the electricity category after homes' use of electrical energy; the BLP's sub-code was flagged 7 times whilst the T&TEC's was recorded 6 times (see Table 15 on page 189).

It is worth noting that whilst the analysis and interview recording focused on the explicitly stated information for transcription, interpretation and coding, it is reasonable to deduce that someone simply stating the company's name implies that electricity is used in the household. But specifically highlighting the company pinpoints the company's main function of electricity-provisioning as the answer to the question and not necessarily solely electricity.

From the types of responses presented thus far it is no surprise that electricity is more widely considered to be the most important energy carrier (Demirel, 2016). It is a necessity for living and once accessible becomes a prevalent part of households regardless of income (Hiemstra-van der Horst and Hovorka, 2008; Winther and Bouly de Lesdain, 2013); it has no substitutes (Sovacool, 2009; 367). So, provided that there is no transition away from electricity to another primary residential energy carrier, these chapter's findings should stand.

Another household energy resource was LPG. LPG is primarily made up of propane and butane (McGuire et al., 2009; Kojima, 2011; Sepp, 2014; Demirel, 2016). It is produced from oil and natural gas production; oil refining and gas purification (which yields the propane and butane); upstream transport, refining and storage; and then downstream transport, storage, bottling and retailing (U.S. Department of Energy, 2003; Kojima, 2011; Sepp, 2014; BW

LPG, 2015; Van Leeuwen et al., 2017).

LPG is the most common cooking fuel in the English-speaking Caribbean (Wartluft, 1984) and was flagged in 3 responses (2 Barbadians' and 1 Trinidadian's). There were 3 different sub-codes that arose from the responses: the RAMCO retails LPG cylinders; homes combust LPG for heat energy; and LPG is used for specified appliances. The LPG category's sub-codes accounted for 2 out of the 20 different sub-codes in Barbados, and 2 of the 12 in Trinidad. In terms of their frequencies, they made up 4 of Barbados' total 53, and 2 out of Trinidad's 30.

The 2 Barbadians explicitly stated that their stoves use gas whilst the Trinidadian, *Respondent 16FTTD*, stated that they purchase gas cylinders from the RAMCO Industries Limited (a Trinidadian LPG retail company) and implied that they used LPG through their stove - but the household cylinders commonly referred to as cooking gas, bottled gas, propane or butane are all connotations pointing towards LPG (McGuire et al., 2009; Van Leeuwen et al., 2017).

Electricity and LPG were observed in both islands, but two other energy inputs emerged in Barbados. The first was highlighted by 1 individual, *Respondent 10FBDS*, who stated that batteries powered some of their appliances; they did not specify the type(s) of batteries being referred to. The second input was more significant and was solar energy. Barbadian respondents gave responses such as:

"Practically, most, about 90% comes from [the] Barbados Light and Power [company] and 10% from solar water heating for the kitchen and bathroom." (*Respondent 05MBDS*)

"A SunPower water heater for bathing and washing dishes, electricity, and gas for the stove i.e. a bottle/tank of gas - I only have three sources." (*Respondent 15FBDS*)

There were 11 sub-codes that were structurally related through 4 codes, 2 sub-categories, and 1 solar energy category. Table 17 illustrates the relationships between these coding classes and their respective frequencies. This solar energy category was so significant that it accounted for 25 of Barbados' total sub-code frequency of 53.

CODING STRUCTURE				SUB-CODE FREQUENCY
Solar energy	Solar energy is a domestic energy input			9
	Distributed solar energy technology	Photovoltaic technology	Photovoltaics facilitates solar's utility as a domestic resource	1
			Photovoltaics involve electrical energy	1
			Ambiguity in how photovoltaics work	1
		Solar water heating technology	Solar water heating facilitates solar's utility as a domestic resource	6
			Solar water heating brand recognition	1
			Solar water heating location reference	1
	Solar technology operates within defined energy dimensions	Defined energy space for solar technology	Solar hot water used in defined energy spaces	1
			Photovoltaics used in defined energy spaces	1
		Defined energy service provision from solar technology	Solar hot water used for defined energy services	1
			Photovoltaics used for defined energy services	1
				1
CATEGORY	**SUB-CATEGORY**	**CODE**	**SUB-CODE**	

Table 17 showing the 'Solar energy' category's sub-codes that emerged from the inductive coding of the 17 Barbadian respondents' answers within the energy supply domain

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
Generated by the Author using Microsoft Word

The respondents not only connected with the sun as the resource, but also with the utility of photovoltaics and solar water heating - though photovoltaics was mentioned by only 1 respondent, *Respondent 03MBDS*, who owned outdoor solar lighting in addition to their solar water heater. By comparison solar water heating was recorded 6 times.

The solar technologies were noted to operate within defined energy spaces and used for defined practices. In the case of solar water heating, the technology provides hot water for bathing, or washing dishes and/or clothing (practices) that take place in the bathrooms or kitchens of homes (energy spaces); the quotes from *Respondent 05MBDS* and *Respondent 15FBDS* (page 193) provide references for this and Appendix I that looks at the incumbent hot water practices in the energy cultures contextualizes it.

5.5. Chapter Conclusions

A home's infrastructure creates cultural energy spaces for its residents. This analysis showed that the energy cultures of the respondents interviewed in Barbados and Trinidad are electricity-oriented; a cultural lock-in exists where the material culture is largely household appliances that have been designed to run on electrical energy, and many of the norms and practices have been institutionally locked-in to the relationship between homes and their electricity provider. This showed that electricity as a cultural notion is part of the regime but also the landscape of energy transitions (ETs) in the Multi-Level Perspective (MLP) of socio-technical ETs.

Given the cultural lock-in brought about by energy-provisioning, consumption and paying bills, the residents connect with the fact that using more energy correlates to higher costs - which is independent of changes in market-prices. The respondents' accounts of using their material culture was found to help explain the relationships between energy usage and its costs e.g. using more lights (the material culture and practice) means higher energy consumption and costs (the norm).

Material culture is also a cultural proxy for energy services as well as norms, practices and external influences. In the earlier lighting example, lights are the material culture; a norm is the expected increased visibility due to the illumination from the lighting fixture; and the darkness of nightfall is the external influence.

Related to energy services are the technological transitions happening in homes and transitioning to solar water heating may be one. The lighting transition observed from incandescent to light emitting diode and/or fluorescent options in Appendix F illustrates that the energy service i.e. lighting remained constant though the technology changed. So, the heating service through hot water may be constant despite there being a change to solar water heating from incumbent water heating methods such as electric water heating as would be the case in Trinidad (see Appendix I).

Appendix F's supporting discussions also show that the most consumptive appliances are not the most socio-culturally visible and this visibility will affect the timing of technological transitions (as would be the case for a transition to solar water heating). Owning an appliance does not automatically equate to high cultural visibility since this is dependent on the lifestyle contact energy users have with it.

Appendix F also shows that despite the variation in lifestyles that would account for cultural quirks, the respondents' perceived peak energy demand times align well with the conventional notion that technical energy consumption is usually at its highest in the evening; a daily phenomenon that is repeated enough to scale-up into a longer-term temporal feature in the landscape of the MLP.

Energy cultures are practical phenomena that are 'lived-in'. They vary in structural complexity from one regime to another and within the energy usage, costs and supply domains of an energy culture, there are multiple features that reside in and define it. But there are features that are more strongly expressed in one domain than another and even in one energy culture than another. This shows that energy cultures are highly convoluted and there is no distinct boundary between what constitutes culture during an ET.

An energy culture has features which have varying perceived socio-cultural salience over time so there is arguably no fixed constellation of features in any given energy culture or at any one point in time in an energy culture. Changes in the salience of cultural features are time-dependent and technological transitions are an example of a process that may spur changes in salience.

5.5.1. Answering the Research Questions

5.5.1.1. Conclusions for Trinidad's Residential Energy Culture and Solar Energy Adoption

At the end of this first of two cultural results chapters, a question that needs answering is how do these results give insight into the role(s) of culture in energy transitions (ETs). There are proactive and reactive roles that were found.

The thesis' first research question is: *How could the adoption of distributed residential solar energy technologies and the residential energy culture(s) of Trinidad affect each other?* The interaction more strongly investigated in this chapter was the impact of adoption on the

energy culture (the reactive role of culture); the next chapter will look more explicitly at the influence of the energy culture on adoption (the proactive role of culture).

However, it is worth highlighting that both the Barbadian and Trinidadian respondents' energy culture is electricity-oriented. This indicates that 'electricity' as a socio-technical construct is a cultural landscape force which can create a techno-cultural niche for electricity generating technologies like photovoltaics. The added landscape-level influence of external institutions on householders' presences in homes creates a more specific (though still broad) niche for grid-connected or battery-integrated photovoltaics.

However, whilst these are elements of culture that are socio-technically locked-in, they seem to exhibit a passive force on the regime - which is partly why household solar energy technologies have not been mainstreamed yet in Trinidad (in addition to the barriers raised in Chapter 4). Nevertheless, this shows that culture's role during an ET can be proactive.

In terms of the reactive role of culture, there was no prior understanding of Trinidad's residential energy culture let alone the potential cultural impact of adopting solar energy technologies. Therefore, the incumbent residential energy culture needed to be understood first, and only then could the impact(s) of adopting solar energy technologies be considered. The next two subsections illustrate the reactive aspects of culture.

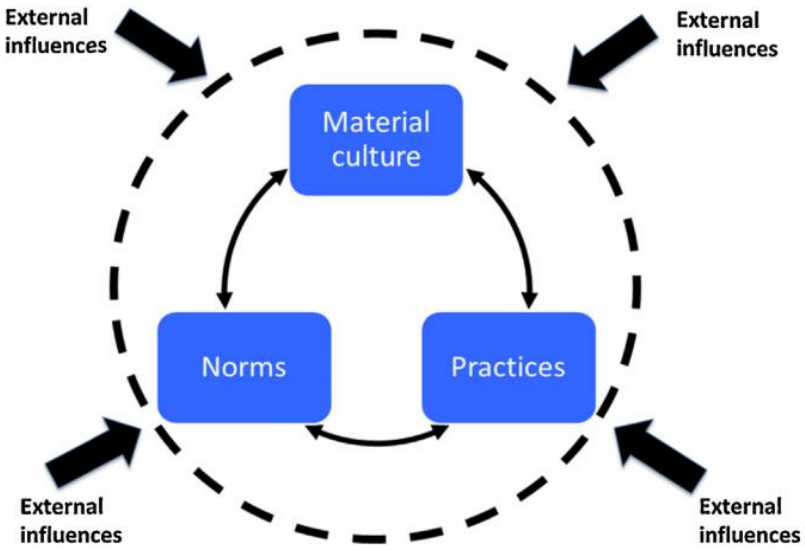
5.5.1.1.1. Trinidad's Incumbent Residential Energy Culture

The respondents' underlying energy culture is structured around the relationships between households and the electricity utility company, the Trinidad and Tobago Electricity

Commission (T&TEC). The company transmits and distributes electricity to households, and households consume and pay for this electricity. Figure 40 shows three examples of each of the incumbent energy culture's features.

External influences
E.g. tropical heat; retail electricity tariff; fuel costs

Material Culture
E.g. Air conditioners; refrigerators; televisions



Norms
E.g. the expectation and aspiration for cooler temperatures; the belief and expectation that using more appliances for longer periods of time increases the amount and costs of electricity; the belief that frequent power cuits can damage appliances

Practices
E.g. Showering; watching television; ironing

Figure 40 showing the 16 Trinidadians' incumbent energy culture

Adapted from Stephenson et al. (2015; 118) using Microsoft Word

The respondents' energy culture's electric-oriented structure is further seen with respect to the norms surrounding the perceived energy supply; the norms primarily relate to electricity and some liquefied petroleum gas. With respect to electricity, householders are aware that it is

generated by fossil fuels but at the interface of the technical household energy input and energy culture, electricity is the culturally salient norm.

The energy culture's underlying norms, practices and material culture are also strongly affected by the more specific external influence of institutions such as workplaces and schools - the energy culture evolved around energy behaviours that use the most energy during the evenings since householders are more likely to be at home at this time i.e. after work and/or school. This put the respondents' lives into the context of daily lifestyles, routines and habits.

5.5.1.1.2. The potential impact of adopting residential solar energy technologies on the incumbent energy culture using the example of solar water heating

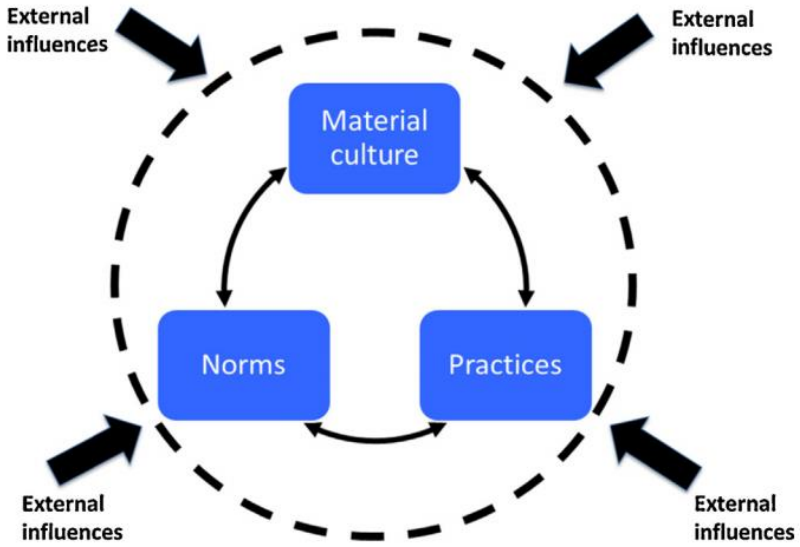
It is important to point out that different residential solar energy technologies will have different impacts on an energy culture. But solar water heating was the technology looked at in the comparison between the 17 Barbadians and 16 Trinidadians' energy cultures. Figure 41 (next page) summarizes the anticipated impacts on Trinidad's incumbent energy culture and its material culture, external influences, norms and practices.

Based on the comparison with Barbados' householders who adopted solar water heating, the first expected impact on Trinidad's energy culture is that the solar technology would become material culture.

A second impact is that the sun and weather would be maintained as external influences on the energy culture but expressed differently. They are present as external drivers of consumption such as cooling for example but through the adoption of solar, they will also be drivers of power generation.

External influences
1. The weather limits the hot water supply from the solar water heater because the incident sunlight on the system is limited

Material Culture
1. The solar water heater becomes a household appliance



Norms
1. Solar energy is a household energy input
2. Using solar water heating reduces the costs and consumption of liquefied petroleum gas
3. Using solar water heating reduces the costs and consumption of electricity
4. Flipping the electrical auxiliary heater switch increases the costs and consumption of electricity

Practices
1. Adopting the solar water heater
2. Flipping the electrical auxiliary heater switch
3. Usage of electric water heaters is discontinued

Figure 41 showing the expected impacts of adopting solar water heating on the Trinidadians' incumbent energy culture based on the impacts observed from the Barbadians' interviews

Adapted from Stephenson et al. (2015; 118) using Microsoft Word

Third is the development of new norms. There would be the belief that solar energy will be a household energy input in addition to the incumbent electricity and liquefied petroleum gas (LPG). Additionally, there would be an aspiration to reduce the costs and consumption of electricity and LPG. By adopting solar water heating this would be expected and by using solar water heating there would be the expectation that this will happen - particularly in the

case of electricity since switching on the solar water heater's electrical auxiliary heater increases the costs and consumption of electricity.

Fourth is the emergence of new practices. The most obvious practice would be adopting the solar water heater. Adopting the system is a compound practice that involves contacting retailers, paying for the system and having the system installed. Given that there are technological and resource substitutions surrounding the adoption and subsequent replacement of incumbent water heater methods e.g. electric water heaters in Barbados, discontinuing the use of incumbent water heating technologies represents the discontinuance of a practice and material culture transition. In addition, the actual flipping/not flipping of the solar water heater's electrical auxiliary heating switch is another practice.

It is clear that adopting distributed residential solar energy technologies will instigate an energy cultures shift and highlights reacting to changes as one role of culture during energy transitions. The fact that the new norms and practices are linked to electricity further shows that electricity acts as a cultural connector across this transition space.

5.5.1.2. Implications for Trinidad's Residential Solar Energy Policies

The thesis specifically investigates the interactions between culture and policy so it is worth highlighting the policy implications of the chapter's findings. The chapter's results led to several insights into how Trinidad's resident population's energy culture can influence and be influenced by State-level residential solar energy policies:

i. Policies are external influences. The energy cost domain is also the most sensitive to external influences, but the most impactful policies would affect the energy usage and costs domains based on the types of features listed in Appendix H.

ii. The energy cultures' features are predominantly related to electricity and its perceived peak consumption in the evening. This suggests that there is a broad niche for policies that support the continued use of electricity at this time of day without disruption to a given household's electricity supply and the quality of services it affords during these times.

iii. The development of new norms and practices, and acquisition of new material culture marks an energy cultures shift. Policies can directly and indirectly (through their supported technologies) catalyse cultural shifts, and these shifts will be dependent on the policy's design (as will be shown in Chapter 9).

iv. Technological (material culture) transitions unfold in energy cultures. This suggests that policies should capitalize on their technologies relative advantages since the incumbent technologies will be put up against the incoming solar technologies. Chapter 6 provides more detail on the relative advantages of solar energy.

v. Solar energy technologies and policy designs that allow households to use their solar energy in the home make it a norm. Policies that support the household consumption of solar energy in Trinidad would shorten the cultural gap between household energy usage and its supply.

5.5.2. Characterizing Mainstreaming

A lingering thought is how the chapter's findings characterize mainstreaming. The results show that:

i. Mainstreaming requires an awareness of the desired service(s) e.g. hot water; this will be more explicitly explored in the next chapter.

ii. Mainstreaming hinges on the adoption of technologies to provide the desired service(s) e.g. a solar water heater; this will be more explicitly looked at in the next chapter.

iii. Mainstreaming does not always involve complete household-level resource and/or technological substitutions, but they are often involved e.g. LPG or electricity being substituted for solar energy.

iv. Mainstreaming develops practices and norms that are associated with the technology e.g. flipping a solar water heater's electrical auxiliary heater switch (the practice) tends to increase energy consumption and its costs (norms). This gives the technology cultural structuration and makes it material culture.

v. Mainstreaming is most easily facilitated when the technology fits non-disruptively into a users' routines e.g. being able to use solar hot water in the evening when many householders take showers yet there is no incoming solar energy.

6.0. Understanding Solar Energy & Water Heating Adoption in Barbados & Trinidad's Energy Cultures

Synopsis

This chapter compares the understanding of solar energy and water heating in Barbados and Trinidad based on the inductive thematic content analysis of the 33 Barbadian and Trinidadian household interviews.

This chapter's characterization of the incumbent energy cultures of the residents interviewed in the two islands particularly provides insight into the proactive role of culture during energy transitions (ETs) - versus the predominantly reactive role looked at in the last chapter. This fulfils the aim of the thesis i.e. to explore the role(s) of culture in ETs.

The discussion in the chapter helps explore the impact(s) of energy cultures on the adoption of household solar energy technologies - which complements the reciprocal relationship looked at in the last chapter. This helps answer the first research sub-question, "*How could the adoption of distributed residential solar energy technologies and the residential energy culture(s) of Trinidad affect each other?*"

The thesis' research questions are geared towards exploring the ways in which culture can interact with the adoption of residential solar energy technologies and their supporting policies. The underlying structures of the energy cultures of both islands' respondents were characterized in the last chapter so this chapter explores solar energy and solar water heating in the context of these characterizations.

The chapter's data looks at elements of the mainstreaming space between the regime and niches in the Multi-Level Perspective (MLP), and specifically at the adoption of innovations which is central to mainstreaming in the MLP (see Chapter 2). It does so by looking at the respondents' views which fit into the stages of the innovation-decision process; the process outlines the way in which potential adopters gain knowledge about an innovation, become persuaded to use it, make the decision to adopt it, implement it, and later confirm the adoption of the innovation.

The respondents' energy cultures were explored based on interview questions that related to what residents believed to be solar energy (the knowledge stage); how solar water heating works (the knowledge stage); items of information they need and needed to obtain before adopting solar water heating (the knowledge and persuasion stages); the motivations for doing so (knowledge and persuasion stages); and the Barbadians' narratives on adopting solar water heating (decision, implementation and confirmation stages).

The chapter is structured as follows: section 6.1. outlines the respondents' conceptualizations of solar energy and solar water heating; section 6.2. looks at the desired information about and motivations for adopting water heating technologies, as well as the Barbadian respondents' narratives on adopting solar water heating; and section 6.3. presents the chapter's conclusions and how they answer the cultural research sub-question, the conclusions' policy implications, and characterizes mainstreaming based on the findings from the chapter.

6.1. The Cultural Understanding of Solar Energy and Solar Water Heating

6.1.1. The Conceptualization of Solar Energy

The respondents were asked: '*Can you define solar energy?*' This question was asked so that there was some 'baseline' of what respondents' perceptions of solar energy as a resource was in a sample that has not adopted household solar energy technologies (Trinidad's) and one that has (Barbados').

It focuses on the "*distributed residential solar energy technologies*" phrase of the first research sub-question (see page 205) and separates it into the resource and technology so that each could be studied in relation to Rogers' innovation-decision process that relates to the process potential adopters go through when making an adoption decision i.e. knowledge, persuasion, decision, implementation and confirmation (see Rogers (1983)). This subsection's question targets the knowledge stage of that process.

It was also a useful question to ask because distributed renewable energy technologies can create stronger links between the energy (re)source and the energy users because of the technologies' proximity to the point of consumption - the responses to this question would have shown what norms related to solar energy exist, if any at all, independently of adopting any solar energy technologies (in the Trinidadians' case).

Analysing the responses produced 34 different sub-codes in Trinidad and 21 in Barbados; this disparity may not necessarily be attributable to solar hot water adoption in Barbados however. There are 3 central observations: the use of sunlight as a resource, the need for technology to make it practical, and solar energy's relative advantages.

The fundamental acknowledgement that the sun is the energy source and sunlight is the resource was highlighted by 11 Trinidadians and 13 Barbadians through responses such as:

"Energy from the sunlight." (*Respondent 07MTTD*)

"The sun propels solar energy." (*Respondent 09MBDS*)

The sub-code for the energy source being the sun was the most salient.

2 responses in Trinidad further suggested that solar energy was a form of natural energy; one described it as being made up of different wavelengths; and another acknowledged its extra-terrestrial origins as shown by the following:

"Harnessing the natural energy that comes from the sunlight - [and] filtering it to power households or anything." (*Respondent 05FTTD*)

"Energy that comes directly from the solar system." (*Respondent 13MTTD*)

"The energy transmitted by all the various wavelengths from the sun." (*Respondent 15MTTD*)

In addition to the sun and sunlight as core concepts in Barbados, 3 responses described solar energy as a renewable, alternative, and natural form of energy e.g.:

"Well I would say that it's some form of alternative energy not fossil fuel." (*Respondent 03MBDS*)

"Renewable energy that we get from the sun." (*Respondent 11FBDS*)

Relative to the second observation, the use of technology to make solar energy practical, 3 Trinidadians' responses mentioned the need for a solar collector surface:

"There is a glass dish [a solar collector surface] that is put out in the sun to store current…" (*Respondent 09MTTD*)

"Solar energy is using the sunlight [by] using solar panels that convert the electricity and store

it in batteries." (*Respondent 14MTTD*)

"Provision of power through cells which are themselves receiving energy from the sun." (*Respondent 16FTTD*)

In Barbados 3 responses stated:

"[A] transfer of heat to electrical energy using solar [energy]. [It's a] light to electricity [conversion] using photosensors." (*Respondent 01MBDS*)

"Radiation from the sunlight that causes your panels to remain heated." (*Respondent 06MBDS*)

"…comes from the sun and you can use the panels to conduct energy through the house." (*Respondent 08FBDS*)

An interesting observation from the quotes in both islands is that the technological references were largely related to photovoltaics which convert the sun's radiation into electricity which is then transformed by an inverter to the appropriate currents and voltages (van Leeuwen et al., 2012). This is not surprising since the residential market is the most attractive market for photovoltaics (Islam, 2013), and traditional photovoltaic panels have come to epitomize rooftop solar as the mainstream solar technology globally (WEF, 2013; WEC, 2016).

Beyond these material references, 4 Trinidadians additionally suggested that using solar energy involved an energy conversion. *Respondent 14MTTD*'s earlier quote (previous page) is an example and another is:

"…and has a plug that attaches it to a converter as well as a cable which connects it to the household so that the various household appliances can be used." (*Respondent 09MTTD*)

This response particularly suggested that a converter was required to use solar energy. Photovoltaic systems produce a direct current (DC). However, the utility's electricity

provided to homes is an alternating current (AC). So, depending on the type of appliance either DC or AC can be used. But when the latter is needed from photovoltaics, an inverter is required to convert DC to AC (Goss, 2010; The NEED Project, 2016); the converter being referred to by *Respondent 09MTTD* was more than likely this inverter. *Respondent 01MBDS*' earlier quote (previous page) that touched on the heat to electrical energy transfer serves as a conversion example from Barbados.

Other technological references were energy storage and wiring. *Respondent 09MTTD* and *Respondent 14MTTD*'s quotes (page 208 and 209) show the electricity storage-related answers - these were the only 2 responses that included electricity storage-related responses to this subsection's lead question in both islands.

Respondent 09MTTD's quote identifies with the cabling needed to connect the solar system to the home's energy appliances and was the only response that led to a sub-code for wiring in Trinidad. *Respondent 08FBDS*' earlier quoted response on the previous page also implied the need for wiring in Barbados. The respondents therefore described solar collector surfaces, energy conversions, energy storage, and wiring as the technological components of solar energy.

The final observation is solar energy's relative advantages. Relative advantages refer to the extent to which an innovation is perceived as being better than the one it supersedes, and it is often expressed through economic profit and social status (Rogers, 1983). So, this means that solar energy is perceived to have advantages over the incumbent household energy used.

At the systems-level common examples are reduced fossil fuel consumption; reduced need for constructing conventional power generation stations; reduced greenhouse gas emissions;

health benefits from reduced emissions; blackout and power outage mitigation; reduced peak energy demand; reduced electricity transmission and distribution costs; job creation; and use of a ubiquitous resource (Grover, 2007; Naspolini et al., 2010; Kabir et al., 2017; Niu et al., 2017; Kabir et al., 2018).

At the building level examples are increased property value; localized electricity generation; use of a freely available resource; economic benefits from incentives (if available); low maintenance costs; convenience in terms of time and effort spent on sourcing and paying for energy in some cases; reduced energy bills and consumption; lower dependence on public infrastructure; and low operational environmental impact (Naspolini et al., 2010; Leaman, 2015; Kabir et al., 2017; Niu et al., 2017).

In Trinidad 3 responses connected with solar energy technologies' potential to save on energy costs e.g.:

"Using the resources of the sun to save money." (*Respondent 06MTTD*)

"Something that could cost you less than [the] T&TEC [the Trinidad and Tobago Electricity Commission, the utility company]." (*Respondent 08MTTD*)

Respondent 06MTTD's quote hints that because sunlight is freely available versus paying for the incumbent energy used, the sun's energy is directly translatable into monetary savings. *Respondent 08MTTD*'s quote shows that there is the belief that the Trinidad and Tobago Electricity Commission's services can not only be substituted with solar energy, but also that solar energy can act as a substitute for the present sources of electricity.

But these came with *Respondent 11MTTD* acknowledging that the costs of solar energy are still somewhat of a moderating factor at present - given that solar technologies usually have

high initial investment costs (Naspolini et al., 2010; Mathews and Mathews, 2016; Kabir et al., 2017).

Respondent 10MTTD suggested that another advantage would be appliance damage mitigation where any appliance damage due to power outages could be reduced if solar energy is used. Additionally, *Respondent 11MTTD* implied that solar is further advantageous because hydrocarbons are finite when they said that:

"at some point in time, oil and natural gas will become limited." (*Respondent 11MTTD*)

A final relative advantage in Trinidad came from *Respondent 03FTTD* who suggested that solar energy is a strategy that can mitigate climate change since:

"it helps with addressing global warming." (*Respondent 03FTTD*)

In Barbados 2 responses led to sub-codes tied to the savings from solar energy. *Respondent 15FBDS* outlined that solar panels were being installed in their area by the utility company and that it should lower their bills once the installation was complete and power was being generated. In a similar trend of thought the other suggested that:

"solar energy is really the future in terms of bringing down the cost of living." (*Respondent 05MBDS*)

These also suggested that the conceptualization of solar energy was one that is sensitive to it being a substitute for the incumbent electricity as noted in Trinidad.

Based on the data in this subsection, there seems to be a comparable cognizance of solar energy in Trinidad and Barbados where the respondents' beliefs, expectations and aspirations

tied to solar energy are centred on it as a resource but are also sensitive to technologies and technicalities, and relative advantages.

6.1.2. The Conceptualization of Solar Water Heating

The level of culturally salient detail was gauged by asking respondents in Barbados and Trinidad: *'How do you think a solar water heater works?'* This question was asked for similar reasons as the one from the previous subsection - so that there was some 'baseline' of what respondents' perceptions of solar water heating as a technology was in a sample that has not adopted household solar energy technologies (Trinidad's) and one that has (Barbados').

It therefore complements the last subsection's focus on the resource by now focusing on the technology the resource powers relative to the knowledge stage of the innovation-decision process. Again, this question was useful to see if respondents' understanding of the technology is stronger because they have adopted it, as well as if there are any norms related to the use of the technology independent of having adopted it (in the Trinidadians' case).

52 sub-codes emerged from the Trinidadians' responses and 34 from the Barbadians'; only 2 of the Barbadians' sub-codes did not scale up into the central conceptualization of how the system worked versus 20 in Trinidad. This meant that the respondents' core understandings of solar water heating were made up of 32 sub-codes each.

An interesting point to bring up is that Trinidad's sample also produced more sub-codes than Barbados' in the earlier section on solar energy (34:21 respectively). But relative to the responses to this subsection's lead question, the sub-code counts may support the fact that adopting the technology created a higher degree cultural consensus about solar water heating.

The sub-codes that emerged from the Trinidadians' responses can be seen in Table 18. The fact that solar water heating was powered by the sun was flagged in 10 responses and this was the most prominent sub-code. But the sub-codes can be put into a narrative.

FREQUENCY	SUB-CODE
10	Powered by the sun
7	Heat energy transfer
4	Diurnal availability of solar energy
4	Water circulation and flow of water involved in the system
4	Storage tank connection
3	Solar panels collect solar energy
3	Piping connectivity
3	Similar functioning to conventional electric water heating
2	Energy conversion
2	Solar cells collect solar energy
2	Similar functioning to solar lighting
2	Solar water heater has to be installed
1	Solar water heating can function during rainy periods
1	Solar water heating capitalizes on ambient heat beyond direct sunlight
1	Solar water heating capitalizes on a certain light wavelength of the sun's energy
1	Sunlight is made up of different light wavelengths
1	Solar energy to heat energy conversion
1	Solar collectors collect solar energy
1	Solar glass dish collects solar energy
1	Heat energy reflection
1	Heat energy storage
1	Heat energy trapped
1	Coils heat piping
1	Metal tubes encased in glass
1	Metal tubes' material store heat
1	Metal tubes connected to storage tank
1	Solar water heating has heat tubing connected to the storage tank
1	Different to electric water heating since it cannot heat running water
1	Solar water heating needs storage capacity to be effective
1	Storage connection
1	Solar water heating can be installed on the ground
1	Solar water heating can be installed on the roof

Table 18 showing the sub-codes that emerged from the inductive coding of the 16 Trinidadian respondents' conceptualization of how solar water heaters work

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
Generated by the Author using Microsoft Word

Solar energy as a resource: Respondents acknowledged the sun as the source of energy for solar water heating and that it is only available during the day through responses like:

"Heating the water using the sun..." (*Respondent 01FTTD*)

However, this aspect of the coding was sensitive to the fact that sunlight is made up of different wavelengths and solar water heaters are believed to capture a certain wavelength of the spectrum e.g.:

"Converting the relevant [light] spectrum from the sun to provide energy for [the] warming up of the water for your shower." (*Respondent 15MTTD*)

There was also the belief that solar water heating can function during rainy periods because it is able to utilize the ambient heat beyond direct sunlight according to *Respondent 06MTTD*.

Solar collector surface: The incoming solar energy was believed to be captured by a solar collector that coverts solar radiation into heat and there were references to generic collector surfaces, panels, cells, and glass dishes e.g.:

"There are also solar water heater tanks with solar collectors used to heat and store water." (*Respondent 02MTTD*)

"Solar panels trap sunlight and has the ability to store this energy as an attachment to a water heater to transmit the energy to heat the water." (*Respondent 13MTTD*)

Heat transfer and water circulation: The respondents suggested that the solar collector enabled an energy conversion where there is a heat energy transfer such that thermal energy is trapped, stored, and reflected during the actual water heating. The heat was thought to be applied to the water via circulation plumbing.

Respondent 06MTTD thought that the system had metal pipes which enable the water heating as part of the circulation system. Another, *Respondent 14MTTD*, said that some solar water heating technologies use coils to heat the water. Nevertheless, the hot water plumbing leads to a storage tank. Responses included examples such as:

"There are metal tubes made out of a material that stores heat - [they are] surrounded by glass that gets hot. The top of the tubes run into the storage tank and the water is transferred down [from the storage tank] into the pipes." (*Respondent 06MTTD*)

"I never saw one in real but through the internet, [specifically] YouTube, there seems to be water pipes involved where some do-it-at-home versions have foil paper that reflect heat towards the piping and others that use coils for heating." (*Respondent 14MTTD*)

Water storage: 2 respondents, *Respondent 05FTTD* and *Respondent 06MTTD*, outlined that solar water heating uses a storage tank that is connected to the water circulation system. *Respondent 05FTTD* believed that solar water heating was different to electric water heating because the former cannot heat running water which meant that it needs a storage reservoir to be effective.

Installation: Respondents identified with solar water heating as a technology that needs to be installed. But *Respondent 02MTTD*'s answer was of particular interest because they outlined that solar water heating can be installed on the ground or roof of a home. Though they did not mention a specific solar water heater design, their views surrounding installation drew on references to passive systems:

"There are several different types. Piping from natural sunlight where one lays a grid of PVC [Polyvinyl Chloride] pipes on the roof and the sun heats it - it gets very hot. Laying it on the roof allows the water to flow. Pipes can also be in the ground and that gets hot as well." (*Respondent 02MTTD*)

With this idea of how the Trinidadian respondents believed solar water heating worked, the

overall idea of the system could best be described as a technological installation that converts sunlight into thermal energy which is transferred to the water circulating in the system and later stored for providing hot water.

But beyond this general understanding there were also potential technological misconceptions worth highlighting. There were references to photovoltaics which is solar electricity versus the solar thermal used for heating water. Respondents outlined photovoltaic systems' connections and the potential for energy storage through responses such as:

"There is a glass dish [a solar collector surface] that is put out in the sun to store current and has a plug that attaches it to a converter as well as a cable which connects it to the household so that the various household appliances can be used." (*Respondent 09MTTD*)

These photovoltaic references were also accompanied by references to smaller-scaled applications such as solar lighting e.g.:

"[Solar water heating] Works on a similar principle as the solar garden lights." (*Respondent 01FTTD*)

"I have solar lighting outside, but I only bought 1 as a trial before buying more. It has worked consistently well so far so solar water heating should work well also." (*Respondent 16FTTD*)

These misconceptions came with some respondents simply not knowing how solar water heating worked, having never seen the technology, or even not being aware it exists e.g.:

"It breaks down usage in electricity. It functions similar[ly] to an electric water heater but uses the sun instead. I'd prefer to use that if it's invented." (*Respondent 12FTTD*)

Table 19 (next page) shows the sub-codes that emerged from coding the Barbadians' responses. 15 respondents' answers connected with the power of the sun as the energy

resource driving solar water heating and this was the most frequent sub-code. But like in the Trinidadians' energy culture, these sub-codes also had an operational narrative.

FREQUENCY	SUB-CODE
15	Powered by the sun
10	Heat energy transfer
6	Storage tank connection
4	A solar water heater has an electrical backup booster
4	Solar panels collect solar energy
3	Diurnal availability of solar energy
2	A solar water heater has an internal household switch
2	A solar water heater has a heating element
2	Electrical backup (through the household switch) used in rainy periods
2	Acknowledges that it takes time to heat and fill the storage tank so the process is not instantaneous
2	Water circulation and flow of water involved in the system
2	Solar glass panel collects solar energy
1	A solar water heater is a machine.
1	Cold water input
1	Electric water heating still requires some time before providing hot water
1	Electricity may support water heating during decreased solar radiation periods
1	Energy transfer
1	Hot/cold water piping connectivity
1	Prolonged decreased solar radiation means the stored water cools over time
1	Reduced sunlight means reduced output
1	Similar functioning to conventional electric water heating
1	Solar glass panel made of copper pipes
1	Solar plates collect solar energy
1	Solar surface collects solar energy
1	Solar water heater has a built-in thermostat
1	Solar water heater has cathodes/anodes
1	Solar water heating can be installed on the roof
1	Solar water heating can be installed on the roof or ground-level
1	Solar water heating has practical utility
1	Solar water heating provides instantaneous hot water
1	Storage connection
1	Use is generally unrestricted once the system is at capacity

Table 19 showing the sub-codes that emerged from the inductive coding of the 17 Barbadian respondents' conceptualization of how solar water heaters work

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
Generated by the Author using Microsoft Word

Solar energy as a resource: The respondents outlined that sunlight drives the system's performance and when it is limited the hot water provided is consequently affected. Examples of responses are:

"When the sun is out, light rays shine into something that generates energy and [is] linked to the water." (*Respondent 03FBDS*)

Solar collector surface: The respondents acknowledged that the system used a solar collector surface to trap the incoming solar energy. They provided answers such as:

"I believe that through the panels sunlight is trapped and filtered-in and heats up the water." (*Respondent 08FBDS*)

"It has panels to heat the water." (*Respondent 13MBDS*)

Heat transfer and water circulation: As hinted by the earlier quotes, the collected energy is transferred as thermal energy to the water, and so done through plumbing. *Respondent 02MBDS* provided the most apt quote to illustrate this:

"Cold water passes through a solar glass panel with copper pipes in there. The water is transferred to the tank on the roof or ground and it's heated and kept in there for a while - because when it's rainy for several days, the water in the tank doesn't get cold but rather cool." (*Respondent 02MBDS*)

Water storage: The tank referred to in *Respondent 02MBDS*' quote above is the solar water heater's storage tank for the heated water. Other respondents connected with this component through responses such as:

"From using sunlight and it stores water." (*Respondent 03MBDS*)

"The sun's heat is converted to heat to heat the water in the storage tank." (*Respondent 12MBDS*)

Installation: Respondents acknowledged that a solar water heater is a machine made up of a series of components working in a system that needs installing e.g.:

"A solar water heater is a machine that converts the sun's energy into energy I can use." (*Respondent 14MBDS*)

"It is installed on the house. The hot water pipes are connected to the cold pipes which take it to the tank and the sun generates a certain amount of heat during the day to heat the water." (*Respondent 15FBDS*)

Electrical backup: A solar water heater was thought to have an electrical auxiliary backup switch that enables the water circulating in the system to be heated by electrical energy instead of solar energy - and is particularly useful during times of low radiation such as during rain events. For example, respondents said:

"But if rainfalls…you use the electrical booster by flipping the switch." (*Respondent 06MBDS*)

"If you have 2 cool days without sunlight you can use the electrical booster to heat the water." (*Respondent 09MBDS*)

Based on this narrative the Barbadian respondents' solar water heater cognizance could best be summarized as it being an installed technology that relies on the availability of sunlight incident on its solar collector to effectively transfer thermal energy to its cold water input which can be then stored as hot water - and the heating can be supplemented by conventional electric water heating during periods of limited sunlight by flipping the related switch.

The first similarity worth pointing out between the energy cultures is that there was some conceptual consistency between the notions of 'solar energy' and its application through the 'solar water heater' i.e. a resource and technology consistency because the role of the sun and sunlight was found to be the key feature of both.

Further commonalities were the fact that solar water heaters are affected by the diurnal availability of sunlight; use a solar collector surface to capture sunlight; enable heat energy transfers; circulate water; and store water in storage tanks. This demonstrates that there was a comparable notion of what the technology is and does which exists independently of adopting the technology itself in the Trinidadians' case - though there were still uncertainties and misconceptions that were more prominently recognized in the Trinidadians' energy culture surrounding photovoltaics.

The main difference is the electrical backup switch's relationship to the system's water heating which was pointed out by the Barbadians. This is quite significant because it supports the findings in the last chapter that outlined that the Barbadians' energy culture experienced an energy culture shift related to the norms and practices behind flipping the electrical backup switch that were developed post-solar water heater adoption.

6.2. Detailing the Adoption of Solar Water Heating

6.2.1. The Pre-Adoption Information and Adoption Motivations

6.2.1.1. The pre-adoption information

In light of the barriers to solar energy adoption raised in Chapter 4, the previous subsections' misconceptions and uncertainties show the value of information especially for the Trinidadians - since people may not adopt solar energy technologies because of information deficits (Attari and Rajagopal, 2015).

This subsection looks at the pre-adoption information respondents would want (in Trinidad) and wanted (in Barbados); each group was respectively asked: '*What specific information would you like (to have) if you were thinking of getting solar energy technology like solar water heating for your home?*', and '*What specific information did you look for when you were thinking of getting solar water heating for your home?'*

These questions are directly related to the knowledge and persuasion stages of adopting innovations in what Rogers refers to as the innovation-decision process (see Rogers (1983)). Additionally, adoption is central to mainstreaming (see Chapter 2) which means that the data is quite useful for understanding mainstreaming. Analysing the Trinidadians' responses resulted in 27 different sub-codes, and 1 main retail market theme/concept. Table 20 (next page) shows their coding relationships.

Table 20 shows that there were 2 sub-codes outside the main coding structure: *Respondent 02MTTD* wanted to gain a better understanding of the plumbing requirements for solar water heating since their home had a pre-existing plumbing system from an older standing-tank electric water heater (see Figure 42 on page 224) which was condemned after they installed a showerhead version (see Figure 43 on page 224) instead, and *Respondent 07MTTD* who wanted to know how the weather and local sunlight availability would affect the solar water heater's rate of cold to hot water conversion.

Table 20 shows that the respondents' information requirements largely scaled-up into industrial and technological categories of the retail market. The industrial category was built on references to the retailers' installation, maintenance and auxiliary services. Respondents wanted to know more about the general convenience of installing, flexibility of where the

system could be installed in and/or around the home, and what is involved in the actual installation process. Respondents also wanted generic information about the system's maintenance, the replacement regimen for the solar collector, availability of trained personnel to service the system, and the convenience of the maintenance. Lastly, auxiliary services specifically referred to any warranties that solar water heater systems may have.

CODING STRUCTURE			SUB-CODE FREQUENCY
THEME/CONCEPT	CATEGORY	SUB-CODE	
Retail market	Industry services	Installation convenience	1
		Installation flexibility	2
		Installation process	2
		Maintenance	3
		Replacement regimen for parts	1
		Maintenance convenience	1
		Support services available	1
		Warranties available	3
	Technological market	Brands available	1
		Capacities available	1
		Types available	1
		Temperature guarantee	1
		Hot water residence time	1
		Lifetime	2
		Durability	1
		Effectiveness	2
		Reliability	3
		Efficiency	1
		Safety	2
		Operability	2
		Usability	1
		Lifestyle compatibility	1
		Cost vs. conventional electricity	1
		Cost	9
		Installation cost	1
Other		Plumbing requirements	1
		Natural solar energy potential	1

Table 20 showing the basic inductive coding structure relating to the information that the 16 Trinidadian respondents would want before adopting solar water heating

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
Generated by the Author using Microsoft Word

The image showing an example of a standing-tank electric water heater's storage tank originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Cape Plumbing Incorporated. 2018. Water Heater Repair Fort Lauderdale FL. Water Heater. Website: http://www.capeplumbinginc.com/water-heater-services-fort-lauderdale/ (accessed 13th April, 2018)

Figure 42 showing an example of a standing-tank electric water heater's hot water storage tank

Extracted from Cape Plumbing Incorporated (2018)

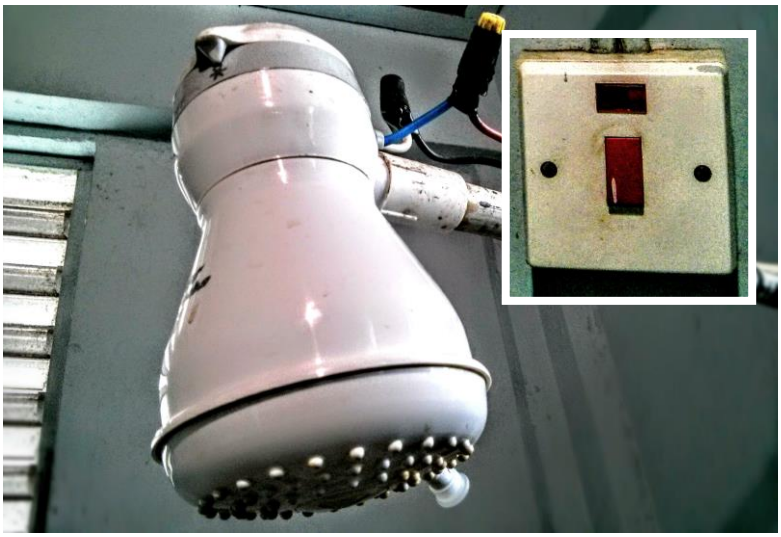


Figure 43 showing an example of a showerhead electric water heater installation and its on/off switch as the inset

Photographs taken by the Author

In the technological category the information desired was the technologies available on the market, technologies' designs, and their cost-effectiveness. The marketed technologies referred to the systems available for purchase from retailers and specifically captured brands, capacities, types of systems, temperature guarantees and hot water residence times in the storage tank. The information required on the technologies' designs were centred on the solar water heater's longevity, performance and utility. Respondents wanted information on the lifetime; durability; effectiveness; reliability; efficiency; safety; operability; usability; and lifestyle compatibility.

With respect to cost-effectiveness, the information respondents wanted related to the system's costs, installation costs as well as the relative advantages of the system versus conventional electrical water heating costs. This cost aspect of the coding was the most salient observation as shown by the frequency for cost in Table 20 (page 223) where it was flagged 9 times.

Examples of phrases that led to some of the above observations are:

"How durable it [the solar water heater] is…" (*Respondent 12FTTD*)

"Since there would be a water flow in the [solar water heater's] system where hot water flows out and cold water comes in, I would want to know how long the water would be able to stay hot, and I would also like information pertaining to the reliability of the system in terms of the costs of it versus it performing how it should." (*Respondent 14MTTD*)

The coding of the Barbadians' responses produced 20 different sub-codes and like Trinidad's, were linked to 1 main retail market theme/concept; Table 21 (next page) shows the relationships between the codes. Compared to Trinidad's coding, Barbados' showed a lesser number of emergent sub-codes (27 versus 20 respectively).

This may have been as a result of the Barbadians' memory since they would have been answering based on when they adopted their solar water heaters - which for some was as long ago as 1983. In addition, the Trinidadian respondents have had no substantial contact time with solar energy technologies and would have desired more information to satisfy their pre-adoption 'curiosity' as it were.

CODING STRUCTURE			SUB-CODE FREQUENCY
THEME/CONCEPT	CATEGORY	SUB-CODE	
Retail market	Retailers' systems in stock	Operability	1
		Effectiveness	1
		Reliability	1
		Retailer system durability	1
		Lifetime	1
		Capacities available	5
		Retailer system capacities available	2
		Retailer system types available	1
	Retailer services	Retailer system maintenance regimen	2
		Cost	1
		Retailer system capital cost	1
		Retailer system cost	1
		Retail cost package	1
		Market retailers	3
		Popular market retailers	1
		Cost vs. conventional electric water heating	1
	Other	Consumer experiences with retailers	1
		Household size impact	1
		Infrastructural house size impact	1
No information desired			5

Table 21 showing the basic inductive coding structure relating to the information that the 17 Barbadian respondents wanted before adopting their solar water heating

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
Generated by the Author using Microsoft Word

The first observation of note is that there were 5 respondents whose responses indicated that they did not search for any information prior to purchasing their systems e.g.:

"None. We were building the house at the time and I went to a sale and it was offered for 500 dollars [Barbadian dollars]. You wouldn't take it at that price? I asked someone the average price for such a system just to compare prices and was told it is usually around 5,000 dollars." (*Respondent 10FBDS*)

"None actually. We were using solar power since the early [19]80s and got it because we needed hot water at the taps for showering and that sort of thing." (*Respondent 13MBDS*)

Based on such statements it is easy to see why residents consider solar water heating as a common consumer good bought to meet lifestyle demands (Niu et al., 2017).

Other observations came from *Respondent 07FBDS* who wanted to know how the size of their home and number of persons in the home would have affected their solar water heating needs. *Respondent 16FBDS* was also interested in getting user-testimonials from others who have used solar water heating.

The retail market coding was built on the retailers' systems in stock, and their services as categories. With respect to the former the systems' operability; performance i.e. effectiveness and reliability; longevity i.e. durability and lifetime; capacities; and types of systems the retailers had available for sale emerged as sub-codes. The most salient information respondents sought however was related to the capacities of the solar water heaters available and its sub-code was flagged 7 times (see Table 21 on the previous page).

The retailers and their services' category had sub-codes centred on costs and the retailers' presence in the market. The costs were associated with not only the systems' costs but the retailers' cost packages since their services often include the system's cost in the final quote. One cost-related observation from *Respondent 09MBDS*'s response also outlined the relative advantages of solar versus conventional electric water heating especially as it pertained to the costs of continuously replacing the elements i.e. the technical heating component of the latter.

In terms of the retailers' presence, respondents sought to find out who were the retailers on the market and a respondent, *Respondent 04FBDS*, even pointed out that they wanted to know who the popular suppliers were.

Examples of responses which led to some of the aforementioned observations are:

"But if I had to look at specific information, the upfront cost, maintenance, and lifetime of the system before it needs repairs in relation to comparing retailer's products would be amongst the main ones [items of information]." (*Respondent 03MBDS*)

"The biggest one [item of information] was the size of [storage] tanks available - how much hot water would it provide since it needs to be adequate enough for our usage. You don't want to have a case where the hot water runs out." (*Respondent 12MBDS*)

In Trinidad the most important information was the system's cost and the coding suggested that the respondents were focused on understanding the actual solar water heater as a technology and how it works. Appendix J also shows the information channels that individuals would use to get this information. In Barbados the most salient information was the system sizes available on the market and the Barbadian respondents were more interested in the retailers' ability to provide an adequate size of solar water heater.

6.2.1.2. The adoption motivators

Human beings make decisions that are biased and reflect emotions and instincts (Gordon, 2011) so an area that is worth exploring is the motivators for adoption. The Trinidadians and Barbadians were respectively asked: *'What made you get your water heating technology?'* and *'What made you get solar water heating for your home?'*

Similarly to the previous sub-section's questions, these questions are directly related to the knowledge and persuasion stages of adopting innovations in Rogers' innovation-decision process (see Rogers (1983)). These questions therefore complement the previous ones by looking at adoption motivations and their links (if any) to the information required in order to make an adoption decision - this is even further related to the awareness of the resource and technology that was presented in the first section of this chapter.

The Trinidadians' responses led to 20 different sub-codes and 8 different motivators that drove respondents to adopt their respective water heating technologies - which were mainly electric water heaters (see Appendix I for the incumbent water heating technologies). The motivators being discussed are the codes that were assigned to each energy culture's related sub-codes and represent the interpretation of the respondents' statements at the time of data collection.

2 responses suggested that respondents bought their electric water heaters because there were no perceived alternatives available at the time. *Respondent 04FTTD* outlined that their father installed a standing-tank electric water heater (see Figure 42 on page 224) a long time ago and said:

"I guess it [the standing-tank electric water heater] was the only one available at the time." (*Respondent 04FTTD*)

Another said:

"It [the showerhead electric water heater] was the only one really available" (*Respondent 02MTTD*)

Respondent 02MTTD also said that the only other option was the standing-tank version. This showed that the respondents may value having choice on the market as the first motivator; making an informed decision to get a solar water heater should be based on understanding the options available (Department of Mechanical Engineering, 2008) because if adopters are unaware of alternatives, this is one of the reasons why they would not be adopted (Grieve et al., 2012).

Respondent 01FTTD outlined that they got their standing-tank electric water heating because there are no issues with replacing parts, or their costs as usually associated with showerhead electric water heaters (see Figure 43 on page 224). Another response from *Respondent 03FTTD* outlined that the showerhead version of the electric water heater does not last long but the standing-tank version they adopted does. This showed that durability is valued as a second motivator.

Respondents suggested that they got their standing-tank electric water heating system because they wanted:

"luxury." (*Respondent 01FTTD*)

Additionally, the standing-tank electric water heater system was believed to have been state of the art technology for water heating at the time and *Respondent 10MTTD* said:

"that was the ultimate." (*Respondent 10MTTD*)

Interestingly *Respondent 06MTTD* who owned solar water heating (an unexpected observation) said that they adopted the system because they wanted to be up-to-date with the latest energy technologies. These suggested that status could be a third motivator. *Respondent*

06MTTD also said that they adopted solar water heating to help promote solar energy in Trinidad so sustainability could be seen as the fourth motivator.

The respondents connected with varying perceptions of cost and viewed showerhead and wall-mounted point-of-use electric water heaters (see Figure 44) as cheap technologies to purchase. There was also the belief that showerhead electric water heaters were cheaper than the standing-tank versions in some instances, but in others, standing-tank electric water heaters were cheaper than the showerhead versions. This may have been due to varying outlooks and valuation of cost. Nevertheless, they valued cost-effectiveness and this is the fifth motivator.

The image showing an example of a wall-mounted electric water heater originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Global Sources. 2018. Wall mounted electric instant shower hot water heater for bathroom with booster pump. Electric water heaters. Website: http://www.globalsources.com/gsol/I/Electric-water/p/sm/1152553426.htm#1152553426 (accessed 13th April, 2018)

Figure 44 showing an example of a wall-mounted electric water heater installation

Extracted from Global Sources (2018)

A sixth motivator is the ease involved in installing and using water heaters - which meant that the respondents valued convenience. Respondents were of the opinion that the showerhead and wall-mounted electric water heaters were easy to install e.g.:

"We thought those [the showerhead electric water heaters] would be easy to install." (*Respondent 16FTTD*)

In the case of the wall-mounted version, *Respondent 15MTTD* even suggested that it was easier to install than the standing-tank option. They outlined that because they live in an apartment complex, adopting any other form of water heating would mean redoing the plumbing. However *Respondent 01FTTD* thought that the standing-tank option was more convenient.

Appendix I provides information on the types of water heating used by the Trinidadians. However *Respondent 09MTTD* specifically outlined that before getting their showerhead electric water heater they used to heat their water either in a kettle or on an LPG-fired stove-top burner (see Figure 37 on page 182). The hot water would then be taken to the bathroom to be mixed with the water that was at room temperature (which they described as 'cold water') in a bucket for bathing.

They were of the opinion that these logistics were an inconvenience. The respondent further pointed out that their wife was involved in a tripping accident whilst carrying the hot water to the bathroom and because of this, *Respondent 09MTTD*'s account flagged safety as a seventh motivator.

The final motivator was tied to the use of hot water and the technologies' ability to provide it. *Respondent 11MTTD* implied that their hot water usage is minimal and that their water heater provided the amount of hot water they need. *Respondent 15MTTD* also outlined that there was no need to get any other type of electric water heater beyond their wall-mounted system because it provides hot water where and when it is needed i.e. for showering. So, the

respondents valued the practicality of the technologies.

These results showed that the Trinidadian respondents may value choice; durability; status; sustainability; cost-effectiveness; convenience; safety; and practicality as adoption-motivators - and cost-effectiveness is the most salient as shown in Figure 45.

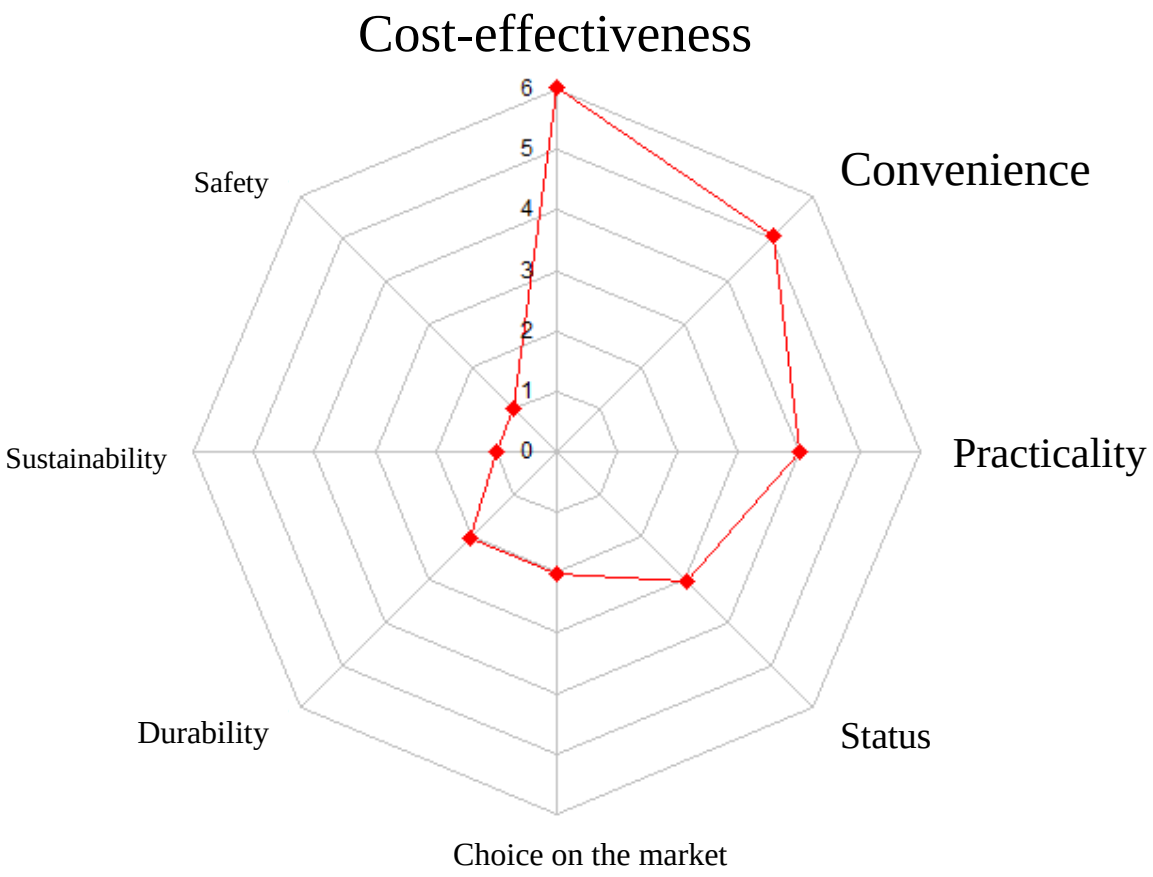


Figure 45 showing the relative significance of the 16 Trinidadian respondents' 8 motivations for adopting their respective water heating technologies as derived from the inductive coding of their responses

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code for a given motivator.
Generated by the Author using Microsoft Excel

In Barbados there were 32 different sub-codes that emerged and 9 motivators for adopting solar water heating. The first motivator is related to the personal dislike for cold water and shows the value of comfort to the respondents. Respondents provided statements like:

"In my school days, I didn't like to bathe in cold water at those early mornings." (*Respondent 02MBDS*)

"My two young children complaining about cold water." (*Respondent 05MBDS*)

The second motivator is based on the beliefs that using electric water heaters and pilot light heating systems to heat water have safety risks, as well as that using solar water heaters are safer. For example, with respect to electric water heating respondents said:

"…with electric water heating, I almost shocked myself." (*Respondent 02MBDS*)

"…after talking to people, many of them reported to have gotten shocked from electric water heating, so an electric water heater was not suitable." (*Respondent 05MBDS*)

The respondent who owned the pilot light heating system believed that:

"it is also not safe having an open fire in the house." (*Respondent 17FBDS*)

These views positioned safety as another motivator; solar water heating was thought to be:

"modern and safer." (*Respondent 17FBDS*)

Thirdly, respondents were thought to value durability. Respondents expressed displeasure with the fact that the electric water heaters' elements, the component that heats the water, are fragile and in need of regular replacements. This was a particular nuisance because:

"You always have to buy replacement elements for electric water heaters." (*Respondent 02MBDS*)

Respondent 07FBDS also added more context by saying that their parents had to replace their electric water heater's element every 6 to 7 months. In addition, *Respondent 15FBDS* compared their solar water heater to the electric water heater's fragile elements and pointed out that by comparison their solar system had a regular service regimen (every 5 years) which meant that it was perceived as more durable.

Respondents also valued reliability as the fourth motivator. This was founded on the beliefs that the sun is an infinite resource so is a guaranteed heat source, and that pilot light water heating systems were not dependable or reliable. The first came from *Respondent 11FBDS* who adopted solar water heating because the source of its energy was the sun, and the latter was brought up by *Respondent 17FBDS* who described their thoughts on their pilot light heating system.

A fifth motivator arose as convenience through beliefs tied to electric water heating requiring some time before providing hot water; pilot light water heating and gas stoves being inconvenient; and the convenience of one-time capital cost payments e.g.:

"Boiling water on the stove was an inconvenience." (*Respondent 05MBDS*)

"You pay a lump sum for your solar water heater but after doing that you don't have to worry about that [paying for the system] again." (*Respondent 15FBDS*)

Related to convenience was practicality as a sixth motivator. It was drawn from the beliefs that the hot water provided by several of the respondents' prior electric water heaters did not provide hot water to where it was needed e.g.:

"Hot water is used for washing dishes and the electric water heater doesn't accommodate this." (*Respondent 08FBDS*)

As stated by *Respondent 08FBDS*' quote (previous page), electric water heating was not capable of providing hot water where they needed it i.e. in the kitchen to wash dishes. This was also complemented by *Respondent 03FBDS*' belief that solar water heating is practical.

The seventh motivator was attached to the beliefs that using electric water heating increases the electricity bill and is expensive - though it is dependent on how often it is used. In addition, using solar water heating was believed to be cheaper than electric water heating and also conserves electricity. These beliefs pointed towards the respondents valuing cost-effectiveness. Examples include:

"…electric water heating makes your electricity bill high." (*Respondent 15FBDS*)
"Electric water heaters are expensive." (*Respondent 16FBDS*)

Finally, the respondents valued social validation and awareness as the eighth and ninth motivators. Respondents reported valuing the word-of-mouth from peers, seeing solar water heaters that have been installed by peers, and seeing television advertisements. The best example of a supporting quote came from *Respondent 09MBDS* who said:

"It [solar water heating] was introduced on television for a period of time, people bought it, and I also heard about it from some of them." (*Respondent 09MBDS*)

As shown in Figure 46 (next page), the Barbadian respondents valued comfort; safety; durability; reliability; convenience; practicality; cost-effectiveness; social validation; and awareness as motivators for technologically transitioning to solar water heating. However, convenience and comfort are the most salient.

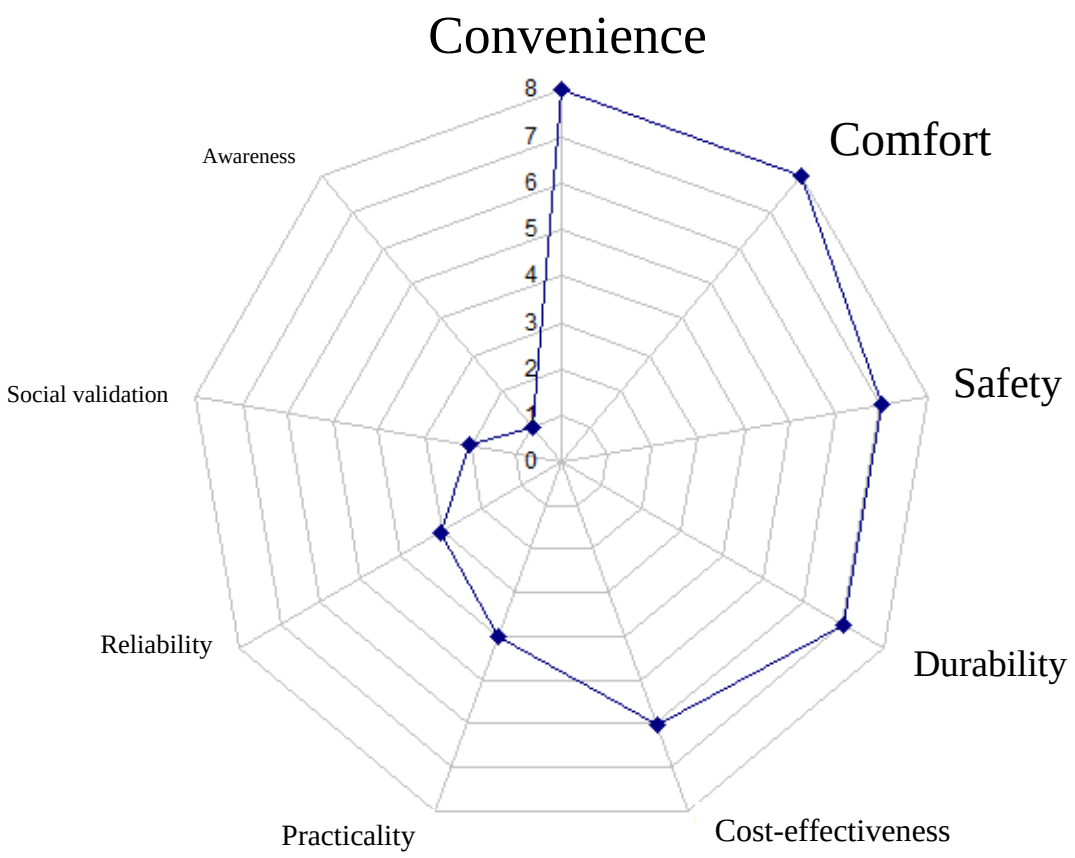


Figure 46 showing the relative significance of the 17 Barbadian respondents' 9 motivations for adopting their solar water heating as derived from the inductive coding of their responses

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code for a given motivator.
Generated by the Author using Microsoft Excel

6.2.2. The Case of Solar Water Heating Adoption in Barbados

There has been a comparison between Trinidad and Barbados thus far, but the Barbadians' insights are now of particular value. The respondents provided narratives on how they went about adopting their solar water heaters in response to: '*How did you go about getting your solar water heater?'*

This question captures the holistic innovation-decision process to see what organic elements of adoption emerge and are shared by the Barbadian respondents; it sets the wider context for

the knowledge and persuasion elements looked at in the chapter thus far by giving insight into the Barbadians' views more related to the decision, implementation and confirmation stages of their adoption of solar water heating. It is worth reiterating that there is no significant solar hot water adoption in Trinidad to compare adoption pathways hence why only Barbados' is characterized here.

There were five different narratives and the most common will be looked at first followed by the other four. 10 respondents' answers explicitly converged on the most popular option and there were 19 sub-codes that were linked to this; Table 22 shows these respondents' solar water heaters' details for reference.

RESPONDENT IDENTITY	ADOPTION YEAR	COST (USD)	INSTALLATION TIME	SIZE	WARRANTY NOTES
Respondent 01MBDS	2000	$750 to 1,000	Hours	80 gallons	Didn't remember. They thought there may have perhaps been a 1-year standard warranty which is what one usually gets with most things.
Respondent 04FBDS	Between 1996 and 2001	$1,000 to 2,000	A few hours	10 gallons	Didn't remember
Respondent 05MBDS	2005	$1,750	2 days	50 to 55 gallons	3 years
Respondent 07FBDS	2006	$1,500 to 1,750	2 days	Didn't remember	3 years
Respondent 09MBDS	2006	$1,500	1/2 hour	Didn't remember	Didn't remember
Respondent 11FBDS	1983	$1,000	1 day	60 gallons	They couldn't say. Maybe 5 years but not a lot of maintenance was needed. They replaced their water heater 3 times since buying the first one. The old ones started giving problems like leaking water and so on.
Respondent 12MBDS	1997	$1,500 to 2,000	A few hours	80 gallons	3 years
Respondent 14MBDS	1996	$1,000	A few hours	Didn't remember	Had a warranty but didn't remember its length.
Respondent 15FBDS	2011	$1,500	A few hours	Didn't remember	1 year
Respondent 16FBDS	2006	Didn't remember	Didn't remember	Didn't remember	Had a warranty but didn't remember its length.

Table 22 showing the solar water heater information for the 10 Barbadian respondents who got their systems from a specialist solar water heater retailer

Generated by the Author using Microsoft Word

2 sub-codes indicated that respondents researched the retailers present on the market. 3 pointed towards engaging the retailer and collecting information about their products, their services and the economics involved. A further 3 sub-codes connected with respondents settling on a retailer. Choosing a retailer was linked to the business' popularity and establishment, and the impression given was that popularity and establishment were linked to the numbers of systems sold, size of customer-base and length of time they have been in business e.g.:

"I asked around from companies. [I] wrote down questions I had and sought the answers from them - and eventually chose the company that was around the longest." (*Respondent 05MBDS*)

The retailers' cost-effectiveness was another factor. Whilst there were inherent values that made more popular, established and cost-effective retailers the best option for residents, in some cases, the retailer was only chosen because they were believed to be the only ones on the island at the time e.g.:

"[I] Called up the retailer, made a down payment, [and] they came and installed it. At that time there was only one retailer - and besides, all the brands that we have today serve the same function." (*Respondent 09MBDS*)

"When we got it, Solar Dynamics was the sole provider at the time then the others came in after." (*Respondent 11FBDS*)

Many industrialized countries established solar water heating industries by the 1980s (McVeigh, 1984). But Barbados' had its origins in the 1960s, and it developed when Solar Dynamics was established in 1974/1975 and its 1st major rival, SunPower, entered the market in 1978 followed by a 3rd, Aqua Sol (which later became Solaris), in 1981 (Bugler, 2012; Rogers et al., 2012; Samuel, 2013; CDB, 2014; Husbands, 2016).

The solar water heating market was dominated by the 3 companies well into the 2000s but Solar Dynamics had 55 to 60% of the market share and the remaining was relatively evenly distributed between SunPower and Aqua Sol/Solaris (Perlack and Hinds, 2003; CDB, 2014); Solar Dynamics was and is the market leader in solar water heating (ECLAC, 2003).

Based on the above insights, at the time of all the respondents' acquiring their different systems (see Table 23) there was more than one company in existence. Therefore, the fact that respondents thought that there was only one company can perhaps be due to retailers' marketing and extent of visible brand adoption at the time.

ADOPTION YEAR	RESPONDENT IDENTITY
1983	Respondent 11FBDS
1988	Respondent 02MBDS
1996	Respondent 14MBDS
1996-2001	Respondent 04FBDS
1997	Respondent 12MBDS
2000	Respondent 01MBDS
2001	Respondent 13MBDS
2005	Respondent 05MBDS
2006	Respondent 07FBDS
2006	Respondent 09MBDS
2006	Respondent 16FBDS
2006-2007	Respondent 17FBDS
2007	Respondent 06MBDS
2011	Respondent 15FBDS
2012	Respondent 10FBDS
2013	Respondent 03MBDS
2014	Respondent 08FBDS

Table 23 showing the Barbadian respondents' timeline of solar water heater adoption

Generated by the Author using Microsoft Word

Nevertheless, after settling on a retailer, 2 sub-codes suggested that the next step was liaising with the selected retailer on the details of the purchase; registering with the company; going

through the scope of the project; and completing the relevant applications associated with the installation. Following this, a sub-code indicated that retailers would make a site visit to the home. 5 sub-codes then captured the respondents' payments for their systems which were a mix of down-payments and upfront payments. Finally, 2 sub-codes related to the system's installation on the home.

Therefore the most common way to acquire a solar water heater involved becoming familiar with the solar water heating retail market and its retailers; liaising with these businesses on investment options; settling on a retailer; signing up with the company; agreeing on a payment plan; and finally having the system installed. Examples of responses that add contextual summaries are:

> "I looked to see who were the main players, then engaged people who have had experience with these players before buying it, and then spoke to the popular retailers relative to quotations; installation; maintenance; savings and discounts; as well as installation time." (*Respondent 01MBDS*)

> "I can't remember exactly but I know at some point, I would have went to the company; filled out their forms; selected an available payment plan; made the down-payment; then came the installation; and finally paying-off for the system." (*Respondent 03FBDS*)

6 respondents reported getting their solar water heaters through 4 other avenues however.

Respondent 08FBDS got their solar water heater through a door-to-door sales representative. They outlined that the salesperson offered them a rent-to-own proposal and after 3 years of 'renting', owned the system. Interestingly this respondent even acknowledged that:

> "most people also usually just go to SunPower or Solar Dynamics." (*Respondent 08FBDS*)

Respondent 13MBDS outlined that they got their solar water heater through a hire purchase

plan with a non-manufacturer retailer (versus the manufacturer-retailers present in Barbados e.g. Solar Dynamics). *Respondent 10FBDS* also got their solar water heater from a non-manufacturer retailer but more informally because they visited a garage sale and was able to buy the system; it was therefore a second-hand solar water heater. Another, *Respondent 06MBDS*, said:

"I got 2 estimates, one from a reputable company and one from a private individual." (*Respondent 06MBDS*)

After getting the estimates and weighing the pros and cons of each, *Respondent 06MBDS* settled on the private installer. This individual used to work with one of the more established retailers but branched off into their own practice.

Another adoption narrative came from *Respondent 03MBDS* who pointed out that when they bought their present home which they have been residing in since 2013 the solar water heater was already installed.

Lastly, *Respondent 17FBDS* said that they got their solar water heater through a family member who owned a solar water heater retail business. They did not name the company however.

Table 23 (page 240) shows the respondents' timeline of adoption where the oldest system was adopted in 1983 and the most recent was in 2014. In the wider industry solar hot water adoption increased from 12 systems in 1974 when the industry started; to 1,848 in 1980; 19,370 in 1990; 31,000 in 1999; between 32,000 and 35,000 in 2002; and between 45,000 to 50,000 in 2009 (Jensen, 2000; UN, 2002; Perlack and Hinds, 2003; Husbands, 2010; NREL[3], 2015).

Getting more recent figures proved challenging but thinking about solar hot water's penetration lends perspective. 75% of solar hot water installations in Barbados are residential (Moore et al., 2014). According to the last Census done by the Barbados Statistical Service in 2010, the total number of occupied households and existing systems puts the penetration at 34% of occupied homes. However more recent sources state that the penetration rate is well beyond 34%.

Castalia Limited (2010) and SEforALL (2012) suggest that 40% of households had solar water heating at the time whilst the Government of Barbados (2013), Moore et al. (2014), and the CDB (2014) state that at this time it was nearer to 50%. Sources such as the CEIS (2015), Gray et al. (2015), and the IEA-ETSAP and IRENA (2015) however, report that 80 to 90% of households now have solar hot water.

6.3. Chapter Conclusions

Solar energy is a culturally-recognized energy resource in both the Trinidadians and Barbadians' energy cultures even though it is not part of Trinidad's technical residential energy mix. The respondents view solar energy as a resource that is powered by sunlight, in need of technology to be practical, and has relative advantages over the incumbent energy used.

This suggests that some understanding of solar technologies and the resource exists independently of adopting the technology to harnesses it in the Trinidadians' energy culture. This cognizance however is not complete because there are misconceptions that surround the technologies and their relative advantages. Most notably are the references to photovoltaics.

The Barbadians' water heating material culture is largely centred on solar water heating. But the Trinidadians' is electric with some inclusion of liquefied petroleum gas (LPG). These material culture observations support the last chapter's findings where solar water heating instigated an energy culture shift in Barbados by prompting the development of new norms and practices.

Interestingly, as seen with the understanding of the resource, solar energy, the respondents' understandings of solar water heating are fundamentally comparable. They acknowledge that the technology is powered by the sun, uses a solar collector surface to facilitate a heat energy transfer to the water, involves water circulation and storage, and requires installing.

However, there is one difference between the Trinidadians and the Barbadians: the Barbadians' understanding includes the use and function of an electrical auxiliary heater for the solar water heater. The auxiliary heater is engaged by flipping a switch during periods when sunlight is limited. This observation threw light on the earlier-mentioned energy culture shift from Chapter 5 and confirmed that such as shift occurred.

Despite these findings there are misconceptions that emerged once again and particularly so in the Trinidadians' energy culture relative to photovoltaics. This shows the value of information prior to adopting an innovation.

People adopting innovations desire multiple items of information to address uncertainties, misconceptions and/or knowledge gaps. But there are some that are more salient than others. The Trinidadian respondents viewed cost as the most salient information needed before adopting an innovation like solar water heating. The Barbadians viewed the capacities of the systems available on the market as the most important with respect to their adoption of it.

From the information desired prior to adopting solar water heating, the Trinidadians are more interested in information about the technology whereas the Barbadians were more interested in market-related information at the time of their adoption.

The respondents also had multiple motivations for adopting an innovation and these are linked to the information needed to make an adoption decision. The Trinidadians value choice on the market; durability; status; sustainability; cost-effectiveness; convenience; safety; and practicality as motivators for adopting their presently used water heating technologies - which are largely versions of electric water heaters (see Appendix I). Motivators have varied saliences relative to the innovation and its services so any transition to solar water heating would need to be aligned with what adopters value as the motivations for doing so.

The Barbadians valued comfort; safety; durability; reliability; convenience; practicality; cost-effectiveness; awareness; and social validation with respect to their adoption of solar water heating. Individuals got their solar water heaters through specialist retail; door-to-door sales; formal and informal non-manufacturer retail; property purchases; as well as through having personal relationships within the solar water heating industry. The most popular option however was through solar water heater manufacturers that also retail their products.

6.3.1. Answering the Research Questions

6.3.1.1. Conclusions for Trinidad's Residential Energy Culture and Solar Energy Adoption

As indicated in the last chapter, culture was found to be both reactive and proactive during energy transitions (ETs). Several aspects of culture's reactive role brought up in the last

chapter once again emerged but were more explicitly linked to the Barbadians' energy culture through their adoption of solar water heaters.

However, unlike the last chapter, culture's proactive role was more explicit. The proactive role was particularly centred on the material culture, norms, practices and external influences surrounding what solar energy means, how solar water heating works and the motivators for adopting water heating technologies.

The thesis' first research question is: "*How could the adoption of distributed residential solar energy technologies and the residential energy culture(s) of Trinidad affect each other?*" The interaction more strongly looked at in this chapter was the potential impact(s) of the energy culture on the adoption of residential solar energy technologies (the proactive role of culture); the last chapter more explicitly addressed the influence of adoption on the energy culture (the reactive role of culture).

As raised in Chapter 5, electricity and the perceived evening peak energy demand are examples of cultural landscape-level factors made up of external influences which affect the incumbent energy culture of the 16 Trinidadians interviewed. In addition to these are climate change, the nation's finite oil and gas reserves and the infinite supply of solar energy as landscape-level external influences in Figure 47 (next page) based on this chapter's findings. These forces suggest that culture has a role in niche-creation and niche-shaping. Other external influences that may create and shape niches at the regime-level are power outages, and the elements that affect the costs of solar energy technologies e.g. the retail electricity tariff and the market price of the available technologies for example.

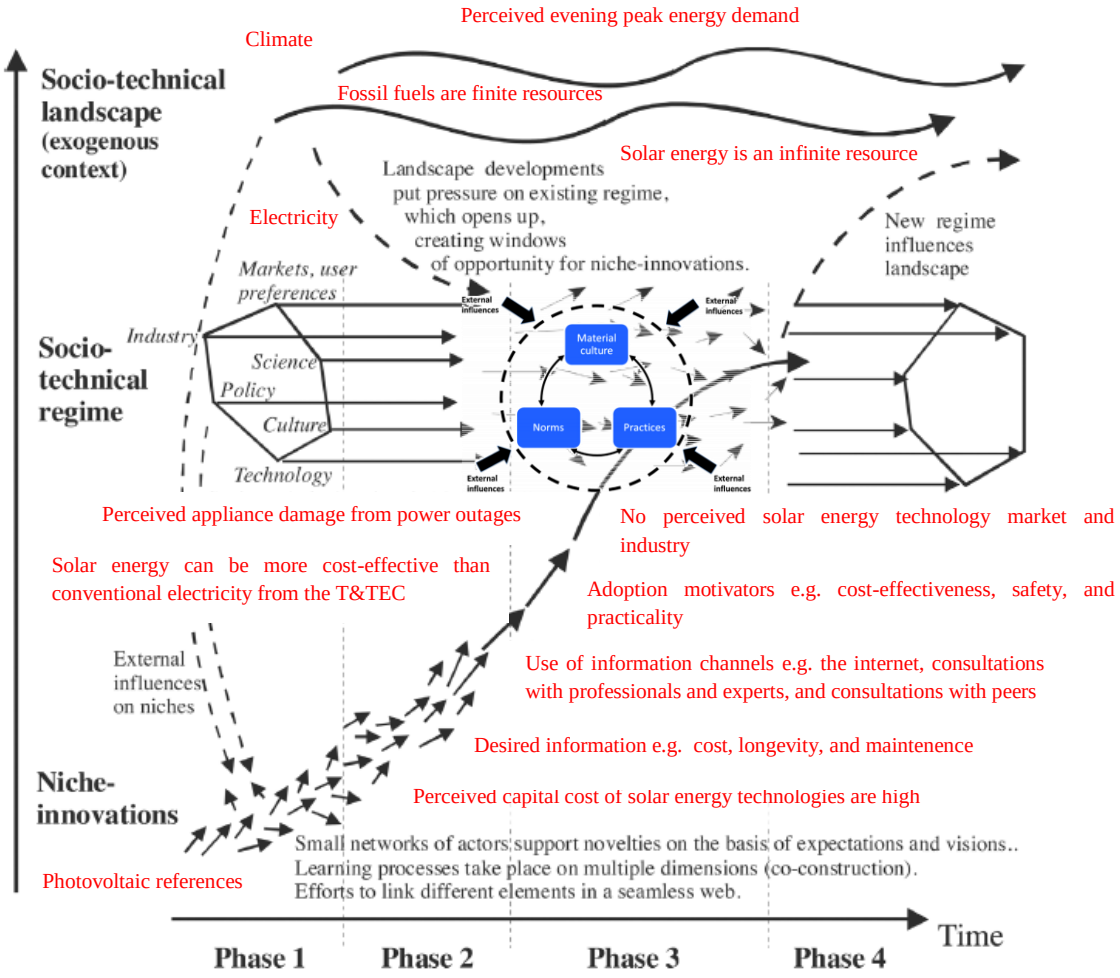


Figure 47 showing the incumbent energy culture features that can influence the adoption of solar water heating based on the 16 Trinidadian respondents' interviews

Adapted from Stephenson et al. (2015; 118) and Geels (2018; 226) using Microsoft Word

Despite the Trinidadians not having adopted solar water heating (like the Barbadians), there are still solar energy norms. There are beliefs, aspirations and expectations surrounding the fact that solar energy is energy from sunlight, needs technology to be practical and has relative advantages over the incumbent electricity from the island's utility company, the Trinidad and Tobago Electricity Commission (T&TEC) - notably so is that solar energy can

be more cost-effective than the incumbent electricity from the T&TEC in the case of last.

There were references to photovoltaics in the respondents' notions of solar energy as well as solar water heating e.g. solar garden lights, wiring and batteries. So, in light of their electricity-oriented energy culture (see Chapter 5), these photovoltaic references suggest that photovoltaics may be more easily assimilated than solar water heating; culture can therefore have a role in technological selectivity.

Related to this is the fact that the Trinidadian householders have a rudimentary understanding of how solar energy technologies like solar water heating and photovoltaics work. This shows that though the technology has not been adopted there is a general awareness that it exists - which is important for the first stage of adopting an innovation i.e. knowledge.

However, there are misconceptions that particularly surround the technologies and their relative advantages. Due to these misconceptions the respondents have uncertainties and are in need of information to fill these knowledge gaps. There are several items of information that respondents want before adopting an innovation like solar water heating for instance, but the costs involved is the most salient.

This is perhaps because there is an aspiration to reduce energy costs by adopting the technology and an expectation that the upfront costs of the technology are significant for example (see Figure 47 on the previous page). Based on the respondents' views, the types of information needed suggest that gaining such knowledge will improve the understanding of the technology itself (versus the market or industry as was the case with the Barbadians). Gaining these items of information should shape the beliefs, expectations and aspirations surrounding the technology and influence the practices that revolve around the adoption of it.

Related practices are the use of information channels to access the desired information. There is a multiplicity of salient information channels which could be used to access the desired information but using the internet, consultations with experts and professionals, advertisements by retailers, and testimonials from present adopters are the most prominent. These channels are also examples of external influences on the respondents' energy culture.

There are motivations for adopting household solar technologies like solar water heating, and they transcend the knowledge and persuasion stages of the adoption process. The Trinidadian respondents shared several accounts which suggest that choice on the market; durability; status; sustainability; cost-effectiveness; convenience; safety; and practicality would be adoption motivators. However, cost-effectiveness is the most significant. If the solar technology being adopting does not conform to the motivators for adoption, then one that does may be more easily adopted. This is another example of technological selectivity.

Mainstream adopters tend to be passive adopters when it comes to collecting information about an innovation (see section 2.2. in Chapter 2). Therefore, any low desire to address misconceptions about and knowledge deficits on solar energy and solar energy technologies, and low desire to access and use the right information channels to find out more about solar energy technologies is a form of passive resistance to change. The influence of workplaces and schools on householders' presences in their homes is another example. These examples show that culture has a role in resisting change and locking-in the incumbent regime.

6.3.1.2. Implications for Trinidad's Residential Solar Energy Policies

Similarly to the last chapter, this chapter's results also led to insights into how Trinidad's resident population's energy culture can influence and be influenced by the Government's residential solar energy policies:

i. There are misconceptions and knowledge gaps existing in Trinidad about solar energy. This calls for a policy solution that includes education and awareness-raising campaigns.

ii. The potential for saving money is the most salient relative advantage of solar energy over the incumbent electricity provided by the Trinidad and Tobago Electricity Commission. Cost is the most salient pre-adoption information desired and cost-effectiveness is the most important adoption motivator. Therefore, fiscal policies that incentivize solar energy can be effective.

iii. Trinidadians value choice; durability; status; sustainability; cost-effectiveness; convenience; safety; and practicality as motivators for adopting its incumbent water heating material culture. This is an important consideration for policies to set industry and technology standards.

iv. There are a number of adoption pathways for solar hot water in Barbados: non-manufacturer retail purchases; purchasing property that already has solar hot water; door-to-door sales; having personal relationships with persons in the retail market; and calling retailers to compare product offerings. Policies should encourage a multiplicity of adoption pathways that are guided by best-practice and lessons-learnt guides, industry and technology standards, and certification schemes.

v. There are a variety of payment schemes for solar hot water systems in Barbados e.g. hire purchase, full capital payment, rent-to-own, and/or deposit and balance payment plans. Policies should encourage flexible payment plans for capital cost payments.

6.3.2. Characterizing Mainstreaming

This chapter's discussions characterize mainstreaming by highlighting that:

i. Mainstreaming requires an awareness of the incoming resource e.g. solar energy.

ii. Mainstreaming requires an awareness of the technology being adopted e.g. a solar water heater.

iii. Mainstreaming a technology involves reducing uncertainty about the innovation and finding out information about it prior to adoption e.g. the technology's costs.

iv. Mainstreaming a technology is more easily facilitated when it meets the culturally valued motivators for adopting it e.g. safety, cost-effectiveness and/or practicality.

v. Mainstreaming a technology establishes more than one adoption pathway which means that its original niche is outgrown e.g. the original adoption niche established by purchasing solar water heaters from manufacturer-retailers being outgrown to include other options such as formal and informal non-manufacturer retailers.

7.0. A Comparative Characterization of Institutionalized Electricity in Oahu & Trinidad's Residential Sectors

Synopsis

This chapter introduces the institutions that exist in the residential electricity regimes of Oahu and Trinidad. Considering the energy history of Trinidad's regime presented in Chapter 4, this chapter helps put this into context by institutionally characterizing the incumbent regime of the island through concept diagrams and institutional narratives. Comparing Oahu and Trinidad allows for a better appreciation of the latter's regime given the fundamental differences between both e.g. Oahu is an energy importer versus Trinidad's energy exportation. This is important because it details the regime and the roles of its actors.

The characterizations of Oahu and Trinidad's regimes are also important because the policies that will be discussed in Chapters 8 and 9 which answer the research sub-question, "*What are the Government's State-level residential solar energy policy options in Trinidad?*", do not exist in isolation in the regime and have coordinating agencies. This chapter therefore sets the context for the policies that will be discussed later in the thesis since the various institutions' roles will be important for understanding the policies' coordination and implementation. It also gives insight into the wider institutional environment that is external to the Trinidadian household respondents' energy culture looked at in Chapters 5 and 6.

This chapter's discussions are based on the deductive thematic analysis of the 22 key-informant interviews conducted in Oahu and Trinidad, as well as the relevant policy-related literature. The various policy literature resources helped inform the institutional concept

diagrams and narratives, but the interviews helped add on-the-ground perspectives to each.

The chapter is structured as follows: section 7.1. overviews the use of the institutional concept diagrams to illustrate Oahu and Trinidad's residential electricity regimes and presents the diagrams; section 7.2. details the respective institutional designs surrounding the regimes' energy resources, electricity generation, and consumption; section 7.3. outlines the institutional designs surrounding the respective regulation and governance of electricity in the regimes; and section 7.4. presents the chapter's conclusions, its cultural implications, and characterizes mainstreaming based on the findings from the chapter.

7.1. Regimes as Institutional Networks

Chapter 2 shows that Geels and Schot's (2007) Multi-Level Perspective of socio-technical energy transitions (ETs) is a framework that has landscape, regime and niche planes. The socio-technical regime is the plane that undergoes the ET. It has multiple actors sharing dynamic interrelationships (Markard and Truffer, 2008; Lockwood et al., 2013). These actors' interactions are not isolated (Cressman, 2009; Nimmo, 2011; Pollack et al., 2013) so they and their interactions form networks of nodes (institutions) and links (relationships) (Cook et al., 1983; Lucas and Mayne, 2013).

The regime is a multi-actor network constructed from series of other financial, supplier, user, producer, research, societal and public actor-clusters whose functions (agency) interact at the socio-technical level (Geels, 2002; Geels, 2004). The network is therefore influenced by actors' agency but also provides the exhibition space for their agency (Brass and Burkhart, 1993; Geels, 2004).

An ET is a change in regime-state (Geels and Schot, 2007). So relative to its multi-actor network, an ET institutionally re-aligns the incumbent network. Managing sustainable ETs should involve clearly identified actors (Lockwood et al., 2013) because there is a relationship between the diffusion of innovations and the system that it is set within (Rogers, 1983; Lucas and Mayne, 2013); diffusion is most common in heterogenic networks that have well-defined actors (Rogers et al., 2005).

Institutional concept diagrams were prepared after reviewing each island's relevant energy policy literature and considering the institutional informants' recommendations (see Figures 48 and 49 on the next two pages); Chapter 3 details the designing of these diagrams. The diagrams show the institutions as colored textboxes and their relationships as colored connectors. Each color symbolizes a different type of institution/relationship.

The placement of the textboxes and connectors is not significant - this particularly applies to the placement of the advocacy textboxes which are not directly connected to any neighboring institutions. These specific textboxes have dotted outlines and are seen in more than one place in the diagram to represent the broad institutional focus that their advocacy may have in the diagram.

The diagrams' textboxes are arranged to ensure that the elements fit and are visible; the diagrams are therefore purely illustrative and not overly referenced throughout the chapter to ensure that the descriptive narratives are clear. The network-characterizing's main objective was to create an institutional narrative for each residential electricity regime.

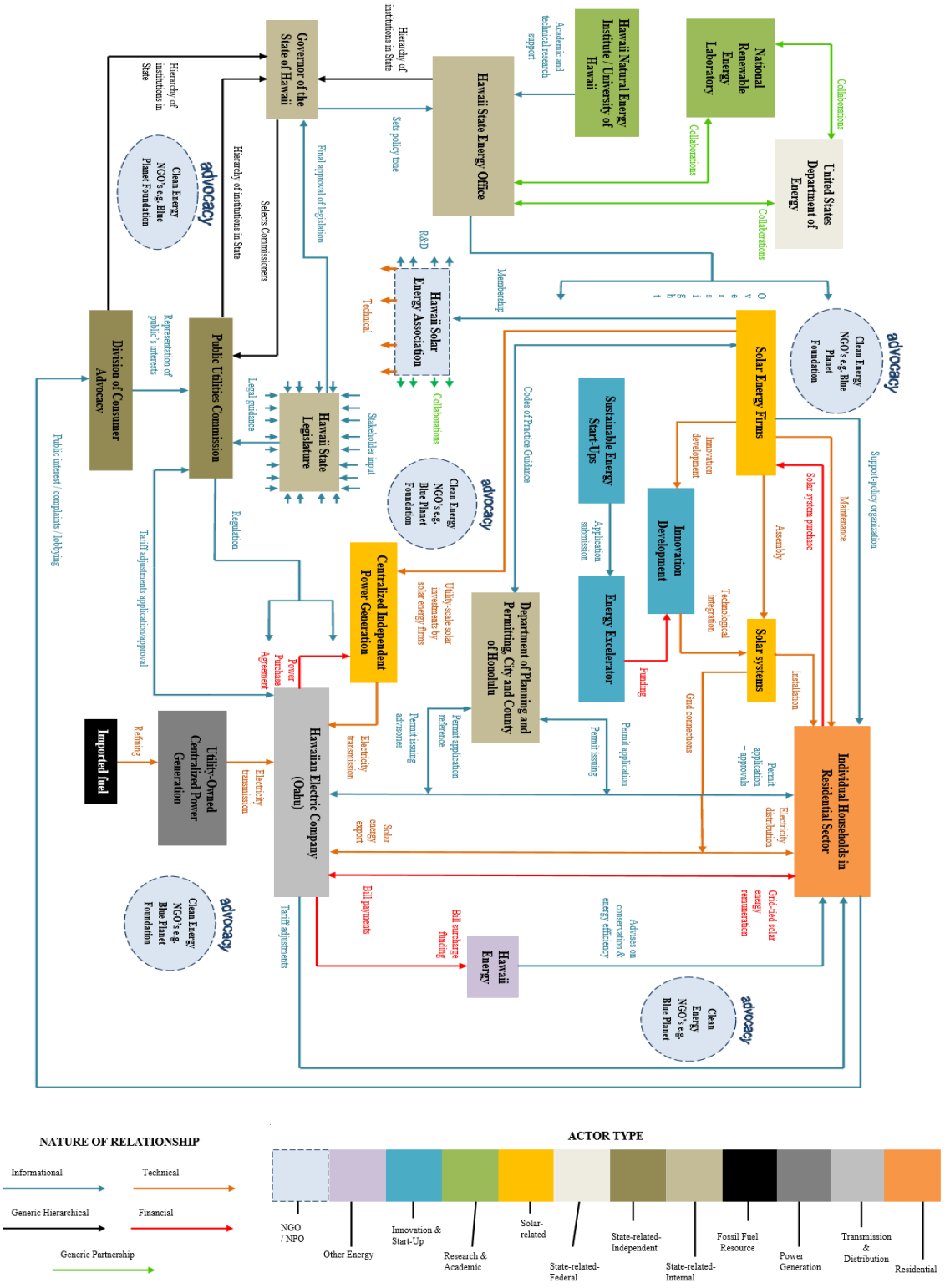


Figure 48 showing Oahu's institutional concept diagram for its residential electricity regime

Generated by the Author using Microsoft Word

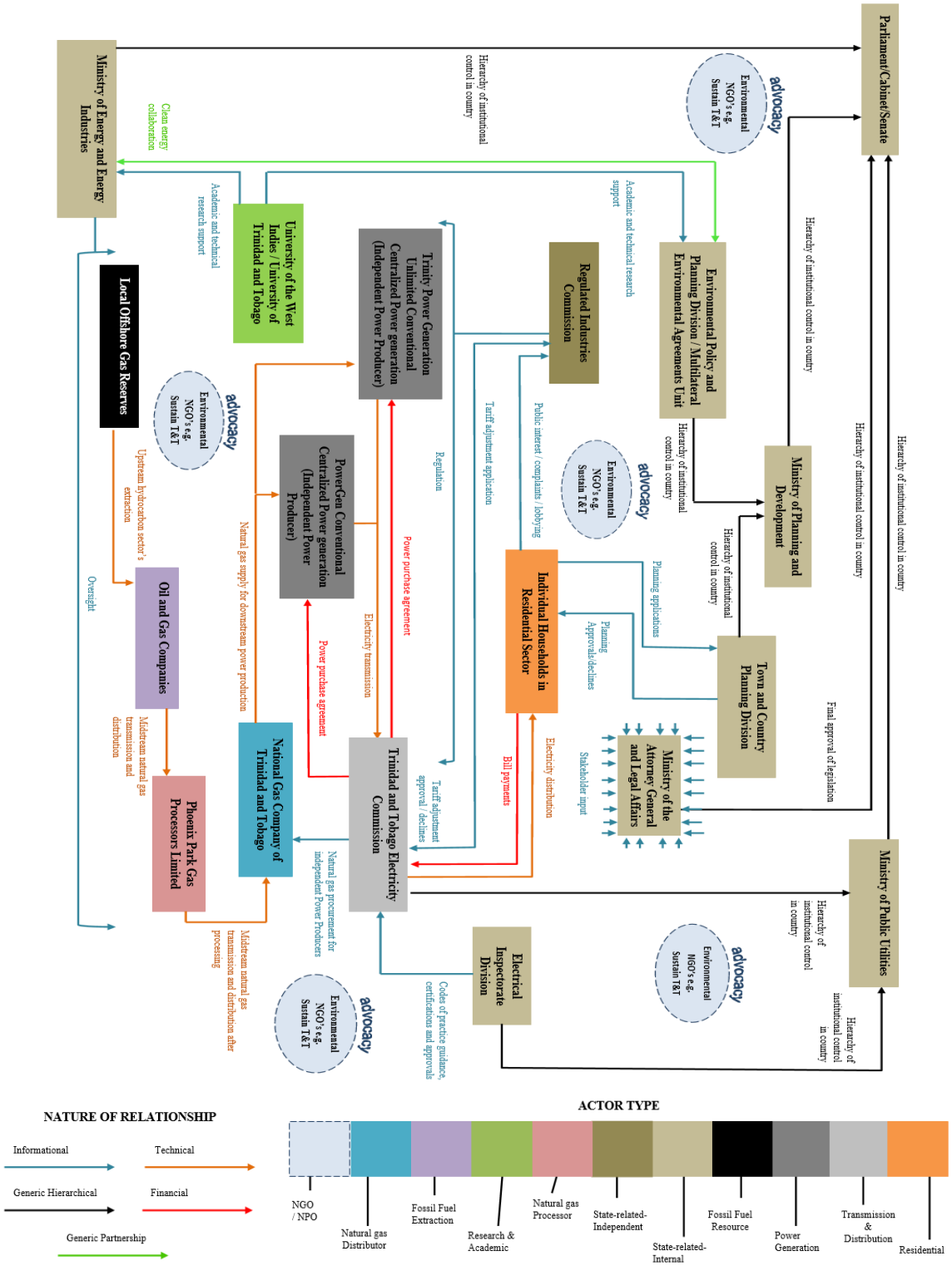


Figure 49 showing Trinidad's institutional concept diagram for its residential electricity regime

Generated by the Author using Microsoft Word

7.2. A Comparative Description of the Energy Sourcing, Power Generation and Electricity Consumption in Oahu and Trinidad

7.2.1. Oahu's Energy Sourcing, Power Generation and Electricity Consumption

7.2.1.1. Oahu and Hawaii's energy sourcing

Hawaii has no indigenous fossil fuels (Global Energy Concepts LLC, 2006; Institute for Energy Research, 2013; Alm, 2015). It is almost 90% dependent on imported oil/petroleum (Rocky Mountain Institute, 2008; Corbus et al., 2013; ACORE, 2014; HNEI, 2016). 63% of its petroleum imports are sourced directly from foreign territories (Leung and Hsu, 1984). Most come from the Middle East (Global Energy Concepts LLC, 2006; Rocky Mountain Institute, 2008) - namely Saudi Arabia and Oman but also further afield from places like Indonesia and Malaysia (Shupe, 1982; Jensen, 2000; HECO, 2011).

Nearly 45 million barrels of oil are imported into Hawaii annually (Biello, 2012). Each barrel produces jet fuel, diesel, gas, gasoline, marine fuels as well as bunker type oil (Alm, 2015). The annual petroleum import bill ranges from USD $4.5 to 6 billion (Global Energy Concepts LLC, 2006; Wu, 2013; Paulos, 2014, Morita, 2014; Pintz and Morita, 2017) and was closer to $1 billion in the 1990s (Phillips et al., 1992).

As an oil importer, oil price decreases benefit Hawaii because of lower importation costs and vice versa when prices rise (Rocky Mountain Institute, 2008; Johnson and Chertow, 2009; Alm, 2015). This means that Hawaii is the most petroleum-dependent State in the U.S. (Jensen, 2000; Global Energy Concepts LLC, 2006; Corbus et al. 2013; DBEDT[2], 2017) and is an energy price-taker (Bass and Dalal-Clayton, 1995; Rocky Mountain Institute, 2008).

Hawaii's electricity sector uses between 26 and 28% of the State's petroleum imports (Pintz and Morita, 2017; DBEDT[2], 2017). This dependence on imported oil exposes the sector to the oil markets' fluctuant prices and they are reflected in the electricity tariffs (Research and Economic Analysis Division, 2014; Morita, 2014; Holier, 2015; DBEDT[1], 2016; Pintz and Morita, 2017). For households this means that when the oil price is high, the retail electricity rate is high and vice versa because the importation costs are transferred onto the tariff through cost recovery mechanisms. Appendix E gives more detail on the cost recovery in Oahu and how it affects the retail electricity rate.

The average retail rate in Hawaii is between USD $0.30 and $0.37 per kilowatt-hour (kWh), and in Oahu is between $0.26 and $0.32 (Sillaman, 2015; Electricity Local, 2017; DBEDT[2], 2017). The State's retail rates are often twice that of the national average (Sillaman, 2015; DBEDT[1], 2016; DBEDT[2], 2017), and are the highest in the U.S. (Stockton, 2004; Global Energy Concepts LLC, 2006; Piwko et al., 2012; Sillaman, 2015; Electricity Local, 2017).

Data from the DBEDT[2] (2017) show that Hawaii's power production mix is largely made up of imported petroleum and coal. There are also smaller contributions from renewable resources like wind, geothermal, hydro, biomass and biofuels, and solar energy (see Table 24 on the next page); Table 24 shows that solar energy (specifically distributed photovoltaics) is the largest contributor to the State's renewable energy generation. Through the rapid expansion of these renewables (and particularly solar energy), the earlier quoted '90% dependence' on imported oil is closer to 80% now (State of Hawaii[1], 2018).

The table showing Hawaii's renewable energy generation breakdown for 2016 originally presented here cannot be made freely available via ORA because of copyright. The information was respectively sourced from:

Department of Business, Economic Development and Tourism[2] (DBEDT). 2017. Hawaii Energy Facts & Figures May 2017. Hawaii State Energy Office. Website: https://energy.hawaii.gov/wp-content/uploads/2011/10/HSEOFactsFigures_May2017_2.pdf (accessed 16th September, 2017)

Table 24 showing Hawaii's renewable energy generation in 2016

Generated by the Author but adapted from the DBEDT[2] (2017; 9) using Microsoft Word

7.2.1.2. Oahu's power generation

Each Hawaiian island has its own electrical grid (Global Energy Concepts LLC, 2006; Kaya and Yalcintas, 2010; R.P. Delio and Company, 2012; Piwko et al., 2012). There are six independent grids that transmit and distribute electricity across the archipelago's eight main islands (see Figure 50 on the next page) (Jensen, 2000; Rocky Mountain Institute, 2008; Morita, 2014).

There are four electric utilities: the Kauai Island Utility Cooperative on Kauai; Hawaiian Electric Company (HECO) servicing Oahu; its subsidiary, the Hawaii Electric Light Company on Hawaii Island; and another subsidiary, the Maui Electric Company serving the islands of Maui, Molokai and Lanai (HNEI, 2008; Kaya and Yalcintas, 2010; Morita, 2014; DBEDT, 2014; Gorak, 2016). The last three fall under the Hawaiian Electric Industries (HEI).

The image showing the map of the Hawaiian Islands originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Bullerman, M. 2010. Hawaiian Language Tutorial. Society to Advance Indigenous Vernaculars of the United States. Website: http://hawaiian.saivus.org/hawaiianpreface.pdf (accessed 10th November, 2016)

Figure 50 showing the Hawaiian utilities' operating domains

Note: The red highlights the Hawaiian Electric Industries' domains and the yellow highlights the other two utilities' domains.
Adapted from Bullerman (2010) using Microsoft Word

It is Oahu's grid and the HECO that are of interest (see Figure 50). Oahu's total power generation capacity is rated at 2,428 Megawatts (MW) and made up of 1,278 MW from utility-owned generation and 1,150 MW from independent power producers (IPPs) (HECO[1], 2018) (see Table 25 on the next page). The HECO therefore generates its own power as well as purchases power from IPPs (Rocky Mountain Institute, 2008; DBEDT, 2014; DBEDT[2], 2017).

The last subsection showed that Hawaii has several alternative energy resources in its energy mix and recently, solar has become the main renewable energy resource in the State (DBEDT[2], 2017). Figure 51 on page 262 illustrates this as solar generation (blue bars) increased over time whilst its proportional contribution to the islands' total renewable energy

generation also increased (red line). Figure 52 on page 263 also puts this growth into further context.

The table showing Oahu's power generation capacity originally presented here cannot be made freely available via ORA because of copyright. The information was respectively sourced from:

Hawaiian Electric Company (HECO) Incorporated[1]. 2018. Power facts. Website: https://www.hawaiianelectric.com/Documents/about_us/company_facts/power_facts_2017.pdf (accessed 16th September, 2017)

Table 25 showing Oahu's power generation capacity

Generated by the Author but adapted from the HECO[1] (2018) using Microsoft Word

Oahu has utility-scale IPPs' photovoltaic systems as well as distributed photovoltaics. There are around 12 large-scale solar plants in Oahu and examples include the 28 MW EE Waianae Solar plant in Waianae (the largest) and the 250 kilowatt Hawaii American Water Solar Array plant in Hawaii Kai (the smallest) (DBEDT[2], 2017).

The figure showing the growth in Hawaiian solar photovoltaics from 2007 to 2015 originally presented here cannot be made freely available via ORA because of copyright. The image and information was respectively sourced from:

Department of Business, Economic Development and Tourism[1] (DBEDT). 2016. Hawaii Energy Facts and Figures May 2016. Hawaii State Energy Office. Website: http://energy.hawaii.gov/wp-content/uploads/2011/10/FF_May2016_FINAL_5.13.16.pdf (accessed 1st. November, 2016)

Figure 51 showing the growth in Hawaiian solar photovoltaics generation from 2007 to 2015

Extracted from the DBEDT[1] (2016; 24)

However, unlike utility-scale solar, distributed photovoltaics is characterized by decentralized, smaller generators (Johnson and Chertow, 2009; Goss, 2010). With rooftop photovoltaics the technical linkage between generation and consumption is shorter than utility-scale solar because the latter connects to the grid at the transmission level whilst distributed photovoltaics connect at the distribution level (Codiga, 2013).

Distributed solar energy dominates the Hawaiian market and has accounted for as much as 92% of the growth in solar generation capacity at one point (ACORE, 2014; DBEDT[2], 2017).

Of Hawaii's total renewable energy generation of 2,466 Gigawatt-hours (GWh) in 2016, 33.5% came from distributed photovoltaics and 4.9% came from large-scale solar (DBEDT[2], 2017). Table 24 on page 259 shows these figures for distributed photovoltaics and utility-scale solar, and Figure 52 shows the renewable energy mix from 2010 to 2016 and distributed photovoltaics' increasing contributions.

The figure showing Hawaii's renewable energy generation mix from 2010 to 2016 originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Department of Business, Economic Development and Tourism[2] (DBEDT). 2017. Hawaii Energy Facts & Figures May 2017. Hawaii State Energy Office. Website: https://energy.hawaii.gov/wp-content/uploads/2011/10/HSEOFactsFigures_May2017_2.pdf (accessed 16th September, 2017)

Figure 52 showing Hawaii's renewable energy generation mix from 2010 to 2016

Note: The yellow and orange segments represent the distributed and utility-scale photovoltaics' contributions respectively, and GWhs stands for Gigwatt-hours.

Extracted from the DBEDT[2] (2017; 8)

Figure 53 (next page) shows the penetration of residential photovoltaics in Oahu and is a useful graphic to show in light of the theoretical 16% adoption pseudo-threshold which was outlined in Chapter 2 as part of the theory behind mainstreaming. This shows that the island has enough adoption to make residential photovoltaics a mainstream energy technology.

The image showing Oahu's residential photovoltaics concentration by district originally presented here cannot be made freely available via ORA because of copyright. The image and information was respectively sourced from:

Coffman, M., S. Allen and S. Wee.2018. Determinant of Residential Solar Photovoltaic Adoption.The Economic Research Organization at the University of Hawaii. Website: http://www.uhero.hawaii.edu/assets/WP_2018-1.pdf (accessed 10th January, 2019)

Figure 53 showing the concentration of residential photovoltaics on the island of Oahu by district

Notes: The concenrtration is based on the proportion of occupied housin gunits with photovoltaics installed

Extracted from Coffman et al. (2018; 13)

In the wider scheme, the State has nearly 51,000 solar-owners and the archipelago has varied solar penetration rates that range between 9 and 12% overall (Trabish, 2015; Research and Economic Analysis Division, 2015). But since Trabish's 2015 article, Gorak (2016) and Trabish (2017) state that there are 77,000 solar systems installed or approved by the HEI. Figures from the DBEDT[2] (2017) however put the utility-registered solar systems closer to 69,800.

Oahu has just over 47,200 systems which account for 383 MW under the NEM, FiT, customer grid-supply and self-supply, and standard interconnection agreement policies (DBEDT[2], 2017). The HECO[1] (2018) however state that it's customer-sited solar is estimated

to be 502 MW (see Table 25 on page 261). The discrepancy between the earlier 383 MW and this 502 MW could be due to the fact that the former refers to solar that has been enrolled under the specific policies listed at the time so the 119 MW difference may be solar that is outside the policies' remit.

The mid-to late 2000s were believed to be a key time for Hawaii's solar energy growth because there were developments that encouraged its widespread adoption according to several key informants e.g. *Informants OH01* and *OH11*. There were several specific factors which supported solar as an alternative and understanding the factors as landscape and regime-level forces put them into the context of the theory from Chapter 2. At the landscape-level, the factors were specifically the global recession and market recovery together with its associated increases in the international oil price as suggested by *Informants OH07* and *OH11*. Figure 54 illustrates this as the red shaded area.

The figure showing the West Texas Intermediate oil pirce from 1983 to 2014 originally presented here cannot be made freely available via ORA because of copyright. The image and information was respectively sourced from:

FedPrimeRate.com. 2015. Crude Oil Price History: NYMEX- West Texas Intermediate (WTI)- December 1, 1983 to December 1, 2014. Website: http://www.fedprimerate.com/nymex-crude-oil-price-history-chart.htm (accessed 30th June, 2015)

Figure 54 showing the West Texas Intermediate oil price in USD from 1983 to 2014

Note: The red area highlights the oil prices around the 2008 economic recession which marked a significant time in solar adoption in Hawaii.

Adapted from FedPrimeRate.com (2015) using Microsoft Word

Additionally, the plummet in the international cost of solar systems was another landscape-level force as suggested by *Informant OH01*. The price drop was as a result of the introduction of dedicated solar silicon feedstock for manufacturing panels (versus the prior waste from the semi-conductor industry), as well as the mass production of cheap Chinese brands adopted in European and North American markets (Earth Policy Institute, 2015). Figure 55 shows the module costs around this time as the red shaded areas for reference.

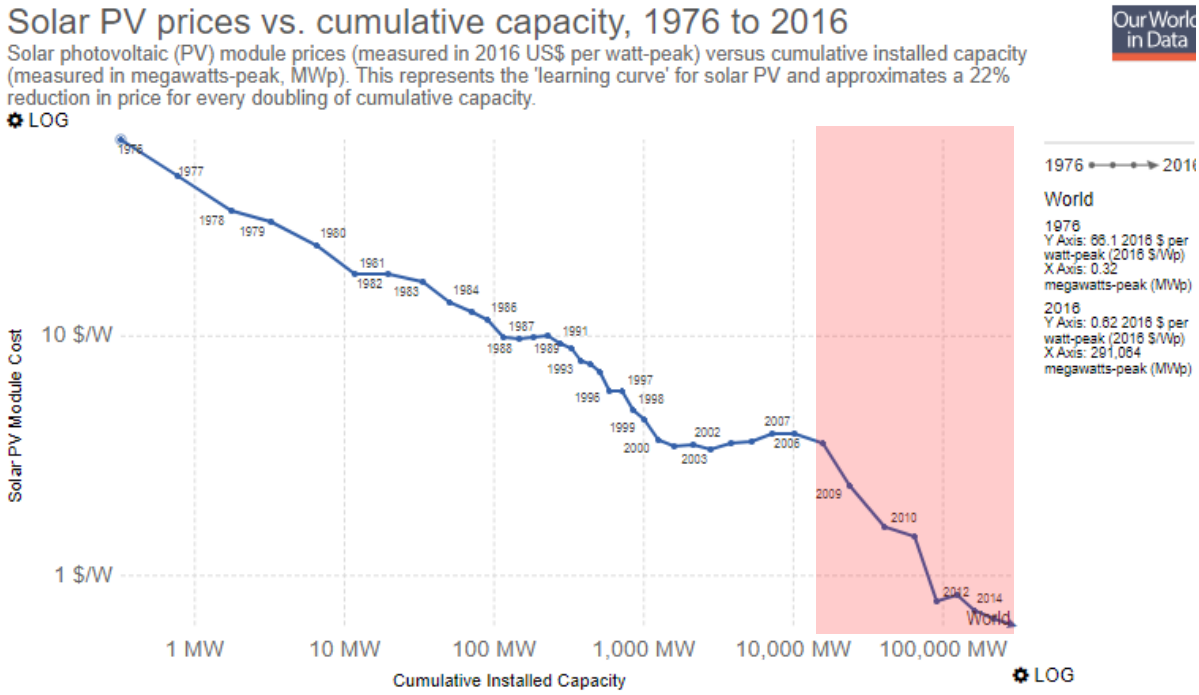


Figure 55 showing the global annual photovoltaic module cost in USD and cumulative installed capacity in Megawatts from 1976 to 2016

Note: The red area highlights the fall in photovoltaics prices around 2008 which marked a significant time in solar adoption in Hawaii.

Adapted from Ritchie and Roser (2018) using Microsoft Word

At the regime-level *Informants OH01* and *OH11* specifically touched on the influence of the domestic electricity costs on the island (which Appendix E shows are strongly linked to the

prices of oil on the international markets), as well as the implementation of policies which support solar energy adoption.

In the case of the last, the feed-in tariff (FiT) entered in 2009 (PUC, 2010; NC Clean Energy Technology Center[1], 2015; R.P. Delio and Company, 2012); net energy metering (NEM) in 2008 (NC Clean Energy Technology[2], 2015); and tax credits were made accessible in 2009 (NC Clean Energy Technology Center[3], 2015). Others such as the GreenSun Hawaii loan programme was made available through the American Recovery and Reinvestment Act of 2009 (NC Clean Energy Technology Center, 2014). The real estate market also felt the solar growth in 2009 since solar installations on properties since then qualified for property tax exemptions over the systems' lifetimes (DBEDT[2], 2015).

The landscape and regime-level factors which emerged from several informants' views show that the mainstreaming of solar energy in Oahu (and by extension Hawaii) was not an endogenous process or solely due to one causative change agent. The changes observed due to solar energy's introduction mean that the relationship between the utility, energy producer, and consumer can become quite different compared to the pre-existing design (R. P. Delio and Company, 2012).

An electricity system that has distributed solar energy integrated into it is more complex (Wüstenhagen et al., 2007; ABB, 2012; R.P. Delio and Company, 2012; International Electrotechnical Commission, 2014; WEC, 2016). This is because there are two-way streams of electricity where solar electricity is exported from households and electricity is imported into households (Brooks, 2003) - as with several of the policies mentioned above e.g. NEM.

This two-way exchange also applies to information and finance. For example, households are

either paid for their solar electricity exported to the grid and/or pay the utility for consuming its electricity from the grid based on the corresponding billing/crediting information. It would therefore be expected that the institutional network needed to support a solar-hybridized grid be more complicated than a conventional, centralized, fossil fuel-based one because of the distributed and decentralized nature of household photovoltaics. This is also consistent with the notion that each energy transition increases the regime's complexity (Chabrol, 2016).

7.2.1.3. Oahu's residential electricity consumers

Given the data and the figures quoted for distributed solar in the last subsection, it is unsurprising that most of the solar permit applications are residential applications (Research and Economic Analysis Division, 2015). The HSEO (2014) point out that solar system installations require permit applications and approvals, and householders need to apply for a permit from the Hawaiian Electric Company (HECO) as well as Department of Planning and Permitting (DPP) - the latter is involved because installing solar is a construction-related project (HCEI, 2010).

In terms of households acquiring solar systems, the most obvious interaction is between households and solar retailers where householders purchase the systems from retailers. But based on the above permit application interactions it can be expected that solar retailers receive guidance from the HECO and DPP on issues such as codes of practice, health and safety, certification, and registration. The Energy Resources and Technology Division (2003) state that solar system dealers and professional contractors must also have a solar speciality license to do installations whilst in the case of do-it-yourself projects, the electrician and like

tradespersons must be licensed.

The relationships between the utility and households revolve around the technical distribution of electricity, its consumption and the payments for it. Data from the DBEDT[2] (2017) show that the average household energy consumption has decreased from 584 kWh per month in 2011 to 484 kWh in 2016 for Hawaii, and from 609 kWh to 488 kWh in Oahu. The State's average monthly bill also decreased from USD $203 to $135, and in Oahu, from $195 to $127 over the same period (DBEDT[2], 2017). Other data from the DBEDT[2] (2017) supports these trends by showing that the kWh sold to the residential sector has been decreasing.

This is an interesting trend to flag because the Research and Economic Analysis Division (2014) indicates that the growth in renewable energy usage may be a key causative agent. This is because the reduction in electricity sales is not necessarily tied to energy conservation but rather to the growth of customer-sited renewables (particularly solar) shown in the last subsection and Figure 52 (page 263) which substitute where households' energy comes from; it is coming from these renewables instead of the HECO through the grid.

Chapter 2 showed that an energy transition (ET) has both supply and demand side changes so the above trend coupled with the earlier outlined changes in Oahu's power generation mix and the mainstreaming of residential photovoltaics shows that Oahu's residential electricity regime represented in Figure 48 (page 255) underwent an ET.

7.2.2. Trinidad's Energy Sourcing, Power Generation and Electricity Consumption

7.2.2.1. Trinidad's energy sourcing

Mitchell (2014) outlines that there is an outsourcing of energy in many countries so there is a difference between territories that produce and use energy. Unlike Oahu, Trinidad has indigenous oil and gas (O&G) (Espinasa, 2008). Chapter 4 detailed this so it will not be elaborated on here. 7% of Trinidad's energy is imported as oil (for refining) but 42% of its energy production is exported as O&G (Espinasa and Humpert, 2016).

Trinidad's hydrocarbon exports are sold to markets in East Asia (e.g. China, Japan and Korea), the U.S., Caribbean, and South America (e.g. Argentina and Brazil) (Snow, 2012; Jobity, 2013; Statistics Section, 2017). So in contrast to Oahu, oil price increases create more revenue for Trinidad and vice versa when prices fall; the exports put the sector's annual revenue in the vicinity of USD $3.5 billion (Driver, 2014; Singh, 2015) which amounts to 57 to 60% of the government's revenue (Espinasa and Humpert, 2013; Marzolf et al., 2015).

Key differences between Trinidad and Oahu are Trinidad's use of indigenous fossil fuels, the O&G companies exploiting them, the use of natural gas not petroleum for power generation, and the presence of a state-owned gas company, the National Gas Company of Trinidad and Tobago (NGC). McGuire et al. (2007), Blechinger and Shah (2011), Jobity (2013), and Russell and Bududass (2014) outline the interactions between O&G companies, the NGC, and Trinidad and Tobago Electricity Commission (T&TEC) seen in Figure 49 (page 256).

Informant TD04 thought that the O&G companies were key players because they provide the raw resource for the entire network and dictate the national state of the economy and finances.

These O&G companies enter bidding negotiations with the Government once select areas are opened for exploration and production (McGuire et al, 2007; Jobity, 2013). Successful bids therefore determine which firms are involved in the regime. But whilst both oil, and gas exploration occurs, gas is used in electricity generation (Marzolf et al., 2015; Espinasa and Humpert, 2016).

The extracted gas is first processed by the Phoenix Park Gas Processors Limited and then placed under the NGC's control (McGuire et al., 2007; Blechinger and Shah, 2011). McGuire et al. (2007), and Espinasa and Humpert (2013) describe the NGC as the sole purchase and sale price negotiator for gas and the national gas distributor and transmission agent; *Informant TD04* believed that the links between the NGC and O&G companies were influential because it accommodates the provision of the network's power generation feedstock.

Trinidad and Tobago's energy mix consists of natural gas, oil products and crude oil (Marzolf et al., 2015; Espinasa and Humpert, 2016). Its power generation mix however is made up of diesel and natural gas, and the latter is solely used for power generation in Trinidad (Marzolf et al., 2015; Espinasa and Humpert, 2016). Trinidad has not integrated renewables and this is another difference between Oahu and Trinidad.

7.2.2.2. Trinidad's power generation

Since the inception of electricity use in 1886 Trinidad's electricity industry has been privatized but it was converted into a State-led, vertically-integrated monopoly with the enactment of the Trinidad and Tobago Electricity Commission (T&TEC) Ordinance No. 42 1945 (McGuire et al., 2007; Samuel, 2013; Solaun et al., 2015; Espinasa and Humpert, 2016).

This legislation empowers the T&TEC as the sole legal electricity distributor and transmitter (Samuel, 2013).

The Ministry of Energy (1987) and McGuire et al. (2007) add that in time the nation's gas producers were directed to dedicate a portion of their reserves for the T&TEC's use and so provided at a preferential low price; Trinidad's regime supports hydrocarbon subsidies and Appendix E provides more detail.

In Trinidad the arrangement is such that the T&TEC purchases gas from the National Gas Company for the independent power producers (IPPs) to generate power (RIC, 2006; McGuire et al., 2007; Blechinger and Shah, 2011). Trinidad and Tobago's power is provided by four producers (Trinity Power, Trinidad Generation Unlimited, Power Generation Company (PowerGen), T&TEC) that operate 8 power plants (6 in Trinidad and 2 in Tobago) (Marzolf et al., 2015; Espinasa and Humpert, 2016). Table 26 shows Trinidad's natural gas power generation units.

The table showing Trinidad's power generation capacity originally presented here cannot be made freely available via ORA because of copyright. The information were respectively sourced from:

Espinasa, R. and M. Humpert. 2016. Energy Dossier: Trinidad and Tobago. Energy Division, Infrastructure and Environment Department, Inter-American Development Bank. Website: https://publications.iadb.org/bitstream/handle/11319/7447/Energy-Dossier-Trinidad-and-Tobago.pdf (accessed 20th January, 2017)

Table 26 showing Trinidad's power generation capacity

Note: There are only 5 power plants listed here though there are 6 in Trinidad. The missing one is likely due to the turbine count in which case a steam turbine at the PowerGen's Port of Spain facility is the omitted system.

Generated by the Author but adapted from Espinasa and Humpert (2016; 11) using Microsoft Word

The power plants in Trinidad are all IPPs' and amount to 2,341 Megawatts (MW) whilst Tobago's is utility-owned and rated at 85.7 MW (Espinasa and Humpert, 2016). Marzolf et al. (2015); *Informant TD08* outlined that one of the PowerGen's plants has been recently decommissioned so Trinidad's capacity would be smaller. Trinidad and Tobago are also connected by an undersea power cable (Espinasa and Humpert, 2016). So unlike Hawaii's 6 independent grids, Trinidad and Tobago has 1 grid.

In order to provide the IPPs with their power generation feedstock the T&TEC entered into long-term power purchase agreements (PPAs) with them. These PPAs determine the wholesale electricity price at which the T&TEC purchases power and examples include the PowerGen's 15-year, 819-MW PPA from 1994, and Trinity Power's 30-year, 215-MW PPA from 1998 (RIC, 2006); though there are different IPPs McGuire et al. (2007) state that the agreements are similar.

Unlike Oahu that has both utility-owned and IPP conventional, centralized power generation, Trinidad's regime is powered by IPPs' conventional, centralized generation units. Despite this difference in power generation ownership, one commonality between Oahu and Trinidad is that their regimes are primarily supported by conventional, centralized power generation - and the centralized generation-consumption pathway is a linear one (Paulos, 2014).

Informant TD16 was of the opinion that the IPPs are influential practical implementers. This is likely because they deal with the technical and infrastructural aspects of generating power. *Informants TD01*, *TD02*, *TD03*, *TD08*, *TD012*, and *TD013* thought that the T&TEC was also amongst the regime's implementation institutions, and as the island's sole utility, is one of the most influential actors because it is crucial at any level of the network's operations e.g.

overseeing the implementation of electricity-related protocols; designing the systems that would facilitate solar energy; generator licensing; electrician and solar energy companies' certification and codes of practice; and proper health and safety monitoring.

7.2.2.3. Trinidad's residential electricity consumers

The Trinidad and Tobago Electricity Commission (T&TEC) has a direct link to households by providing electricity and generating revenue from customers' bill payments - their two main public services i.e. electricity transmission and distribution, and the administrative elements involved e.g. billing of accounts (RIC, 2002). The households are seen as the orange textbox in the center of Figure 49 (page 256).

The retail rate is set at USD $0.04 for the first 400 kilowatt-hours (kWh), $0.05 USD for the next 600 kWh, and anything above this 1000 kWh threshold is rated at $0.06 per kWh (Espinasa and Humpert, 2016); these rates can be compared to Oahu's $0.30 USD per kWh (DBEDT[2], 2017). The rate is therefore a rising block tariff design where a lower price is charged for basic needs such as lighting and refrigeration and higher charges thereafter (Citizens Advice, 2016).

The 'typical' Trinidadian household uses between 458 and 1,090 kWh (no air conditioning) or between 1,390 and 1,543 kWh (with air conditioning) every month (Renewable Energy Committee, 2011; Marzolf et al., 2015); Oahu's monthly consumption is closer to 488 kWh (DBEDT[2], 2017). These consumption figures also put the monthly bill of an 'average' Trinidadian household between USD $21 and $59 (no air conditioning) or $76 and $86 (with air conditioning) - versus Oahu's monthly average of USD $127 for reference (DBEDT[2],

2017).

Based on these figures, electricity is cheaper in Trinidad and residents consume more comparatively. This cheap electricity is as a result of the energy subsidy on the natural gas that is used as the power generation feedstock (see Appendix E). Another contrast between Oahu and Trinidad is the increasing sales of residential electricity in Trinidad (Marzolf et al., 2015; Espinasa and Humpert, 2016) versus declining sales in Oahu.

There was no data available which offered more insight into the reasons for this disparity from the Trinidadian side of the comparison but it is highly likely that it is driven by the norms and practices that are affiliated with using cheap electricity and 'wasteful' practices.

There are several solar energy retailers in Trinidad. But the barriers to solar energy presented in Chapter 4 are the reasons why there was neither a solar energy retailer textbox nor connectors to households or other institutions represented in Trinidad's diagram (as could be seen in Figure 48 on page 255 for Oahu). *Informant TD15* believed that the local solar firms were more actively working in the wider Caribbean e.g. Barbados, Grenada, Jamaica and Antigua and Barbuda, or involved in small-scaled local applications e.g. street lighting or mobile phone charging stations according to *Informant TD10*. This is because the local market is stifled due to barriers such as the energy subsidy on conventional electricity which makes photovoltaics highly uncompetitive (see Appendix E for details on the subsidy mechanism).

In the wider scope of the industry and larger commercial projects, *Informant TD10* believed that traditionally once a 'Request For Proposals' is announced, many companies (beyond solar retailers) claim to be versed in solar energy and lodge applications usually using foreign

expertise to not only draft proposals but also oversee installations. They stated that:

"it could be as much as 50 companies out there that will say they can do solar. Basically every construction company will call up some American firm and say you all do up the proposal and they submit it… So basically any company can do it - any company will do it." (*Informant TD10*)

However:

"eventually if you do enough projects and people [i.e. local solar retailers] get regular projects then the interaction you'd need from a foreigner coming down would be less. Eventually the staff would be trained-up and you could have an industry going…once the industry gets started there'll be a chain reaction with all the other elements." (*Informant TD10*)

This therefore means that the island's industry suffers from low local technical capacity. *Informants TD01*, *TD10*, and *TD15* stressed the need for technician training since there is neither the technical capacity to install solar technologies nor any form of certification schemes to address the industry's knowledge deficiencies. The Renewable Energy Committee (2011) further outlines that identifying and filling skills gaps via training is one of the development areas for renewable energy training and education.

Informant TD11 and *TD16* believed that the skillsets which are useful for the renewable energy industry need to be developed so that its human resources can better support any incentives implemented (as has been done for hydrocarbons according to *Informant TD11*). *Informant TD16* also thought that this skills-development does not only apply to the solar retail business but also to the Government's agencies that would be administering incentives.

7.3. A Comparative Description of the Regulation and Governance of Electricity in Oahu and Trinidad

7.3.1. The Regulation and Governance of Electricity in Oahu

7.3.1.1. The role of the regulators and State in managing electricity in Oahu

This subsection will look at the roles of the Public Utilities Commission (PUC), Division of Consumer Advocacy (DCA), Hawaii State Energy Office (HSEO), Hawaii State Legislature, and Office of the Governor.

The PUC is one of the institutions responsible for reducing the State's reliance on fossil fuels and promoting increased renewable energy generation (Marumoto, 2013). *Informant OH11* described the PUC as the electricity regulator for the Hawaiian Electric Company (HECO) and not the independent power producers. *Informant OH08* also stated that whilst the PUC has directives that influence the utility's operations, the Commission also implements and regulates the policies that the Legislature passes on.

The DCA is an institution that is related to the PUC because it is a State-established entity set up with the purpose of protecting and representing consumer-interests before the PUC as it relates to electricity rate-increase applications from the HECO at public hearings (State of Hawaii[2], 2018).

The HSEO works on solutions geared towards removing the barriers to renewable energy and energy efficiency rollouts, aligning regulations and legislations with clean energy objectives, and promoting Hawaii-based clean energy research and investments (Marumoto, 2013). It seeks to lead the transition towards energy independence by diversifying the energy portfolio; encouraging market competition; connecting the Hawaiian grids; promoting Hawaii as an

energy innovation test-bed; and balancing the considerations of stakeholders (Marumoto, 2013; DBEDT[2], 2016).

The HSEO's role is set within the State's four energy objectives of fostering: 1) reliable and effective energy systems capable of supporting society's needs, 2) increased energy independence where the ratio of indigenous to imported energy use is increased; 3) increased energy security in light of any threats to Hawaii's energy system; and 4) the reduction of greenhouse gas emissions from energy supply and usage (HNEI, 2008).

Informants OH09, *OH10* and *OH11* suggested that one of the most influential entities in the regime is the State Legislature. *Informant OH08* stated that the Legislature enacts energy policies. *Informant OH08* believed that these are developed with the input of the stakeholders involved in Hawaiian energy and once they become enshrined in law they serve as directives for all actors - though the informant thought that these directives would have specific influence on the electricity regulators and market.

Informant OH08 specified that in their opinion the Legislature has important interactions with the HSEO and PUC where these:

"work under the framework the Legislature establishes." (*Informant OH08*)

Informant OH08 stated that the Legislature can advise the PUC on broad directives and the PUC then works out the specifics. This informant also clarified that in practicality, policy design moves back and forth between the HSEO and Legislature so it is not exclusively top-down prescriptions from the latter - the HSEO may propose an idea then the Legislature assesses its legal applications.

Informant OH08 pointed out that a proposal can be made by any of the network's institutions and the Legislature will consider the proposal and relevant input from January through May each year. Transitioning to renewables involves a multiplicity of actors and interests (Gorak, 2016) and making policies are compromises between stakeholders' perspectives and achieving consensus (Beerepoot and Beerepoot, 2007) - and *Informant OH08* acknowledged that one of, if not the greatest, legislative challenge is reconciling different actors' views.

The Legislature drafts and designs legislation but the power of ratification resides with the Governor (Marumoto, 2013). *Informant OH11* suggested that the Governor can also set the policy tone for the HSEO which then affects the PUC's decision-making processes. *Informant OH11* also noted that the Governor has a more direct impact on the PUC through the appointment of Commissioners.

The Governor has a 4-year term in office whilst Commissioners serve 6-year terms; *Informant OH11* pointed out that the 2-year stagger was originally designed to reduce the PUC's vulnerability to political influence. Additionally, Commissioners should not have any interest in or income from any of the State's utilities (Marumoto, 2013).

These roles and the fact that the Governor is responsible for setting the broad goals of the State and the priorities for achieving these goals (Marumoto, 2013) therefore illustrate why *Informant OH11* thought that the Governor's Office was a key institution.

7.3.1.2. The role of non-governmental institutions in Oahu's electricity sector

This subsection will briefly describe the roles of the non-governmental organizations (NGOs) using the University of Hawaii and Hawaii Natural Energy Institute (HNEI), Hawaii Solar Energy Association (HSEA), and Blue Planet Foundation as examples.

The HNEI is a research unit of the University of Hawaii which was established to work with the government to reduce the State's fossil fuel dependence (HNEI, 2016). It has interests in alternative and renewable energy, building efficiency, transport, grid integration and electrochemical power systems (SOEST, 2013; HNEI, 2016).

The State Legislature established a statute that supports the Institute's collaboration with State and federal institutions (SOEST, 2013) - institutions like the Public Utilities Commission, Hawaiian Electric Company, the Legislature itself, and State Energy Office (SOEST, 2013; HNEI, 2016). Therefore, the University and Institute are part of the governance through their supporting mandates.

Informant OH08 suggested that organizations like the Blue Planet were amongst the influential actors because they act as:

"a think tank for policy research" (*Informant OH08*)

The Blue Planet Foundation's (2017) objectives target policymakers as well as communities in an effort to influence the top-down and bottom-up segments of the energy system to inspire persons to believe in the possibility of transitioning away from fossil fuels.

The other NGO shown in Figure 48 (page 255) is the HSEA. It is a professional trade association affiliated with the solar energy industry and is made up of businesses and firms that support solar energy along all segments of the supply chain (HSEA, 2012; Cole-Brooks, 2014). The Association adds an overarching industrial solar voice within the regime through legislative, regulatory and educational outreach initiatives for businesses and homes (HCEI, 2011).

7.3.2. The Regulation and Governance of Electricity in Trinidad

7.3.2.1. The role of the regulators and State in managing electricity in Trinidad

This subsection will look at the actors that are part of Trinidad's electricity governance and regulation: the Regulated Industries Commission (RIC), Electrical Inspectorate Division and Ministry of Public Utilities, Ministry of Energy and Energy Industries, and Environmental Policy and Planning Division/Multilateral Environmental Agreements Unit (EPPD/MEAU).

Notwithstanding the regime-specific agency displayed by the networks' actors, Oahu's Public Utilities Commission (PUC) and Trinidad's RIC show an actor-likeness. *Informant TD13* described the latter as an authority involved in balancing the rights of service providers and those of consumers.

In monopolized markets consumers have no choice between suppliers and the supplier often allows the quality of service to depreciate since there is no incentive to maintain it (RIC, 2002). The RIC ensures that good quality and efficient services are being provided by the nation's utilities at equitable costs (McGuire et al., 2007). It acts as a watchdog agency over

quality (RIC, 2006; Samuel, 2013) - especially considering that the quality of service and price of the service tend to increase commensurately according to *Informant TD13*.

Solaun et al. (2015), and *Informants TD08* and *TD13* specified that the RIC regulates the Trinidad and Tobago Electricity Commission (T&TEC) and power generators especially as it pertains to rate-setting. This process involves the T&TEC presenting its case for rate-reviewing, the RIC making its recommendations after public hearings, and final approvals being sanctioned by the Government (McGuire et al., 2007).

The rates are set at the best reasonable prices using the methodology provided in the RIC Act (RIC, 2002; Ministry of Legal Affairs, 2014) and *Informant TD13* stated that based on the RIC's expertise in rate-setting the tariff results are not scrutinized in rate-case hearings but rather the process and methodology are.

Oahu's PUC and Trinidad's RIC perform a similar role in the islands' respective regimes. Both the PUC and RIC regulate their respective islands' utilities i.e. the Hawaiian Electric Company in Oahu and T&TEC in Trinidad, and their power generation. The T&TEC's power generation capacity is located in Tobago which means that Trinidad's power is generated by independent power producers (IPPs) i.e. Trinity Power Limited, Power Generation Company of Trinidad and Tobago (PowerGen) and Trinidad Generation Unlimited (TGU). *Informant TD08* and *Informant TD13* outlined that the RIC has regulatory influence over the IPPs. But the TGU is primarily regulated by its power purchase agreement (PPA) with the T&TEC (Espinasa and Humpert, 2016).

Informant TD13 outlined that a commission in the institutional sense has some form of regulatory power. The T&TEC displays this in the power generation and licensing arena but

when the RIC was consolidated, the regulatory power distribution changed such that quality and rate-setting came under the RIC; each actor's regulatory boundaries are determined by their instituting legislations i.e. the T&TEC and RIC Acts.

Informant TD13 stated that the RIC Act and Parliamentary decisions determine which entities fall under the RIC's schedule of service providers (e.g. PowerGen and Trinity Power). This is a grey area concerning any future grid-integration of solar because households adopting photovoltaics will be under the jurisdiction of the T&TEC in terms of the generator licensing but any generation-tariff may be determined by the RIC - since the latter is only responsible for its scheduled agents and individual generator-households are not featured presently. Therefore, there is the need for legislative revisions. But based on its present role, *Informants TD03*, *TD12*, *TD13*, *TD15*, and *TD16* spotlighted the RIC as an important institution because it orchestrates the regulatory environment for electricity.

Not only does the RIC have influence on the T&TEC but so too do the Electrical Inspectorate Division and its line Ministry, the Ministry of Public Utilities; they provide the T&TEC with support services according to *Informant TD03*. The interactions between these three actors were viewed as the most influential relationships by *Informants TD01* and *TD03* given their importance in the practical delivery of electricity.

Informant TD08 and *TD13* stated that the Division has oversight over some of the more technical aspects of the grid such as the internal wiring of homes which will be essential for residential solar projects and would include items like codes of practice. *Informant TD10* stated that the Ministry helps with the policy and legislation surrounding electricity-provisioning. *Informant TD08* also revealed that the Ministry of Public Utilities acts as an

occasional financer of the T&TEC although they thought that in a scenario where there is seamless regulation it may not be pivotal at least in relation to the utility's operations.

Trinidad's Town and Country Planning Division, and Oahu's Department of Planning and Permitting show another actor-resemblance. The Planning Division is responsible for managing applications, approving and also issuing permits for building development projects according to *Informant TD03*. The line Ministry, the Ministry of Planning and Development, was likewise significant according to *Informants TD03*. This is because it has input in the national developmental agenda which includes environmental issues and to some extent energy issues.

One of the most relevant units in the planning and development Ministry is the Economic Development Board. This Board reports to the Ministerial Council on Economic Development on broad economic diversification strategies aimed at achieving sustainable development which includes seeking out alternative energy initiatives (Ministry of Planning and Development, 2012). Based on these roles, *Informant TD03* suggested that the relationship between these actors and households are important since they would give permit application guidance for homes intending to install solar.

Energy systems need to transition away from fossil fuel resources and environmental institutions will be part of that transition. *Informant TD01* outlined that the EPPD is not an implementing actor but rather one that works on the overall policy vision for environmental issues through monitoring and coordinating functions. This informant suggested that the environmental and energy policy agendas have been aligned by the EPPD in the climate change arena - likely in relation to the publishing of the National Climate Change Policy and

the role of the MEAU.

Climate change as a stand-alone policy area is under the purview of the MEAU, another influential entity according to *Informant TD05*, because of the threats that climate change poses. *Informant TD02* described it as a coordinating agency that specifically looks after the local stakeholder interactions relevant to the climate change policy, carbon reduction strategy and international agreements to which the country is a signatory e.g. the United Nations Framework Convention on Climate Change.

The Office of the Governor in Oahu and the Office of the Prime Minister in Trinidad are both very alike in their functions as the highest elected Offices in the institutional hierarchies. The Office of the Prime Minister is not seen in Figure 49 (page 256) since the overarching role of high-level ratification for energy and electricity-related matters is vested with the Parliament/Cabinet/Senate which is included in the diagram.

According to McGuire et al. (2007) and Samuel (2013) the Parliament/Cabinet/Senate's most important decision-making body with respect to energy is the Cabinet's Standing Committee on Energy that is comprised of 10 Government Ministers; technocrats from the energy, finance, and planning Ministries; and chairmen and executives of State energy organizations.

The Ministry of the Attorney General and Legal Affairs frame parliamentary bills in law and would include those policy provisions relevant to energy and electricity. However, these items pass through debates in the Parliament/Cabinet/Senate. The Parliament/Cabinet/Senate's relationship with the energy Ministry was thought to be of note since it was what *Informant TD02* described as a pathway of least resistance where the Parliament/Cabinet/Senate gives the high-level approvals, the energy Ministry advises on

policies and the T&TEC implements accordingly.

The final governmental authority is the Ministry of Energy and Energy Industries (akin to Hawaii's State Energy Office). The energy Ministry's mandate is guided by the 1969 Petroleum Act, 1970 Petroleum Regulations, and 1974 Petroleum Taxes Act; the Ministry seeks to promote and manage the nation's energy and mineral resources (McGuire et al., 2007; Samuel, 2013; Espinasa and Humpert, 2013; Solaun et al., 2015; MEEA, 2017). In Hawaii however, the goal is to reduce fossil fuel imports by investing in alternatives that include renewable energy and energy efficiency (Jensen, 2000; Yalcintas and Kaya, 2009).

Trinidad's hydrocarbon history outlined in Chapter 4 indicates that the energy Ministry has been and is a powerful institution because it has the political jurisdiction over the hydrocarbon wealth of the country. Hawaii however does not have such a fossil fuel background or governmental authority linked to it. Therefore, the politics of energy unfold differently in both locations because of the conventional fossil fuel sector and vested political interest in its development in Trinidad.

Informants TD01, *TD03*, *TD08*, *TD10*, *TD12*, and *TD13* thought that the energy Ministry is amongst the most influential actors in the network because its remit is energy which includes solar energy developments and ties into the T&TEC's technical role in solar electrification. So, whilst many governmental actors are policy-based bodies, *Informant TD01* described the energy Ministry as an implementer as well.

Informant TD10 believed that the National Energy Corporation (NEC) was one of the specific influential agencies related to the energy Ministry. The Corporation is a subsidiary of the National Gas Company (NGC), the nation's natural gas operator - and the NGC's line

Ministry is the energy Ministry (Samuel, 2013). The NEC has a broad mandate to oversee the sustainable management and development of energy-based industries and marine ports (Rapid Environmental Assessments Limited et al., 2008; Samuel, 2013).

There are many institutions that should be included in Figure 49 (page 256) but including all would be difficult. Solaun et al. (2015) outlined that in the wider scheme, the Ministries of Finance, Local Government, and Housing and Urban Development would need to be part of the discussions. With respect to the Ministry of Finance *Informant TD08* flagged its significance for its role in setting the national budget which dictates ministerial allocations for the fiscal year, and addressing matters related to fiscal policy and taxes and exemptions (McGuire et al., 2007).

Dodman (2008) also suggested that the housing Ministry's Urban Development Corporation of Trinidad and Tobago will play an influential role in planning urban solar energy projects. This is because national issues related to the housing sector (as would be the case for solarizing homes) are directly under the housing Ministry's portfolio. In the case of the Local Government Ministry, their role in facilitating residential solar energy will be through the governance and administration of projects and issuing of support at the municipal level (versus the national scale).

7.3.2.1.1. Supporting Solar Energy Institutionally

In addition to the institutions listed at the end of the last subsection, there has been consideration extended towards creating a specialized governmental authority to oversee renewable energy developments. In 2008 the Trinidad Cabinet agreed on the formation of a

Renewable Energy Committee. It consists of nine members who are members of the University of the West Indies; University of Trinidad and Tobago; National Energy Corporation; T&TEC; and the Ministries of energy, trade and industry, public utilities, planning and development, and science and technology (Renewable Energy Committee, 2011) - which are all agencies that have been looked at in this chapter. The Committee subsequently published the national framework for a renewable energy policy in 2011 as a guide for the Government's renewable energy plans.

The Renewable Energy Committee (2011) advises the Government to establish a Renewable Energy and Energy Efficiency Agency (REEEA) charged with the duty of developing, assessing, implementating and auditing of energy efficiency and RE (renewable energy) policies and programmes. Based on the Committee's recommendations the REEEA would:

- Develop a register of local renewable energy and energy efficiency businesses, technology providers, and experts.
- Create an appropriate regulatory environment for renewable energy and the promotion of energy efficiency and conservation.
- Oversee a national programme of energy audits to determine the present level of energy efficiency, and to identify areas for improvement.
- Institute energy efficiency programmes.
- Oversee the introduction of renewable energy technology such as solar water heaters and photovoltaics to the public.

- Promote public awareness campaigns, and education and training related to renewable energy and energy efficiency.
- Develop incentive programmes for renewable energy technologies.
- Identify and assess proposed renewable energy projects.
- Organize long-term studies and surveys to produce national wind and solar atlases.
- Pursue funding for renewable energy projects from international financial agencies.
- Promote renewable energy businesses.
- Establish working relationships with similar renewable energy authorities and governing bodies in other nations.

This proposed Agency is significant to mention because several of the policies that are highlighted in Chapter 8 (see Table 28 on page 300) fit within the recommended remit of the REEEA. The policies are currently coordinated by many governmental institutions (namely the energy Ministry) but an institution like the REEEA could potentially be a more appropriate entity.

7.3.2.2. The role of non-governmental institutions in Trinidad's electricity sector

The non-governmental organizations (NGO) that will be looked at are the University of the West Indies and University of Trinidad and Tobago (UWI and UTT), and Sustain T&T. An actor-semblance was seen between the UWI and UTT, and the University of Hawaii and its Hawaii Natural Energy Institute.

Informant TD12 thought that these academic institutions have a role to play in innovative research and they should form partnerships with the education Ministry to work out formal curricular for renewable energy at all levels e.g. the UWI's present MSc in renewable energy. *Informant TD03* also thought that these institutions were crucial in the research and development of energy technologies. *Informant TD12* gave the UWI's planned smart grid and micro-grid projects as examples, and *Informant TD11* gave the UTT's model solar energy house as another.

Informant TD16 outlined that Sustain T&T acts as a sustainability and environmental education advocate involved in educational climate change and renewable energy workshops at schools and communities through video productions and film content. *Informant TD16* thought that the organization was also involved in branding services through film production, graphic-designing and drafting environmental speeches in the governmental development sector; it acts as a:

"de facto environmental communication agency." (*Informant TD16*)

However, *Informant TD16* said that the organization is not at the policy-writing stage just yet but hopes to influence policy through its work. *Informant TD15* nevertheless viewed

institutions like Sustain T&T as important because of their roles related to educating the wider public on renewables and instigating the public pressure needed for change. The impression given from the interviews with NGOs was that their role in Trinidad is not as developed as in Hawaii. This is important because they will have a key role to play in public education initiatives and cultural engagement on solar energy issues.

7.4. Chapter Conclusions

Oahu and Trinidad's networks have evolved around the predominant use of hydrocarbons. Oahu imports petroleum for its power generation but Trinidad uses locally-produced natural gas. Both locations' electricity transmission and distribution are provided by a single utility company from conventional, centralized power generation units.

Oahu however has significantly integrated renewable energy which includes distributed solar power. Solar energy works outside the conventional technical electricity system as a disruptive stimulus. Therefore, another key difference between both islands' regimes is that distributed photovoltaics are a part of Oahu's regime.

A conventional, centralized power generation regime (like Trinidad's) that integrates distributed solar becomes more complex (like Oahu's). Households are important actors that will be affected by this increased complexity. Incentivizing distributed solar energy through solar energy policies also increases the interactivity between households and utility company and so adds to this complexity.

The conventional institutional design involves households consuming electricity and paying

the utility for providing this electricity through the bills issued. With the introduction of grid-connected incentives like feed-in tariffs and net energy metering (NEM) households can be paid for the solar power they generate and export, and the utility company gains added power on their grid - which is in addition to the original interactions between both actors. Household photovoltaics therefore introduce new dimensions of electricity generation, transmission and distribution; financing and expenditures; fixed-cost recovery; and customer-service.

A key point to add to the above is that Oahu's high retail electricity rates that are designed to recover the fuel costs of imported petroleum have incentivized the adoption of residential solar energy technologies. Several legislative, regulatory and incentivization policies were also implemented and this made household solar even more attractive e.g. NEM. However, Trinidad's currently subsidized energy skews the electricity prices and is a strong barrier to the introduction of solar energy; the subsidy itself is looked at in Appendix E and was highlighted as a barrier in Chapter 4.

The integration of residential solar energy constitutes an industrial transition as the conventional energy industry made up of oil and gas firms and power generation companies transition into an industry that includes solar energy retailers and households. There is also a technological transition tied to this industrial change where centralized power generation units transition into a system that includes decentralized household units.

The institutions' influences on and in their networks are related to their realized agency. This is significant to consider since it gives insight into how power and agency distributions can thwart or support solar. The methods were not designed to perform an actor-network analysis but rather to provide descriptive characterizations. So, there is an opportunity for further

research on actor-networks undergoing an energy transition (ET) and to compare these networks before, during and after the ET.

The Ministry of Energy and Energy Industries and the Trinidad and Tobago Electricity Commission were viewed as the most influential actors in Trinidad - *Informant TD08* described the Ministry as the engine of the car and the Commission as the driver. The Ministry and Commission were flagged by 6 informants each, and the Regulated Industries Commission completes the network's influential triumvirate and was flagged by 5.

The political systems differ in each island and this affects the relationships and nature of the institutions present in the regimes. But despite the stark differences observed they showed several institutional-semblances as shown in Table 27.

NETWORK-ROLE	OAHU ACTOR	TRINIDAD ACTOR
Electric utility company	Hawaiian Electric Company	Trinidad and Tobago Electricity Commission
Electricity regulator	Public Utilities Commission	Regulated Industries Commission
Governmental energy body	Hawaii State Energy Office	Ministry of Energy and Energy Industries
Electricity users	Residential households	Residential households
Research, innovation and policy advice	University of Hawaii / Hawaii Natural Energy Institute	University of the West indies / University of Trinidad and Tobago
Construction planning and urban development	Department of Planning and Permitting	Town and Country Planning Division
Legislation designing and enactment	Hawaii State Legislature	Ministry of the Attorney General and Legal Affairs / Parliament/Cabinet/Senate
Highest elected Office	Office of the Governor of the State of Hawaii	Office of the Prime Minister of the Republic of Trinidad and Tobago

Table 27 showing the institutional semblances found between Oahu and Trinidad's residential electricity regimes' institutional concept diagrams

Generated by the Author using Microsoft Word

In terms of the wider governance there is the need for reform at the functional level of institutions i.e. the implementing entities and not overarching governing agencies since there is a managerial spectrum of energy-specific issues that gradually become incorporated into more generic governance issues as the agenda moves up the 'chain of institutional command'.

Governments have a major role through their policy implementation but whilst policy implementation may be Government-led, policies' success depend on the network because they are not stand-alone features of an ET.

7.4.1. Implications for Trinidad's Residential Energy Cultures

The thesis specifically investigates the interactions between culture and policy so it is worth highlighting the cultural implications of the chapter's findings. The chapter's results led to several insights into how the regime's institutional network which supports and will support the Government's policy options can influence and be influenced by the resident population's incumbent energy cultures:

i. Integrating distributed photovoltaics into Trinidad's residential electricity regime will complicate its multi-actor network. This suggests that residents' energy cultures will become more complex as well.

ii. The utility's cost recovery is mitigated by a subsidy on the costs of the natural gas used for power generation in Trinidad. Removing the subsidy will increase the residential retail tariff and consequently affect the norms and practices surrounding

energy usage and costs because the tariff is an external influence on the energy culture (see Chapter 5).

7.4.2. Characterizing Mainstreaming

Oahu's regime includes distributed residential photovoltaics and its supporting institutional actors which contrast with Trinidad's. So relative to mainstreaming there are several tenets inspired by the chapter's comparative characterizations of institutional residential electricity networks:

i. Mainstreaming a technology introduces a new group of institutional actors into the regime's multi-actor network e.g. solar retailers.

ii. Mainstreaming a technology is likely to spur new institutional relationships in the network e.g. households lodging photovoltaic interconnection permit applications with the utility company.

iii. Mainstreaming a technology catalyzes actor-agency changes (which may have corresponding changes in actor-power distributions) e.g. changes in the utility's generation, and changes in electricity regulation in the management of the impact of solar on rate-setting. Agency changes can also be coupled with the reformation of existing relationships or the development new ones.

8.0. Residential Solar Energy Policies as Energy Transitions Instruments: A Look at Oahu's Policy Experience and Trinidad's Policy Plans

Synopsis

This chapter outlines the role of residential solar energy policies in helping household solar energy technologies out of niches. It specifically helps answer the research sub-question: "*What are the Government's State-level residential solar energy policy options in Trinidad?*" In so doing it also identifies some of the policies that would be featured in the central discussion (Chapter 9) which answers the overarching research question related to the interactions between culture and policies.

This chapter's discussions are based on the deductive thematic analysis of the 22 key-informant interviews conducted in Oahu and Trinidad. Whilst various policy literature resources characterized the policy environment in each island, the interviews helped identify the key policies that have been implemented and are being planned in each island. Therefore, the chapter's discussions focus on the policies which arose during the primary data collection and use the policy literature to detail their designs.

This chapter builds on the previous one because the policies discussed are implemented by the various institutions characterized in the islands' regimes. They can help household solar energy technologies evolve out of their niches to become mainstreamed through their respective designs, so the chapter addresses the way in which the various policy mechanisms operate as agents in mainstreaming.

The implementation of such policies can translate into increased adoption of the supported technologies - and this is a key process in mainstreaming (see Chapter 2). It also shows how they can act as catalysts for change based on the comparison between Trinidad and Oahu in Chapter 7 since policy interventions and renewable energy generation are strongly linked in the latter island. Related to this is the likely impact on energy cultures because of a given policy's implementation since it is an external influence (see Chapter 2).

The chapter is structured as follows: section 8.1. details how the key policies to be discussed were identified (i.e. renewable energy targets, renewable portfolio standards, net energy metering (NEM), and feed-in tariffs (FiTs)) as well as justifies why they are being discussed; section 8.2. outlines the use of renewable energy targets and renewable portfolio standards in Trinidad and Oahu respectively; section 8.3. looks at NEM and FiTs as examples of grid-tied policy strategies in the islands; and section 8.4. presents the chapter's conclusions, its cultural implications, and characterizes mainstreaming based on the chapter's findings.

8.1. Identifying the Key Residential Solar Energy Policies in Oahu and Trinidad

The 22 institutional informants were asked: '*What are some of the traits that an innovation needs to have in order to become mainstreamed?*' The way the question was asked allowed the informants to characterize an innovation by providing one or more attributes that would give it have a higher chance of being mainstreamed e.g.:

"…the more economically viable the technology is the more it will be able to be implemented." (*Informant TD01*)

This was important to see what would be the institutional description of a 'successful' energy innovation in each island's regime, and how the islands' policies capitalize or can capitalize on these attributes. There were 30 different attributes that emerged from the 22 informants' characterizations. There are 11 attributes that were similar in both Oahu and Trinidad. Figure 56 shows these characteristics and of these 11, cost-effectiveness is the most prominent; it was flagged 9 times in Oahu and 11 times in Trinidad. The earlier quote is an example of transcript text that would have led to coding labels associated with cost-effectiveness.

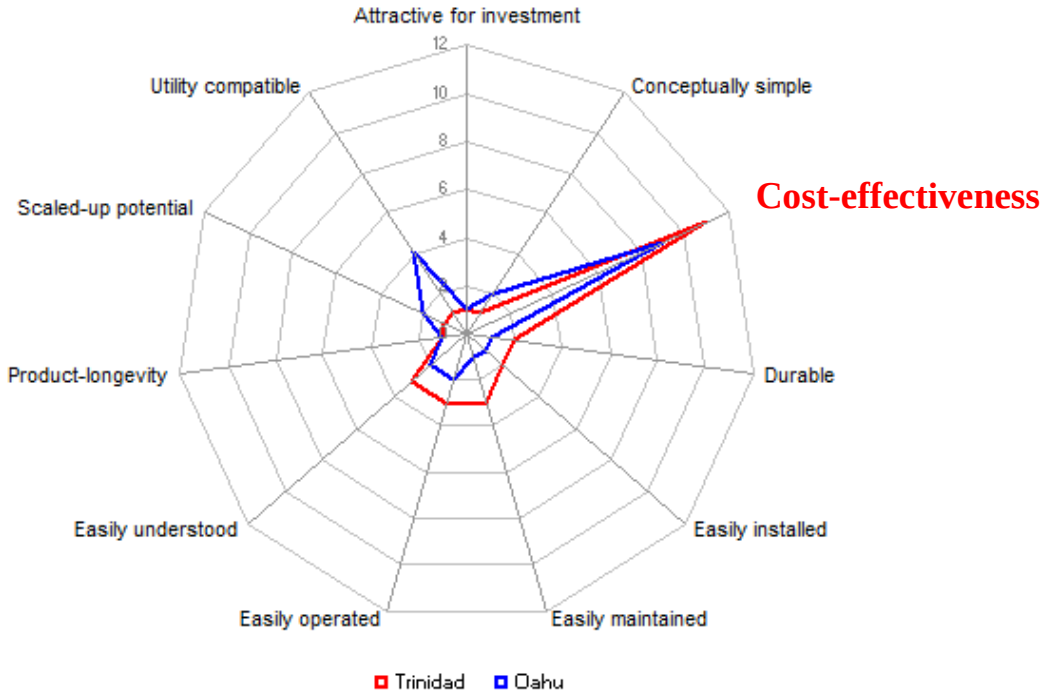


Figure 56 showing the relative significance of the cross-cutting niche-innovation attributes based on the energy officials' responses from Oahu and Trinidad

Note: The frequency refers to the number of times each attribute was flagged in the energy officials' responses.

Generated by the Author using Microsoft Excel

The institutional significance of cost-effectiveness in Figure 56 (previous page) is important because policies can change the economics of solar and influence investment decisions (Durham et al., 1988). They can therefore be influential agents in the household adoption of solar technologies (Bauner and Crago, 2015). However solar energy's future can only be as bright as it is claimed to be through the appropriate government policies (Blake, 2015).

The key-informants were questioned along the lines of '*What are the State's main residential solar energy strategies?*' in Oahu, and '*What are some of the State's residential solar strategies that have been/should be implemented?'* in Trinidad. This was useful for because it:

- Gave the most recent account of the policy situation in each island - especially where the policy environment was developing so fast that there was no solidified body of policy literature to reference e.g. Oahu's transition away from net energy metering (NEM).
- Helped narrow down the policies that should be looked at with respect to the scope of the research and the interactions between culture and policy.
- Allowed for a more thorough look at Oahu's policy experience that is transferable to Trinidad's policy plans.
- Directly helps answer the research sub-question surrounding what policies the Trinidadian Government should consider.

The data from the 11 institutional interviews done in Trinidad led to 20 sub-codes linked through 5 codes. The coding was based on grid-connected solar energy, renewable energy targets (RETs), legislative reform, tax breaks and stimulating the market. This primary data

was coupled with policy-related literature such as the MEEA (2012), NREL[1] (2015), Marzolf et al. (2015), Khan and Khan (2017), and MEEA[1,2,3,4] (2018) to create Table 28 which shows the policy environment for solar energy in Trinidad.

STRATEGY	SOLAR TECHNOLOGY	POLICY STATUS	POLICY NOTES
Legislative reform	Photovoltaics	Pending	The legislations that empower the utility company and electricity regulator need to be revised to facilitate the integration of photovoltaics.
Feed-in tariff	Photovoltaics	Pending	A feed-in tariff is being planned to facilitate the integration of grid-connected photovoltaics.
Renewable energy policy	Solar water heaters & Photovoltaics	Pending	There is a Cabinet-approved Renewable Energy Policy Framework and it has been incorporated into the Draft Policy Green Paper which is being finalized.
Renewable energy targets	Photovoltaics	In place	There is a prescriptive ambition of 10% of the nation's power generation which has to come from renewable energy sources by 2021.
Electric wiring codes	Photovoltaics	In place	The wiring codes applicable to the integration of photovoltaics have been revised and published, and grid-connected photovoltaics demonstration projects have been setup.
Import duty exemptions	Solar water heaters	In place	Components for the manufacture of solar water heaters are exempt from import duties.
0-rated value added tax	Solar water heaters & Photovoltaics	In place	Solar water heaters and photovoltaics panels are free of value added tax upon purchase.
Tax incentives	Solar water heaters	In place	Solar water heater adopters are eligible for a tax credit of 25% the cost of the system up to a maximum cost of USD $1,500.
Wear and tear allowances	Solar water heaters & Photovoltaics	In place	An allowance of 150% of the costs incurred on the acquisition of components used in solar water heater manufacturing, and the acquisition of photovoltaic and solar water heater systems.
Technical standards	Solar water heaters	In place	There are published standards for the design and installation of solar water heaters (inclusive of performance, operation and servicing, safety, reliability and durability).
Education and public awareness campaigns	Solar water heaters & Photovoltaics	In place	There is a national education campaign to raise the public awareness of the energy sector, renewable energy, energy efficiency and energy conservation.

Table 28 showing the extent of Trinidad's State-level residential solar energy policy development

Generated by the Author using Microsoft Word

In Hawaii's case sources such as Coffman et al. (2013); Energy and Environmental Economics Incorporated (2014); the ACORE (2014); GE Energy Consulting (2015); and the DBEDT (2015) state that renewable portfolio standards (RPSs), NEM, tax incentives, the feed-in tariff (FiT), green infrastructure bonds, rebates, loan programmes, and the pay as you save scheme were some key strategies.

But the 11 interviews in Oahu produced 12 sub-codes that are related through 4 codes. The most frequently cited policies were NEM, RPSs and tax incentives which were flagged 17, 16, and 8 times respectively. These counts are based on the frequency of each policy label in the 11 energy officials' transcripts from statements such as:

"Oh yes the RPS [renewable portfolio standards] is a good one too. Actually, it's probably one of the top, most important if only because its sets that long term goal..." (*Informant OH08*)

The data showed that the RPSs, NEM and tax incentives were believed to be the most influential by the 11 key-informants.

All policies should be considered in Trinidad but looking at Oahu's experience and what Trinidad already has in place gives the analysis better focus as already mentioned. Of the policies that have been implemented and are pending in Trinidad from Table 28 (previous page) together with those that arose in the interviews in Oahu, RETs and RPSs, NEM, and FiTs will be discussed with consideration for tax incentives where relevant. This is because:

- Addressing all the policy options would only allow for surface-level discussions.
- Tax incentives have already been put in place in both islands.

- RPSs and NEM are the most influential policies implemented in the case study comparator Oahu - though a caveat is that they may not necessarily the best to implement simply because they arose in the analysis.

- There are key lessons-learnt from Hawaii's RPSs and NEM experience that applies to Trinidad's RETs and intended FiT.

- There are interesting links between RETs and FiTs worth pointing out in Trinidad's context.

- Though the energy cultures policy conclusions from Chapters 5 and 6 show the need for more than solely the policies that will be discussed, Trinidad's FiT is likely to be one of the most culturally impactful policies because it will affect both the energy usage and costs domains of the respondents' energy culture (see Chapter 5).

- Cost-effectiveness is the most salient institutional characteristic of an energy innovation based on the information from Oahu and Trinidad. This means that pricing and designing the tariffs for grid-connected solar energy policies like a FiT will be crucial to the success of residential solar energy in Trinidad.

- The various policies in Table 28 (page 300) and those raised in Chapter 5 and 6's policy implications will be adequately touched on in Chapter 9 as part of the wider discussion on Trinidad's mainstreaming strategy for residential solar energy.

RPSs stipulate legally-mandated proportions of renewable energy that should make up part of the total generation portfolio of electric utilities whilst RETs are not legally-binding and are prescriptive generation ambitions. NEM and FiTs allow household photovoltaics adopters to

be paid for the solar energy they generate and/or export to the grid. Tax incentives are commonly used to reduce the upfront capital costs of solar systems by allowing adopters to get a specified tax return for adopting a solar system. Trinidad's RETs and Hawaii's RPSs will be looked at first followed by NEM and FiTs.

8.2. Using Quantitative Ambitions for Renewable Energy Generation as a Policy Instrument

8.2.1. Trinidad's Renewable Energy Generation Ambitions

Trinidad's National Climate Change Policy sets out a vision for low-carbon development through renewables, clean energy technology and clean production technology (Solaun et al., 2015). *Informants TD01* and *TD02* viewed the Policy's designers, the Environmental Policy and Planning Division, and Multilateral Environmental Agreements Unit, as having aligned the climate change and energy agendas through the country's Intended Nationally Determined Contributions (INDCs).

INDCs are national greenhouse gas reduction targets devised by the United Nations Framework Convention on Climate Change's (UNFCCC) respective signatories under the 2015 Paris Agreement. *Informant TD02* connected with the country's aim of reducing emissions by 15% by 2030 and this ambition was confirmed by literature sources such as the GORTT (2016). The reductions focus on methane, carbon dioxide and nitrous oxide emissions. Under the Paris Agreement there will be regular progress-reporting and international reviews of countries' INDC reports, and ambitions should increase with each subsequent report every 5 years starting in 2020.

This target is laid out in the Government's Carbon Reduction Strategy that speaks to reductions in the power generation (19%), industry (75%), and transport (7%) sectors such that by 2040, the economy will no longer be based on hydrocarbons (Solaun et al., 2015). However, 19% emissions reduction in the power generation sector still suggests that the electricity system will be dominated by hydrocarbons. The cost of implementing the strategies is estimated to be in the vicinity of USD $2 billion (Climate Policy Group, 2016).

The GORTT (2016) outlines that in the power generation sector, the country is presently working on achieving greater energy efficiencies through combined cycle generation at power plants, and renewables are the next step. *Informant TD01* outlined that the energy vision involves:

"going to a cleaner fuel and reducing our [Trinidad and Tobago's] reliance on fossil fuels". (*Informant TD01*)

Solaun et al. (2015) also state that renewable energy will become a reality in Trinidad and Tobago's energy mix.

However, countries with a legacy of industrial development and dependence on fossil fuel income streams often prioritize these sectors in development planning (Kuzemko et al., 2016). The Renewable Energy Committee (2011) asserts that Trinidad and Tobago's petroleum resources have historically been and would foreseeable continue to be the driver of the country's growth and development. The MEEA (2014) echoes this by stating that the upstream energy sector's reinventions also have it set to continue being the keystone economic activity.

The Renewable Energy Committee suggests that Trinidad should however work on achieving

5% of its power generation through renewable energy by 2020. But *Informants TD01, TD02* and *TD08* confirmed reports that the energy and finance Ministers outlined a renewable energy target (RET) of '10% by 2021' i.e. roughly 243 Megawatts. One informant noted that:

"Ministers' utterances are taken as policy" (*Informant TD02*)

So, in their opinion, there are already initiatives for increasing the renewables quota in the power generation sector though the 10% RET is a policy prescription according to *Informant TD01*.

Despite this, *Informants TD01* and *TD02* viewed the target as synergistic with the INDCs' goals (though *Informant TD01* was not sure of the extent of the synergy) because:

"there is this commitment that gives 2030 as the timeline. The Paris Agreement now, means that every 5 years you have to increase your ambition. There is a separate commitment given for 10% penetration by 2021 so all of these working in tandem mean that we have at least the next 15 years within which to work to reduce emissions. Whether that emission reduction occurs as a result of increased efficiency of traditional fossil fuel-generated power is one consideration. Whether it is as a result of a greater penetration of solar technology or renewable energy technology is another one. (*Informant TD02*)

Informant TD03 outlined that these INDCs are set in a wider development plan that updates a previous Government administration's 'Vision 2020' - a national development strategy birthed in 2002 as a driver of public sector development through the National Strategic Plan aimed at achieving 'developed country' status by 2020 (Artana et al., 2007; Programme Management Office, 2009).

Informant TD03 suggested that there should be key performance indicators attached since it would establish a baseline for measuring progress. *Informant TD03* however also noted that some present environmental indicators have been left as 'on-paper' figures where though

there is this risk, renewable energy performance metrics should help frame a common direction for all actors in a step-by-step manner with checks and balances that are scientific and verifiable.

Informant TD16 suggested that in the wider scope the 10% may symbolize a reduction in the number of diesel or natural gas-powered kilowatt-hours but there is no definitive plan for the renewable energy industry especially as it pertains to technologies and their commercial viability i.e.:

"there is no roadmap for introducing renewable energy in a phased way." (*Informant TD16*)

8.2.2. Hawaii's Renewable Energy Generation Ambitions

The Hawaii Clean Energy Initiative (HCEI) was launched in 2008 and is a programme that supports energy efficiency, the regulatory environment for clean energy and inter-island utility company collaborations to increase renewable energy generation and grid connections (State of Hawaii[1], 2018). Braccio and Finch (2011) outline the HCEI's four main strategies for the electricity sector: to deploy grid-compatible renewable energy technology; build confidence in renewables; explore the benefits of innovative and existing green technology; and align the electricity sector's regulatory and policy frameworks with cleaner energy.

The HCEI's renewable energy program is detailed by the State's renewable portfolio standards (RPSs). RPSs are regulatory instruments designed to stimulate an increase in renewable energy production by mandating electricity suppliers to incorporate renewables into their supply mixes and sales through specified numerical targets (Cory and Swezey, 2007; Cory et al., 2009; Lyon and Yin, 2010; Zhai, 2013; NREL[4], 2015).

The image showing the distribution of renewable portfolio standards in the United States originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Lyon, T. P. and H. Yin. 2010. Why Do States Adopt Renewable Portfolio Standards? An Empirical Investigation. The Energy Journal, 31(3): 133 – 157. Website: http://webuser.bus.umich.edu/tplyon/PDF/Published%20Papers/Lyon%20Yin%20RPS%20Energy%20Journal%20Proofs.pdf (accessed 28th March, 2018)

Figure 57 showing the distribution of renewable portfolio standards in the United States

Extracted from Lyon and Lin (2010; 135)

RPSs have been around since the 1990s in the U.S. (Wiser et al., 2007); are the country's most common State-level policy (Cory et al., 2009); and are key drivers of the national renewable energy industry (Burnett, 2011; Zhai, 2013; PUC, 2013). Figure 57 shows the distribution of RPSs in the U.S. and Hawaii is seen as the group of islands to the bottom-left of the figure. It includes the distribution of renewable energy targets (RETs) as well and shows that RPSs are not simply ambitions but legislative regulations. This is an important distinction to make in light of Trinidad's RETs from the earlier subsection.

The NREL[4] (2015) notes that RPSs can be customized based on the utility company-ownership and technology preferences. So, the States utilizing RPSs would have enacted them based on their specific contexts (HNEI, 2008). There is therefore a diversity of RPSs designs and Figure 58 provides examples of considerations that shape RPSs' designs.

Structure, Size, and Application	Eligibility	Administration
• Basis (energy vs. capacity obligation) • Purchase obligations over time • Structure (single tier or multiple tiers) • Resource diversity requirements or incentives • Start date • Duration of obligation (sunset provisions) • Application to retail suppliers, and exemptions from obligation • Product- or company-based application	• Geographic eligibility • Resource eligibility • Eligibility of existing renewable generation • Definition of new/incremental generation • Treatment of multi-fuel facilities • Treatment of off-grid and customer-sited facilities	• Regulatory oversight body(ies) • Compliance verification (RECs, or otherwise) • Certification of eligible generators • Compliance filing requirements • Enforcement mechanisms • Cost caps and alternative compliance payments • Flexibility mechanisms (banking, borrowing, etc.) • Contracting standards for regulated retail suppliers • Cost recovery for regulated retail suppliers • Interactions with other energy and environmental policies

Figure 58 showing the policy design options for renewable portfolio standards

Extracted from Wiser et al. (2007; 11)

RPSs' generation targets should increase over time (Wiser et al., 2008; Lyon and Yin, 2010; Yin and Powers, 2010). Hawaii's RPSs of '7% by 2003' evolved to '8% by 2005'; '10% by 2010'; '15% by 2015'; and '20% by 2020' since its enactment in 2001 (Rocky Mountain Institute, 2008; Yalcintas and Kaya, 2009; PUC, 2013; GE Energy Consulting, 2015; Gorak, 2016).

The RPSs were then increased to '40% by 2030' with an added 30% efficient energy through the HCEI's energy efficiency portfolio standards (EEPS) which has been branded as a total of 70% clean energy (Lim, 2011; R.P. Delio and Company, 2012; Critz et al. 2013; PUC, 2013; Energy and Environmental Economics Incorporated, 2014).

This last target shows how the HCEI's energy efficiency ambitions complement the RPSs in Hawaii and having been implemented after the RPSs, Morita (2014) and Savenije (2015) believe that the EEPS built on the RPSs' success over the years. The original Memorandum

of Understanding between the U.S. Department of Energy and State of Hawaii under the HCEI was also strengthened in 2014 (State of Hawaii[1], 2018).

The Public Utilities Commission (PUC) coordinates with the University of Hawaii's Natural Energy Institute to review the targets every 5 years (Global Energy Concepts LLC, 2006). Electricity suppliers also need to demonstrate their compliance annually (Wiser et al., 2008) so the utilities submit annual status reports (DBEDT, 2015) and the PUC reports on the status of the utilities' strategies to the State Legislature (PUC, 2013). Chapter 7 describes the roles of these institutions in more detail.

R.P. Delio and Company (2012) point out that Hawaii's strong dependence on expensive fuel imports is one of the prime reasons why the State's RPSs have been so ambitious. Glick (2014) highlights the State's ambition to move beyond 40%. This ambition would have been supported by the HCEI's 2014 Memorandum reaffirmation that has been branded as 'HCEI MAX' (State of Hawaii[1], 2018) - because the RPSs and HCEI are linked through the need to reduce oil imports, enhance home security, reduce emissions and the impacts of climate change, as well as promote local economic benefits according to *Informant OH01*.

The State of Hawaii[1] (2018), and *Informants OH08*, *OH09* and *OH11* outlined that the State has set and ratified a RPSs target of '100% by 2045'; Hawaii is the most populated archipelago with independent grids to have such an energy ambition (Renewables 100 Policy Institute[1], 2015).

Informant OHI04 was of the opinion that though Hawaii's RPSs are admirable targets there are no 'real' penalties attached to non-compliance which limits its practical leverage. The strongest RPSs use non-compliance penalties (through fines or alternative compliance

payments) which are predetermined amounts per kilowatt-hour that a supplier pays if they fail to meet their RPSs and which cannot be recovered from ratepayers/customers (Cory and Swezey, 2007). *Informant OH08* outlined that the Hawaiian utilities can be fined and the PUC has the ability to ensure that some public benefit is derived from non-compliance e.g. limiting the utility's revenue such that funding is diverted into RPSs projects or redistributed amongst ratepayers.

The penalties for not meeting the RPSs targets are consequently subject to the PUC's discretion and non-compliant utilities may be granted extensions to meet their obligations, or the penalty may be waived provided that non-compliance resulting from factors reasonably beyond a utility's control could be proven (HNEI, 2008). *Informant OH08* summarized the RPSs' impact by saying that:

"the RPSs created the incentive for the utility [companies] to comply with all these other laws that we're putting in place because at the end of the day, the utility has to be willing to interconnect everybody." (*Informant OH08*)

Another informant asserted that the:

"RPSs law is huge for us [in Hawaii] because that sets the finish line for us - we have to get there. So that totally shapes our resources and what we're able to use." (*Informant OH09*)

Considering the last line of *Informant OH09*'s above statement, a 2006 ruling enabled the PUC to prescribe which renewables should make up stipulated portions of electricity sales (HNEI, 2008). Jensen (2000) and the HNEI (2008) note that the RPSs legislation also enables utilities to aggregate their renewable energy portfolios to meet their targets and is usually done through the utilities' integrated resource planning which is a publicly-vetted process that

looks at balancing the supply and demand-side issues.

Hawaii's 4 utilities meet the RPSs in their own ways (Cory et al., 2009) and 3 of the 4 utilities fall under the Hawaii Electric Industries (HEI); the Hawaiian Electric Company (HECO) in Oahu is the parent company and its subsidiaries are the Maui Electric Company servicing Maui, Molokai and Lanai, and the Hawaii Electric Light Company on Hawaii Island. So, in the case of the HEI, the HECO and its subsidiaries can capitalize on their jurisdictions' most promising renewable resources and contribute to the HEI's overall integrated resource plan aimed at meeting the RPSs.

For example, *Informant OH09* suggested that the HECO have included RPSs considerations in action items like the power supply improvement plans (PSIPs) for each island which is submitted to the PUC. Such documents are designed to layout the company's transformational pathway in order to meet the needs of customers and increasing renewable energy production (Viola, 2014; GE Energy Consulting, 2015). These PSIPs are in their own right an important part of the RPSs' roadmap since *Informant OH09* believed that no one had a clear idea of how the State would achieve its RPSs when they were first instituted.

8.2.3. Linking Renewable Energy Generation Ambitions to Grid-Connected Solar Energy Policies

Renewable portfolio standards (RPSs) or renewable energy targets (RETs) do not directly create an economic incentive for residential solar energy at the household level because they primarily are linked to independent power generators, utility companies, and government agencies. This is where policies like net energy metering (NEM) and feed-in tariffs (FiTs)

which will be looked at in the next section are useful. NEM and FiTs are policies that allow householders to generate and export their solar power to the grid and be paid for it by the utility company. There could be 3rd party asset ownership involved where the solar systems enrolled in NEM or FiT-like programmes are owned by an external company which essentially rents the roof-space of homes for instance. However, for the purposes of exploring the links between culture and policy more clearly within the scope of the thesis (as will be shown in Chapter 9), the asset ownership here is vested with the household.

They can be linked to RPSs and RETs through the programme caps that are set and expected e.g. a total power generation cap under the scheme, and using a generation meter to measure solar systems' power generation can be used to check the grid-connected programme's contribution to RETs and RPSs (Cory and Swezey, 2007). As outlined in the last subsection the Public Utilities Commission can prescribe what proportions of Hawaii's RPSs need to come from specified renewable resources like solar energy. Cory and Swezey (2007) state that some RPSs designs have allocated quotas for solar energy because of its smaller scales (compared to other renewables) and distributed applications.

This is not to say that RPSs should be implemented in Trinidad however. RPSs may not work in Trinidad as they have in Hawaii due to the fact that the electricity utility company is government-owned. Hawaii`s utility companies are private entities that are held accountable by the State (see Chapter 7). In Trinidad there would be an issue with accountability since it would essentially be an internal affair as one State-institution holds another accountable. So, coupling Trinidad's RETs to its emissions reduction commitments would be a better approach.

Trinidad's intended FiT should have a programme-wide capacity cap that contributes to the national renewable energy target of '10% by 2021'. The FiT can also help achieve the national emissions reduction commitments of '15% by 2030' based on the Intended Nationally Determined Contributions and '19% by 2040' in the power generation sector based on the Carbon Reduction Strategy. This is because using solar power mitigates emissions so any contribution that FiT-supported solar power makes to the 10% target automatically contributes to the emissions reduction targets provided that there is proper technical and institutional monitoring of the generation under the programme.

Trinidad uses natural gas for its power generation (see Chapter 7). Chivers (2015) states that electricity produced by natural gas emits between 350 and 490 grams of carbon dioxide equivalent of greenhouse gas emissions for every kilowatt-hour generated (gCO_2e/kWh). By comparison, rooftop photovoltaics produces between 26 and 80 gCO_2e/kWh (Chivers, 2015) - using solar is operationally emissions-free but Chivers' figures are based on construction, fuel use and knock-on effects. Therefore, rooftop photovoltaics under the FiT can abate between 270 and 464 gCO_2e/kWh of emissions.

8.3. Using Grid-Connected Strategies as Policy Instruments

8.3.1. Using Net Energy Metering

8.3.1.1. An overview of net energy metering in Hawaii

According to *Informant OH11* and Gorak (2016) Hawaii's net energy metering (NEM) had its roots as early as 1996. It was instituted in 2001 (Morita and Mangelsdorf, 2015) and came

into force in 2008 (NC Clean Energy Technology Center[2], 2015). Since its inception there have been nearly 60,000 customers who have installed solar under the programme (Paidipati and Romano, 2017). NEM has been described as:

"a huge driver of what happened with us [in Hawaii] over the past 5 years" (*Informant OH09*)

It is designed for distributed generation systems where owners offset their electricity consumption from the grid with that of their system (Price et al., 2013; Eid et al., 2014; Levin et al., 2015; Watts et al., 2015; Ramírez, et al. 2017).

NEM works on the premise that customers are paid per kilowatt-hour (kWh) for the surplus electricity exported to the grid at a rate commensurate with the retail tariff and utilities are legally obligated to buy this surplus energy (PUC, 2015; Watts et al., 2015; Lofthouse et al., 2015; Edison Electric Institute, 2016; Ramírez, et al. 2017). If a customer uses more electricity than is produced, they only pay the utility for the net difference (DBEDT[1], 2015).

The NEM credit arrangement is dependent on the utility company and legal guidance facilitating the scheme (Hughes and Bell, 2006; Shah, 2014). This means that NEM's crediting can use conventional billing regimens and the disbursements can be made within this period or extend as a rolling credit on an annual basis (Dufo-López and Bernal-Agustín, 2015); Hawaii's excess credits are carried forward annually (PUC, 2015; DBEDT[1], 2015).

Southern California Edison (2011) and the DBEDT[1] (2015) add that though credit disbursements can be annual, the pre-existing billing regimen can remain the same since ratepayers are billed for non-energy charges e.g. customer charges and/or taxes, and these bills could also have the NEM energy calculation for that period included as customer-

information.

Hawaii's NEM design enables customers to discount their bills up to the point where consumption negates generation i.e. 'net-zero'. This means that any excess generation exported is so done freely and not remunerated according to *Informants OH06* and *OH10*. For this reason, these two informants were of the opinion that there is a risk of increased household electricity consumption since installing solar can offset consumption and householders can gain the benefits of using more energy as opposed to not being paid for its exportation (see Appendix K). This is an example of why Goss (2010) advises that other energy conscious steps such as conservation should be adopted in tandem with alternative energy technologies.

Rooftop photovoltaics is the most popular system enrolled in NEM (Edison Electric Institute, 2016), and Southern California Edison (2011) presents Figure 59 (next page) that illustrates the dynamics behind grid-connected photovoltaics for a given day. Figure 59's lines show arbitrary representations of the daily load curve for a household (yellow line) i.e. the householders' energy services that create the demand on the energy system (Goss, 2010), and arbitrary diurnal insolation/photovoltaic generation (red line).

Poullikkas et al.'s (2013) narrative of daily energy use is an example that can give context to the yellow line in Figure 59. The morning peak occurs when the household awakes and begins their preparations for work and school by making breakfast and taking hot showers. The mid-day trough occurs because no one is at home to use energy. As the household returns from work and school in the evening the demands are ramped-up and peaks in the night when dinner is being prepared, and television, computer and lighting use are high.

The image showing the illustration of a home with solar photovotlaics originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Southern California Edison. 2011. Understanding Your Energy Bill For Net Energy Metering Customers. Website: https://www.sce.com/wps/wcm/connect/b94f53d4-81f5-4e7f-ad0d-1c60c2a1fa64/NEM_FactSheet.pdf?MOD=AJPERES (accessed 15th October, 2015)

Figure 59 showing the daily cycle of a grid-connected photovoltaic system

Notes: The red line is the solar insolation/generation, and the yellow line is the household demand. Adapted from Neill and Granborg (1986; 47) (annotations) and Southern California Edison (2011; 2) (image) using Microsoft Word

Air conditioning in tropical locations like Oahu and Trinidad may also contribute to the evening's peak - which Coffman et al. (2016) show occurs between 5:00PM and 9:00PM in Hawaii for instance. Though this narrative is quite generic, it gives insight into what drives NEM's energy determinations.

Grid-connected solar energy customers are what Eid et al. (2014) and Georges et al. (2014)

describe as 'prosumers' i.e. consumers that not only consume but also generate their electricity. Net consumers import more electricity from the grid than is generated from their distributed system and net producers export more than is consumed over the billing cycle (Xcel Energy, 2010).

Sources such as Cory et al. (2009), Klein et al. (2010), Poullikkas et al. (2013), Shah (2014), and Watts et al. (2015) further add that a conventional meter would only measure electricity consumption but NEM uses a bi-directional meter which also measures generation over the billing period. Practically a conventional meter spins forward but NEM's bi-directional meter also spins backwards (measuring generation) and the difference here is the 'net energy' in NEM (Hughes and Bell, 2006; Edison Electric Institute, 2016).

There are 6 main elements of Hawaii's NEM: 1) consumption of solar power by the household; 2) use of a bi-directional meter to measure both solar power generation and export, and electricity consumption from the utility's grid; 3) export and sale of surplus solar power to the utility company; 4) an export rate that is commensurate with the retail rate for consuming electricity; 5) an annual rolling credit scheme for any net energy exported; and 6) a sale cap through the 'net-zero' target for the generation and consumption determinations.

8.3.1.2. The lessons-learnt from using net energy metering in Hawaii

Net energy metering (NEM) has been described as an economic, simple and rather straightforward means of integrating solar energy into a utility's business model (Poullikkas et al., 2013). But from the householder's perspective energy savings, personal budgets and payback periods are important considerations (Attari and Rajagopal, 2015) surrounding the

classic trade-off between solar systems' capital costs and the returns from the energy generated (Bauner and Crago, 2015).

This trade-off is one of the reasons why solar adoption has been low in Trinidad since there is uncertainty clouding whether or not the system will pay for itself within its lifetime (Bauner and Crago, 2015). The payback period and the internal rate of return are often used as proxies for determining the economic potential of solar (Dorf, 1984).

Bauner and Crago outline that solar would be in good standing if conventionally-sourced electricity prices are high and vice versa if it is low - as in Oahu and Trinidad respectively. In Hawaii the average payback for residential solar is 6 years (Peterson, 2017) and has an internal rate of return of 9% (UHERO, 2013). So, Hawaii's high retail rates combined with NEM makes solar very attractive.

NEM also integrates well with other strategies like tax incentives. Like NEM, Hawaii's tax credits scheme has been legislated by the State Legislature and was described as a:

"huge driver of the market here [in Hawaii] for customer-sited renewables." (*Informant OH09*)

These credits allow solar owners to get an additional refund with their annual tax return for installing an eligible solar system. At the time of conducting the interviews in Oahu, *Informants OH10* and *OH11* explained that residents were eligible for a 65% credit that was a combination of State and Federal contributions (35% and 30% respectively). The credits were respectively thought to be generous and quite beneficial by *Informants OH09* and *OH10* hence why:

"U.S. consumers like tax credits." (*Informant OH05*)

But with due consideration for the eligible technology, customer-tiers, maximum system size and utility business design Stoutenborough and Beverlin (2008), The Electricity Journal (2013), and Shah (2014) suggest that NEM is aimed at promoting the investment and expansion of distributed generation - and according to Gorak (2016) Hawaii's NEM did its job of kickstarting renewable energy adoption.

NEM's one-to-one tariff rate encourages a high profitability for the owners of an enrolled solar system because the retail rate paid to the owner is higher than the rate that would have been received by a conventional generator for the same electricity (Watts et al., 2015).

With authors like Nolden[2] (2012) acknowledging the increasing sensitization of government policy to social issues, *Informants OH06*, *OH07*, *OH09*, *OH10*, and *OH11* were of the opinion that one of the greatest weaknesses of Hawaii's NEM programme was that NEM customers were paying proportionately less towards the grid`s maintenance and operation.

In the most extreme case when an NEM customer is at 'net-zero', they do not pay for the grid's services or its maintenance at all (Wood, 2016). So, this shifts the burden to non-NEM customers and instead of being a tariff, NEM becomes a subsidy (Wood, 2016). According to *Informants OH03*, *OH04*, *OH05*, and *OH07* higher-income households are also likely to adopt solar energy first so this creates a social inequity because higher-income households under NEM can benefit from the programme the most. Appendix K gives more detail on the potential inequity behind NEM in Hawaii.

Informants OH06, *OH09*, and *OH10* as well as Paidipati and Romano (2017) thought that this

equity argument supported the utility's 'resistance' to the growth of distributed solar energy under NEM in Oahu and was mixed with arguments surrounding the solar market's maturity, circuit saturation and revenue loss. This led to the utility company presenting a case before the Public Utilities Commission to review the NEM programme.

The review resulted in the end of NEM in 2015 and a move towards customer grid-supply (CGS) and self-supply (CSS) programmes that are a less-remunerative grid-connected policy and battery storage incentive scheme respectively (Gorak, 2016; Arik, 2017; Paidipati and Romano, 2017). Figure 60 shows how NEM and CGS works for reference.

The image showing the illustration of a home with solar photovoltaics under net energy metering and customer grid-supply originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Hawaiian Electric Company (HECO) Incorporated[4]. 2018. Customer Grid-Supply. Producing Clean Energy. Website: https://www.hawaiianelectric.com/clean-energy-hawaii/producing-clean-energy/customer-renewable-programs/customer-grid-supply (accessed 21st March, 2018)

Figure 60 showing how a net energy metering and customer grid-supply photovoltaic system works

Extracted from the HECO Incorporated[4] (2018)

Paidipati and Romano (2017), the HECO Incorporated[1,2] (2017), and the HECO Incorporated[4] (2018) point out that the main differences between NEM and CGS are: CGS' rate is lower and fixed unlike NEM which was set at the retail rate and fluctuated with it, and there is no

annual credit rollover as was the case with NEM. CSS allows customers to install rooftop photovoltaics that do no export power to the grid, so all the power has to be consumed directly or stored for later use (HECO Incorporated[3], 2018).

8.3.2. Using Feed-in Tariffs

8.3.2.1. An overview of feed-in tariffs

Feed-in tariffs (FiTs) are one of the most popular renewable energy policies in the world (Cox and Esterly, 2016) and they have been globally considered to be an effective economic tool (Pyrgou et al., 2016). A FiT is a form of power procurement programme designed to increase the proportion of renewable energy in the energy mix (DeShazo and Matulka, 2009). DeShazo and Matulka (2009) state that there is no set FiT design because it is adaptable, scalable and flexible; there is a global diversity of FiT designs which reflect a concomitant variety of policy goals (Couture et al., 2010).

FiTs legally obligate electric utilities to purchase renewable electricity from producers at an agreed rate through a long-term contract (Karekezi et al., 2009; Cory et al., 2009; Cornfeld and Sauer, 2010; Couture et al., 2010; Cox and Esterly, 2016). The contract is usually a 10 to 25-year power purchase agreement (PPA) (Mostafa, 2014; Pyrgou et al., 2016).

Solano-Peralta and Moner-Girona (2009), Karekezi et al. (2009), Couture et al. (2010), Cornfeld and Sauer (2010), and Cox and Esterly's (2016) work describe FiTs' basic components: a payment per kilowatt-hour (kWh) of generated electricity, the long-term PPA, and priority access to the grid for the renewable energy generated - the last component ensures that the energy is consumed before other sources.

FiTs encourage the adoption of renewables and accelerate the renewables electricity market (Cornfeld and Sauer, 2010; Mostafa, 2014; Pyrgou et al., 2016). They allow the industry to take advantage of economies of scale and create competition that causes prices to decrease to a level that encourages wider implementation (Cornfeld and Sauer, 2010; Muhammad-Sukki et al.[2], 2014). So FiTs are positive elements for building business opportunities for renewable energy (Muhammad-Sukki et al.[2], 2014).

FiTs reduce carbon emissions; create jobs; diversify renewable energy portfolios; improve domestic energy security and market equity for renewable energy; and increase the affinity for energy innovations (Mendonça and Corre, 2008; Muhammad-Sukki et al.[2], 2014).

FiTs potentially broaden the adoption audience for solar energy (Schelly[2], 2014). But with the pros and cons of FiTs usually being economic (Couture et al., 2010), the real detail lies within its payments design. The FiT rate is usually set at a level that provides a reasonable rate of return over the PPA (Cornfeld and Sauer, 2010), and high enough to attract investors (Mostafa, 2014) - though longer PPAs may occasionally have lower rates (Cox and Esterly, 2016).

Setting the FiT rate is perhaps the most pivotal and difficult element because setting a 'reasonable' rate seeks to balance-out cost recovery and customer profit (Mendonça and Corre 2008; Couture et al., 2010; Nolden[2], 2012; Cox and Esterly, 2016). This is why Cory et al. (2009) assert that detailed analyses are required from the onset to set the right payment level(s). Cory et al. (2009), Couture et al. (2010), Kreycik (2011), and Cox and Esterly (2016) outline that FiTs' rate-determinations can be based on levelized costs, avoided costs, resource quality, or even auction-based considerations.

Levelized costs are usually based on factors such as capital costs, installation, operations and maintenance, and decommissioning (Chivers, 2015) - a method that Cory et al. describe to be the most effective.

Avoided cost considerations are based on the premise that since the utility does not stand the costs of installing FiT projects for instance this can be economically valuated to help determine FiT rates. This can also include social issues like climate change mitigation and reducing the impact of negative externalities e.g. health impacts from emissions (Cox and Esterly, 2016).

With geographically variable resources, resource quality can be a rate-setting consideration. But based on the fact that Trinidad is a small island with an arguably equal distribution of incident solar insolation, geography may not play a significant factor in the tariff design.

Auction-based determinations are done via tendering processes. Governments issue requests for suitable FiT projects which are referenced against a total programme capacity and the Government and/or utility selects winning bids such that the selected bids' capacities add up to the total desired (Cox and Esterly, 2016). This creates lower project costs because of the competitive process but leaves projects vulnerable to submissions by inexperienced developers (Cox and Esterly, 2016).

The use of an auction-based FiT may also raise the costs of capital and leave Trinidad's renewable energy industry open to continued external input where foreign contractors essentially design the projects and stifle the local retailers - based on *Informant TD10*'s description of the present solar energy industry provided in Chapter 7.

Therefore the levelized and/or avoided cost considerations may be the most suitable in Trinidad. FiT work such as Couture et al. (2010), Klein et al. (2010), Cornfeld and Sauer (2010), Pyrgou et al. (2016), and Cox and Esterly (2016) further outline that FiT payments can be either fixed or premium cost designs; the fundamental distinction is whether the payments are linked to the electricity market price.

With premium cost designs the utility pays producers a given margin above the spot electricity price so the producer receives a market-rated payment for the generated electricity as well as a FiT payment (Cory et al., 2009; Klein et al., 2010; Couture et al., 2010; Cox and Esterly, 2016) - and the premium or total FiT payment can be dependent on the market price (Couture et al., 2010).

However premium design FiTs are more of a large-scale solar FiT design and geared towards a market that has spot prices (which Trinidad does not have). So the fixed-rate design is the one that fits Trinidad's residential solar context. Couture et al.'s (2010) work also suggests that fixed-rate FiTs may be more suited to the scope being looked at in Trinidad since solar energy is a time-dependent resource that has variable grid-supply regimens so is less likely to benefit from a market's spot prices - especially at such small scales.

Fixed-rate designs are independent of market prices and are also the more traditional and simpler model implemented in many countries (Couture et al., 2010; Cox and Esterly, 2016). They are more cost-efficient, more transparent, carry lower investment risks than their premium counterparts, and are also able to be adjusted over time for inflation and other time-dependent factors like consumer behaviours (Couture et al., 2010).

Consideration should be extended towards FiTs' evolution because they can be modified to

reflect evolving market conditions and these changes can be pre-determined or they can follow comprehensive reviews and subsequent adjustments which can be based on achieving milestones or following regular revision regimens (DeShazo and Matulka, 2009).

For example Cory (2009) states that tariff degressions i.e. decreasing FiT rates over time can be used in response to the industry's potential to become complacent and dependent on FiTs for developing projects (what she referred to as a policy crutch); tariff degressions usually stimulate market innovations and incentivizes companies' technology cost-reductions (Mendonça and Corre, 2008; Couture et al., 2010). However if the degression is poorly designed then the market and industry can be severely affected.

FiT prices can also change over time to adapt to changes in generation costs relative to the cost of the technology (Cory et al., 2009; Energy and Environmental Economics Incorporated, 2014; Cox and Esterly, 2016) or even inflation (Couture et al., 2010). Energy and Environmental Economics Incorporated (2014) states however that once a customer enters into a contract with their utility, the agreed-to rate is guaranteed over the stipulated period irrespective of changes that occur within this period. Therefore the modifications refer to the FiT programme versus an individual`s FiT contract.

If the FiT's rate is reduced after a revision then it represents a responsive tariff degression (Couture et al., 2010). Couture et al. (2010), and Cox and Esterly (2016) also outline that policymakers may alternatively establish a pre-determined tariff degression. Mostafa (2014) also shows that degressions can be implemented along a constant annual decline profile or even done in a step-like fashion over the lifetime of the FiT.

Nevertheless a FiT's revision regimen should reflect evolving conditions (Cory et al., 2009),

and any changes should be transparent and predictable (Cox and Esterly, 2016). But revising a FiT and adjusting its rates will create uncertainty (WEC, 2016) so any revisions need to take this into account because the solar energy industry needs certainty to thrive and customers need guarantees to build confidence in their investment under the programme.

In terms of the FiT's programme-financing it should be stable and guaranteed so that there is customer-confidence surrounding the payment plans' longevity (Solano-Peralta and Moner-Girona, 2009; Cox and Esterly, 2016). Mendonça and Corre (2008) outline that there are two primary options for financing FiTs: cost recovery across the utility's customer-base or through a specified fund. The funding through specified funds will be looked at in the next subsection however.

Financing FiTs through cost recovery usually creates an increase in the electricity tariff (Couture et al., 2010) that is equally distributed across all ratepayers' electricity bills and appears as a marginal per kWh increase on the retail tariff (Mendonça and Corre, 2008). There are two lenses that the rate-increase can be looked through: an industrial and a social.

In terms of the industrial impact, since such price-hikes drive the FiT and ultimately stimulate renewable energy investment, the increased renewable energy deployment that may accompany increased retail tariffs often creates 'boom-and-bust' cycles in the industry and policymakers have often used caps to address this (Cox and Esterly, 2010).

These caps are 'cost containment' measures that can take the form of maximum eligible system size in each customer tier, number of customers, ceilings for programme-wide installed capacity, tariff degressions based on achieving installed capacity goals through installation quotas, or even closing the FiT once the financing has been exhausted (Cox and

Esterly, 2016).

For example application quotas are often designed to protect the financial sustainability of the FiT (Muhammad-Sukki et al.[2], 2014) by regulating the number of customers that payments need to be made to over the FiT's lifetime - and related to this is the total capacity allocated under the FiT which can be determined based on the technology, time, application, market segment or even project size (DeShazo and Matulka, 2009).

Relative to the social impact, Cornfeld and Sauer (2010) state that FiTs shift the responsibility of renewable energy development from taxpayers to ratepayers since the policy is under the control of the utility and not the Government. Particular care therefore needs to be taken since the Government sets the rate but the market determines the energy production; too low a rate can led to severe underinvestment in renewables whilst the opposite can happen with too high a rate (Cory, 2009; Cory et al., 2009; Cornfeld and Sauer, 2010; Cox and Esterly, 2016).

Though Muhammad-Sukki et al.[2] (2014) state that FiTs rapidly reduce capital costs, this is likely in reference to the policy's ability to stimulate competition in the market which reduces labour costs. So like NEM, FiT customers have to stand the system's upfront costs (Cory, 2009; Cory et al., 2009; Couture et al., 2010; Blechinger and Shah, 2011); tax incentives can once again be useful.

Energy and Environmental Economics Incorporated (2014) outline an example in Hawaii where customers were able to qualify for either a 24.5% or 35% State tax credit where if a customer accepted the lower tax credit, then they were eligible for a higher FiT rate and vice versa. This policy integration represents a small trade-off between capital cost reduction and performance-based incentivization but shows the agency of the Government and utility

company integrating in order to present a policy solution. But even under such scenarios, funding grid-connected solar through rate-increases still warrants (in)equity considerations.

Recalling Hawaii's NEM experience outlined earlier, financing the FiT through rate-increases means that FiT customers are generously rewarded whilst the ratepayer-base not enrolled are faced with the greater financial burden of maintaining the grid and programme - especially if the previously highlighted caps allow residents to install photovoltaics on a 'first-come, first-served' basis where applications are processed based on the order of their arrival and not intrinsic merits (DeShazo and Matulka, 2009).

Lower-income families are the least likely to own residential solar (Couture et al., 2010) so this makes them particularly vulnerable to the rate-increases that could potentially finance FiTs. This funding strategy inadvertently makes FiTs 'regressive taxes' (Cornfeld and Sauer, 2010; Holland, 2015) where lower-income households without solar subsidize higher-income households with solar (Goodall, 2014); Appendix K details the inequity issues.

8.3.2.2. The recommendations for using a feed-in tariff in Trinidad

Feed-in tariffs (FiTs) can be designed to specifically target distributed generation systems like residential photovoltaics. Sources such as Cory (2009), Solano-Peralta and Moner-Girona (2009), Couture et al. (2010), Cornfeld and Sauer (2010), and Cox and Esterly (2016) state that FiTs should detail elements such as eligible technologies, technology generation capacity, project size, location and resource quality.

Cox and Esterly (2016) also state that clearly specifying the participating actors, their roles

and the respective procedures guiding their FiT-interactions can save time and finances. This is important because there is an initial administrative burden involved in setting up FiTs (Cory et al., 2009).

Informant TD02 was of the opinion that Trinidad's FiT was being ironed-out following the Cabinet's approval of the initiative; this planning phase is being used to develop a common sense of direction amongst stakeholders according to *Informant TD15*. So far there has only been a cross-sectoral FiT committee setup to develop the tariff structure and there were only idea-based discussions according to *Informants TD02*, *TD08, TD12*, and *TD15*.

Nevertheless the FiT was hailed as:

"the next step to the Renewable Energy Policy." (*Informant TD02*)

There are 7 recommendations for its design based on the chapter`s discussions i.e. the programme's introduction; use of caps; contracts; metering; crediting/billing regimen; the type of tariff and rates; and its financing. The contracts and broad tariff elements have been outlined in the last subsection i.e. guaranteed long-term contracts based on a fixed-rate FiT which uses levelized and/or avoided costs. In terms of the crediting/billing regimen, FiT payments should coincide with the incumbent billing regimen (Goss, 2010) which is bi-monthly in Trinidad. The programme's introduction, use of caps, metering, tariff type and financing will be looked at here.

Grid-connected solar energy has one of the fastest planning to generation turnarounds. An example emerged in Muhammad-Sukki et al.[1] (2014) where within 3 months of launching a photovoltaics FiT in Japan the imports of solar products increased by almost 80%. Another is

given in Muhammad-Sukki et al.[2] (2014) where within 2 months of launching the online FiT application system in Malaysia in December 2011, the 2012 quota was filled.

For such reasons Cornfeld and Sauer (2010) outline the benefits of designing a FiT trial since it will enhance policymakers' future decision-making capacity. Cox and Esterly (2016) also add that projections and forecasts are useful in planning FiT projects even though this is seemingly harder for smaller generation units like residential photovoltaics. But before a full rollout out of a FiT a formal experimental and demonstration pilot should be considered in Trinidad.

As outlined earlier in the chapter, Hawaii`s net energy metering (NEM) allowed householders to sell their exported power up to the point where their consumption and solar power generation negate each other over the annual cycle. This is an example of a sale cap. But more relevant to Trinidad's FiT are a programme-wide installed capacity cap, individual system size cap, cap on the number of FiT customers, and/or financing cap - these have been already touched on in the last subsection relative to preventing 'boom and bust' cycles in the solar energy industry.

For example Mangelsdorf (2012) mentions the use of grid penetration caps for grid-connected solar in Hawaii. Hawaii's NEM ran as three programmes in the islands of Oahu, Maui and Kauai (R.P. Delio and Company, 2012). The Kauai Island Utility Cooperative stipulated an individual system cap of 50 kilowatts (kW) with an aggregated capacity of 1% of the utility's peak demand, and the Hawaiian Electric Industries operating on Oahu and Maui used a 100 kW cap and a 15% aggregate capacity of the local circuit's distribution (R.P. Delio and Company, 2012).

Caps like these may be used as regulators of solar's entry and as another numerical target that implementation strategies can consider - in light of the popularity of quantitative designations for policymakers and politicians. With respect to Trinidad's FiT there is no traditional sale cap but there could be individual system size caps and an informant thought that this will create:

"a ceiling on how much power you generate in your house so you don't become a generator selling to the grid [as a large-scale independent power producer would]". (*Informant TD02*)

Individual system size caps make the possible maximum generation and sale rather predictable. There can also be a cap on the amount of financing that should fund the FiT over a specified period of time. This means that the number of projects, and size and capacity of these projects will be affected by such a cap.

Caps can contribute to Trinidad's national renewable energy generation target of '10% by 2021' together with the overall emissions reduction goals of '15% by 2030' based on the Intended Nationally Determined Contributions, as well as '19% by 2040' in the power generator sector based on the Carbon Reduction Strategy. This is because the programme's generation can be measured through generation meters and referenced against projections since every kW of solar power generated and used abates emissions that would have otherwise come from fossil fuels (see subsection 8.2.3.).

Hughes and Bell (2006), Mir-Artigues (2013), and Watts et al. (2015) state that NEM uses one bi-directional meter, and there is no direct feed-in to the grid (WEC, 2016). Policies like FiTs use two meters (one for generation and consumption) and the energy exchanges are measured independently using different pricing designs for the imported and exported

electricity. Hughes and Bell (2006), Mir-Artigues (2013), and Watts et al. (2015) state that the two meters are used because the exported and imported electricity are priced differently - which is in contrast to the NEM's one-to-one valuation of the imported and exported electricity.

As mentioned earlier, using a generation meter will also be useful in making sure that the FiT-supported systems' power generation contributes to the national energy and environmental targets. Using a separate generation and consumption meter (versus bi-directional meter as used in Hawaii's NEM) also has cultural advantages and Chapter 9 looks at these as part of the wider discussion on how policies and energy cultures can interact in Trinidad.

Hughes and Bell (2006) outline that grid-connected policies can allow the utility to buy-back a household's solar power free-of-charge; below the retail rate; at the retail rate; or at a premium which is higher than the retail rate and usually offered for specific technologies. The actual rates for Trinidad's FiT are beyond the scope of the thesis given the methodological detail involved in rate-making.

However the FiT's payments can be based on the generation of a customer's solar power and/or the export of this power to the grid. Using a generation tariff means that any solar power exported to the grid is done freely so the Trinidad and Tobago Electricity Commission (T&TEC) would benefit from this free power since they are not paying for it. Therefore using this power in the home is in the adopter's best interest. With export tariffs, if the export tariff is higher than the utility's retail rate then exporting power is more profitable but when the export rate is lower it encourages self-consumption.

As will be discussed in Chapter 9 promoting self-consumption should be a policy goal for

Trinidad`s FiT based on the cultural results from Chapter 5 and 6. This means that any exported power would be aimed at surplus solar power and that there is an incentive to reduce consumption so that more power could be exported.

Trinidad's electricity rates are artificially lowered due to a subsidy (see Appendix E) so this suggests that a FiT tariff will likely be higher than the T&TEC`s rates provided that the current fossil fuel subsidy remains in place. Therefore using a generation tariff, or export tariff for surplus energy should be used. Both tariffs encourage the self-consumption of solar energy and behaviour change. Chapter 9 would give more detail on the rationale behind selecting these using the cultural results from Chapters 5 and 6.

An underlying element in these discussions are time-of-use issues since the technical peak demand for electricity in Trinidad occurs roughly between 6:00PM and 8:00PM (Marzolf et al., 2015) and the peak solar power generation in a location like Trinidad would be around noon. By comparison Hawaii's peak energy demand occurs between 5:00PM and 9:00PM (Coffman et al., 2016) and its peak solar generation occurs around mid-day as well. Therefore both locations show similar patterns.

Hawaii's drive to incentivize battery storage as shown via their customer self-supply policy in an earlier subsection is part of a strategy to deal with the amounts of solar power coming into the grid due to the disparity between peak energy demand and peak solar power generation (Arik, 2017). Other elements of the strategy include time-of-use pricing for residential electricity for instance (Coffman et al., 2016). But storing the solar power means that it can be used during the peak demand periods which reduces the technical demands placed on the grid.

In Trinidad's case this not likely to be as problematic because any excess solar power that

comes into the grid is likely to be used because unlike Hawaii, Trinidad has an energy-intensive heavy industry sector e.g. liquefied natural gas, methanol and ammonia production (see Chapter 4) that constantly requires power. This is also one reason why grid-connected solar energy is likely to be introduced before battery-integrated solar energy designs.

However the disparity between peak demand and solar power generation above, and the cultural goal of promoting solar power self-consumption under the FiT is important to consider and it will be more fully addressed in Chapter 9's discussions on the generation and/or export tariff considerations.

Trinidad's FiT can be financed through an increase in the retail rates. But any increase in retail rates perpetuates the inequity issues outlined in Appendix K. The Appendix also shows that the Green Fund's financing could be used but its funding is not guaranteed, is vulnerable to political agendas and is very restrictive with respect to institutional access to funding. The current subsidy that the incumbent power generation benefits from however can be used to fund the FiT.

This would require institutional and legislative reforms because the subsidy is funded by oil companies and the Government through the Petroleum Production Levy and Subsidy Act (see Appendix E). Nevertheless this is the most promising way to fund the FiT since it is arguably the most secure form of long-term financing in the nation. It also allows nationals to benefit from the nation's abundant solar energy resources which plays on one of the historical motivations for subsidizing hydrocarbon-based energy in Trinidad i.e. allowing residents to benefit from the nation's energy wealth (see Chapter 4).

8.4. Chapter Conclusions

A regime's institutional-network should have a common vision for how it should evolve so that progressive steps could be made towards it. A vision that has some associated quantifier acts as a socio-political tool to measure progress. Trinidad's greenhouse gas emissions reduction targets under the Intended Nationally Determined Contributions (INDCs) and Carbon Reduction Strategy (CRS) can be useful for 'greening' the regime and creating niche(s) for distributed residential solar energy.

But its renewable energy targets (RETs) would be potentially more impactful since the use of emissions reduction targets may be perceived as too broad in scope (both in its sectoral coverage and geopolitical sanctioning) to mainstream renewables' let alone solar specifically. RETs can help direct actors in Trinidad's residential electricity regime to modify their effective agency to facilitate the stipulated requirements. This would however require the network to possess the public pressure, political will, technical capacity and financing.

In Hawaii renewable energy ambitions have been set through renewable portfolio standards (RPSs). RPSs are different to RETs because the former are legally-enforceable ambitions that require electric utilities to generate and sell a specified quantity of renewable energy. Implementing RPSs in Trinidad would be difficult because the utility company is government-owned and will be held accountable by the State - unlike in Hawaii where the utilities are private companies.

Trinidad's RET of '10% by 2021' should be coupled with its national greenhouse gas emissions reduction targets under the INDCs of '15% by 2030' as well as under its CRS of '19% by 2040' in its power generation sector. Trinidad's RETs should also have a specified

proportion dedicated to solar energy so that it creates a national institutional and policy space for residential photovoltaics.

Since photovoltaics generate power and mitigate emissions it contributes to the aforementioned targets. Quantifying these contributions however is beyond the scope of this thesis but it would be predicated on the fact that every kilowatt-hour of solar electricity generated and used abates a specified amount of emissions.

Based on Hawaii's RPSs relationship to the State's most influential institutions, working within the present Trinidadian regime's 'power' structure may be the path of least resistance for its RETs i.e. through the Ministry of Energy and Energy Industries, and the Trinidad and Tobago Electricity Commission (T&TEC) since these actors oversee the electricity sector (see Chapter 7).

The renewable energy and emissions reduction targets need to be periodically reviewed and ambitions increased in the long-term. Increasing these targets to accommodate more renewable energy in the regime requires inputs that may or may not lie within the regime and thus modifies it to facilitate the actors and resources needed to provide this added input. Increasing targets represents an intra-policy transition based on a quantitative modifications.

Both islands have implemented tax incentives to reduce the upfront capital costs of solar energy systems but Trinidad is planning to implement a feed-in tariff (FiT) whilst Oahu's most influential grid-connected policy has been net energy metering (NEM); Table 29 shows the policies' basic designs.

DETAIL	FEED-IN TARIFF	NET ENERGY METERING
Financially liable entity	Electricity utility	Electricity utility
Contract	Long-term, legally-binding	Long-term, legally-binding
Technology under consideration	Photovoltaics	Photovoltaics
Tax incentive relationship	Compatible	Compatible
Energy metering	1 electricity generation meter + 1 electricity consumption meter	1 bi-directional meter
Energy generation	Variable / Sold to utility company	Used in household / Surplus generation exported / Sold to utility company
Tariff rate	Variable	Commensurate with the retail electricity rate

Table 29 summarizing net energy metering and feed-in tariffs

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Analysing Oahu's institutional interviews produced codes that were associated with discrete solar energy policies which have ended and others now beginning. In Trinidad however, the coding produced more idea-based and speculative initiatives with only one emerging as the likely next step i.e. the FiT.

The analysis had codes relating to the impact of NEM, the transition away from NEM, and the relationship between these transitions and their possible repercussions in Oahu. This is indicative of Oahu's longer, more transient solar policy history - and the lessons-learnt are quite applicable to Trinidad's intended FiT.

A caveat however is that the policies that were raised in Oahu and Trinidad based on the coding does not necessarily mean that these are the best policies to consider. But at the very least these policies should be given special consideration and especially so the FiT because it is currently being planned by the Government.

Hawaii's NEM experience illustrates an inter-policy transition as it transitioned to their customer grid-supply and self-supply programmes. Grid-supply continues grid-connected solar's integration but at a lower reward rate whilst self-supply incentivizes battery storage and spotlights the initial stages of a technological transition from grid-connected solar to battery-integrated photovoltaics.

NEM however is not a strategy that should be considered in Trinidad primarily because customers under NEM do not pay for the grid's services. Trinidad's intended FiT would fit better but it should be clear and detailed. This particularly refers to defining the eligible technologies (photovoltaics in this case), the technologies' details (e.g. eligible system sizes), and the facilitating actors together with their roles and responsibilities (e.g. the T&TEC, and Regulated Industries Commission).

The FiT should be based on:

- Fixed-rates
- Levelized and/or avoided costs
- A long-term power purchase contract
- Guaranteed rates over the length of the contract
- Priority access to the grid for exported power
- Periodic but not too frequent revisions
- Programme-wide and system caps

- Bi-monthly crediting
- Contributing to the RETs of '10% by 2021' and emissions reduction targets of '15% by 2030' overall, and '19% by 2040' in the power generation sector
- A generation and consumption meter
- Funding from the financing that currently funds the incumbent fossil fuel subsidy
- A demonstration pilot

The FiT programme should be implemented through a pilot during a formal trial and demonstration period. Post-pilot thoughts are the FiT evolution, rate-revisions and degressions. However these are likely to be post-mainstreaming considerations so do not immediately affect Trinidad's FiT pilot.

Consideration particularly needs to be given to the use of a generation and/or export tariff for surplus solar power where households are paid for the solar power they generate and/or paid for only the solar power that is exported to the grid respectively. By extension this also relates to whether the tariff is set above or below the present retail rates. This is an important consideration since Trinidad's electricity is heavily subsidized (see Appendix E).

The programme's capacity and size(s) of eligible photovoltaic systems also needs to be determined. Using a programme financing and/or installed capacity cap should be linked to the earlier-mentioned allocated quota under the renewable energy and emissions reduction targets. FiT-supported systems' generation would be measured through generation meters and this would allow the programme's solar electricity to be accounted for in the targets.

The FiT could be funded via rate increases but this perpetuates the social inequity raised in Appendix K. So Trinidad's FiT should be funded through a specified fund like the nation's Green Fund. But its financing is not guaranteed and is very restrictive with respect to institutional access to the fund. However the subsidy that fossil fuels currently benefit from can be diverted to fund the FiT; Appendix E provides details on the subsidy.

8.4.1. Implications for Trinidad's Residential Energy Cultures

Like the last chapter, this chapter also led to insights into how the Trinidadian Government's residential solar energy policies can influence the resident population's energy cultures:

i. Renewable portfolio standards (RPSs) (as in Hawaii) or generation targets (as in Trinidad) stipulate renewable energy contributions to the energy mix. But the two are not the same because the RPSs is legally-enforceable and the latter is more of an ambition. Nevertheless the proportion of renewable energy in each should progressively increase over time. These play on the motivation for adopting solar energy because it is a sustainable energy resource as well as existing norms surrounding solar energy's relative advantages such as using solar energy mitigates global warming and the nation's hydrocarbon resources are finite.

ii. Trinidad's potential feed-in tariff (FiT) allows photovoltaics owners to generate and export, and sell their solar power to the grid and utility company respectively. A FiT design that encourages customers to use their solar electricity in the home i.e. solar power self-consumption makes solar energy a household resource and a norm to use it.

iii. Trinidad's FiT will develop new norms, practices and material culture e.g. the photovoltaic system is new material culture, applying for permits is a new practice, and the amount of sunshine affecting electricity bills is a new norm.

iv. The rates provided in the FiT's long-term contracts will affect the Trinidadians' residents' perceptions of energy costs described in Chapter 5 based on the features list from Appendix H.

v. Increasing retail rates will affect the residents' energy usage and costs domain based on the features listed in Appendix H.

vi. Policies that affect the timing of when householders' practices are performed (particularly routinized practices) will be disruptive and create an energy cultures shift based on the perceived peak electricity demand characterizations in Appendix F.

8.4.2. Characterizing Mainstreaming

Oahu used policies such as tax incentives, net energy metering, and renewable portfolio standards to support distributed residential photovoltaics' evolution into the regime from its original niches. So as done in the last four chapters, the chapter's discussions raised several mainstreaming tenets:

i. Mainstreaming a technology is most easily facilitated when the technology's characteristics are aligned with the incumbent regimes' expectations e.g. cost-effectiveness and ease of maintenance. Cost-effectiveness is one of the most important characteristics technologies need to be mainstreamed.

ii. Mainstreaming timeframes can be shortened by implementing policies which incentivize the adoption and use of technologies e.g. net energy metering (NEM).

iii. Mainstreaming has systems-level feedbacks e.g. NEM perpetuating social inequities.

9.0. Discussion & Recommendations

Synopsis

This chapter explicitly addresses the aim of the thesis which was to investigate the role(s) of culture during energy transitions (ETs). The chapter outlines the proactive and reactive roles of culture which are expressed via the five different ways that emerged based on the thesis' findings.

The chapter also ties together the work from the previous chapters to answer the overarching research question: "*How could the resident population's energy culture(s) and Government's residential solar energy policies interact to mainstream distributed residential solar energy technologies in Trinidad?*" It identified eight major ways that both can influence and be influenced by each other.

The different interactions were based on Chapters 5 and 6's conclusions which answered the first research sub-question, "*How could the adoption of distributed residential solar energy technologies and the residential energy culture(s) of Trinidad affect each other?*", by putting those findings into the policy context detailed in Chapters 7 and 8.

Chapters 7 and 8 did not have a subsection that addressed the second research sub-question which was: "*What are the Government's State-level residential solar energy policy options in Trinidad?*" This was because the consequent list of recommended policy options came as a result of one of the ways in which culture can affect policymaking (relative to the lead research question) i.e. providing insight into which policies should be implemented. Therefore this central discussion answers the lead research question as well the second sub-question.

The chapter is structured as follows: section 9.1. outlines the roles of culture in ETs and the five ways it could be expressed; section 9.2. answers the overarching research question by looking at the eight different ways that policies and culture could potentially interact to mainstream residential solar energy in Trinidad; section 9.3. explicitly states the policy recommendations that answer the second research sub-question; section 9.4. provides some critical thoughts on the use of mainstreaming as a concept and studying culture in ETs; section 9.5. outlines the thesis' contributions; section 9.6. outlines the limtations of the study; and section 9.7. gives insight into the opportunities for further research.

9.1. The Role of Culture in Energy Transitions

The literature review from Chapter 2 and results from the previous chapters show that culture has proactive and reactive roles during energy transitions (ETs). Based on the study conducted, these roles are specifically expressed through niche-creation; technological selectivity; resistance to changes and lock-ins; reactions to changes; and adaptive capacity. It is worth pointing out that these roles all transcend the three planes of the Multi-Level Perspective as well (see Chapter 2).

Niche-creation: Based on the household respondents' accounts, their energy cultures' material culture, norms, practices and external influences are electric-oriented. In addition there is a consensus surrounding their perceived household peak energy demand occurring in the evening due to the external influence of workplaces and schools on householders' presence in the home.

This means that there are techno-cultural niches for electric-oriented innovations that will not

hamper the continued use and perceived quality of the electricity required by a given household during the incumbent perceived peak demand times. These niches are not necessarily specific to photovoltaics and are also very broad. For instance at the systems-level, integrating photovoltaics can perpetuate and in some cases exacerbate the technical issues surrounding balancing peak and off-peak supply and demand - this shows why the influence of the other elements of the regime is important in niche-creation i.e. policies, industries, science, and markets.

Examples of other features that can create and shape niches (for solar energy technologies) based on the energy cultures looked at in the thesis are climate change and global warming, international oil markets, finite fossil fuel reserves, and the infinite energy supply from the sun.

Technological selectivity: Niche-creation coupled with the inherent beliefs, aspirations and expectations surrounding innovations that have yet to be adopted can favor one technology over another. For example the norms affiliated with the Trinidadian respondents' understanding of solar energy as a concept largely refer to solar electricity e.g. solar panels, batteries and inverters, as well as their relative advantages over the incumbent electricity from the utility company. So photovoltaics may be more easily assimilated than solar water heating.

In the wider technological sense if a series of innovations which perform similar functions are presented to adopters (e.g. different brands of solar panels), then the ones that are more in tune with the inherent beliefs, expectations and aspirations surrounding the motivations for adopting it (e.g. cost-effectiveness and longevity) will be adopted first - which makes those

adopted more competitive. This is another example of how technological selectivity can be expressed through culture.

Resistance to changes and lock-ins: Adopting technological innovations involves becoming aware of the innovation and gaining knowledge about it. If a potential adopter's specific information needs are not met, one reason why an innovation may not have been adopted just yet is because there is no basis to act on any newfound awareness and information i.e. no motivation. This marks a form of passive resistance to change especially considering the communication channels that may be involved i.e. active versus passive information gathering.

In terms of lock-ins, the aforementioned electric-oriented niche-creation and technological selectivity will stand provided that electricity retains its technical dominance as today's energy carrier. Its technical lock-in is reflected culturally and is further reinforced by other forces such as electric appliance manufacturing for instance.

Another example of a reinforcing influence is the temporal lock-in of external influences like workplaces and schools on energy users' presences in homes and their routines. Whilst this can help create broad niches as shown before, it can also support a lock-in especially when shifting peak demand and behaviour change are considered with the use of photovoltaics for example.

Reactions to changes: Energy cultures can respond to change-influences such that new norms, practices, material culture and external influences emerge after the adoption of an innovation. Energy cultures are likely to increase in complexity after an ET. Energy cultures can also react by forming subcultures based on clusters of defining norms, material culture,

and practices.

For example the Barbadian respondents' energy culture developed the practice of switching their solar water heaters' electrical backup switch on and off to supplement the primary solar energy used for heating the water in the system. This was driven by the external influence of the weather (namely the cloud cover). Associated norms were the belief that switching on the electrical backup increases the electricity bill and vice versa for instance.

Adaptive capacity: This capacity is the ability to adapt to changing conditions in the system. An energy culture can adapt to an ET's changes through the development of new norms, practices, material culture and external influences; the resistance to and/or moderation of changes due to the lock-ins from routines and habits; and guide changes by creating techno-cultural niches that favor certain technologies over others. This adaptive capacity therefore plays on and involves the previous four roles highlighted.

9.2. 'Policy' and 'Culture' as Interacting Elements During the Mainstreaming of Distributed Residential Solar Energy in Trinidad

With the understanding of the roles of culture presented in the last section, the overarching research question, "*How could the resident population's energy culture(s) and Government's residential solar energy policies interact to mainstream distributed residential solar energy technologies in Trinidad?*", can be answered considering the conclusions and implications for culture and policy presented at the end of Chapters 5 to 8. There are four ways that the energy culture of the Trinidadians interviewed and the Government's residential solar energy policies

can interact: policy niche-creation, policy selection, policy goal-setting, and policy designing.

9.2.1. Creating Policy Niches

The results from Chapters 5 and 6 showed that the Trinidadian respondents' incumbent energy culture is electricity-oriented. The norms, practices, material culture and external influences relate to the use and costs of using electricity from the utility company, the Trinidad and Tobago Electricity Commission (T&TEC). This suggests that there are very broad techno-cultural niches for technologies that generate electricity.

Distributed residential photovoltaics can fit into these niches (instead of solar water heating). This is supported by their solar energy norms which largely relate to photovoltaics (see Chapter 6), and the fact that water heating is not as culturally salient as its technical consumption is (see Appendix F).

The cultural consensus that exists with respect to the norms surrounding the respondents' perceiving that they use the most energy during the evening (see Appendix F) suggests that broad techno-cultural niches further exist for photovoltaics designs that do not hamper the continued use of electricity when it is needed most (see Figure 61 on the next page).

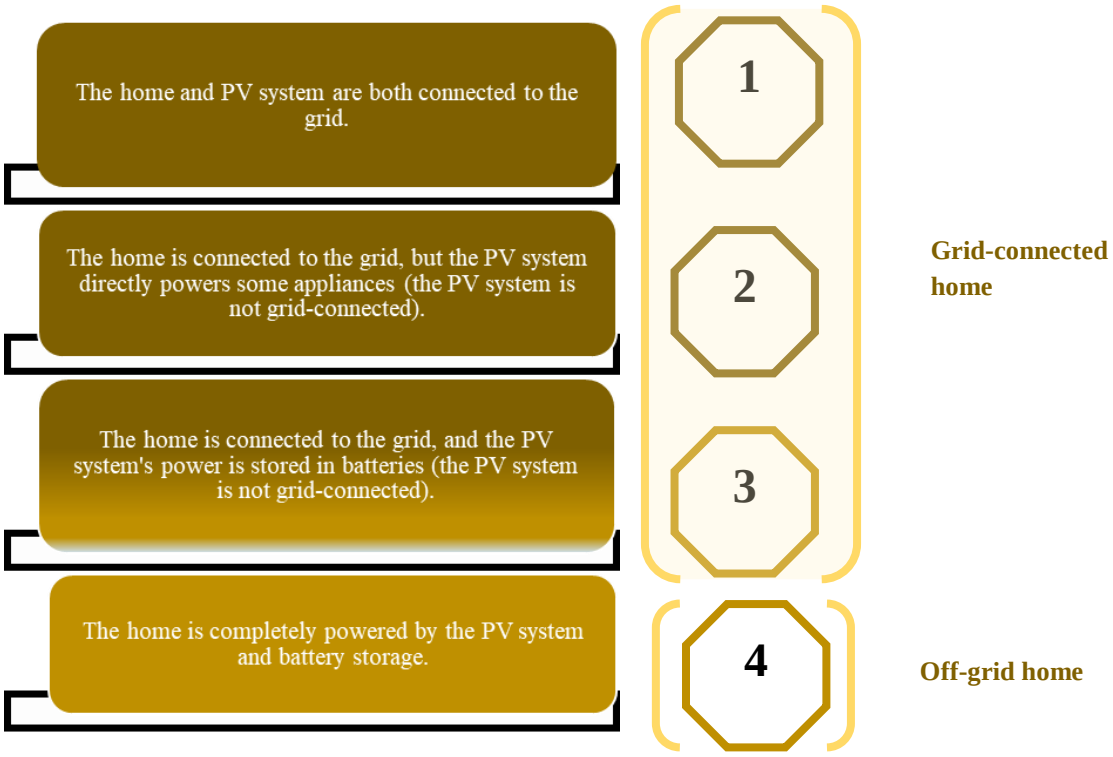


Figure 61 showing the types of photovoltaics (PV) designs that can fit into the broad techno-cultural niche created by Trinidad's incumbent energy culture

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It is worth stating that the battery-integrated options (3 and 4 in Figure 61) are not discussed more because these are likely to enter the regime after grid-connected photovoltaics - even though options 1 and 3 can be combined and fit within the grid-connected niche. Key reasons are that the electricity is cheap in Trinidad because it is subsidized (see Appendix E) so though battery storage costs are falling they are still relatively expensive, and battery-integrated systems are more complex innovations than grid-connected photovoltaics. This complexity relates to the supporting policies, coordinating institutions and cultural understanding of it.

Given the disparity between the respondents perceived and actual technical timing of peak

energy demand (evening) and peak solar power generation (mid-day), storing the solar power that is generated during the day for use during the peak energy demand times is an advantage of battery-integrated photovoltaics. Oahu has transitioned to incentivizing storage for residential photovoltaics because of the excess amounts of solar power exported to the grid (see Chapter 8) - and this is coupled with safety issues and technical concerns about the grid.

However in Trinidad there are energy-intensive industries like ammonia and methanol production facilities that constantly require electricity (see Chapter 4). This means that any solar power generated and exported to the grid during the day will be consumed. Therefore this excess solar power may not be as problematic as it is in Oahu. Chapter 8 also stated that batteries were part of Hawaii's overall strategy to deal with the peak demand and peak generation disparity; it also includes switching to time-of-use rates and the introduction of electric vehicles. But shifting demand will be discussed more fully in subsection 9.2.3. due to its relationship with the cultural policy goal of encouraging solar power self-consumption.

The techno-cultural niches described in this subsection are very broad and not necessarily solar specific. This is because culture is not a stand-alone element in niche-creation - if it was then photovoltaics would have already been more widespread in Trinidad. This illustrates the interconnectedness of the regime's elements (i.e. policy, markets, industries, cultures, science and technology) and in Trinidad's case shows why other elements such as policy will be instrumental in mainstreaming distributed residential solar energy. Nevertheless the creation of these broad techno-cultural niches shows that the incumbent energy culture looked at has long-term cultural structures built around electricity as the dominant energy carrier.

National renewable energy targets (RETs) can support such techno-cultural niches because it

creates the broad institutional and policy space for renewable resources which complements the cultural elements creating the niches in question. RETs also capitalize on the sustainability-related motivators for adopting solar energy because national RETs offer quantitative references which photovoltaics adopters can feel a sense of ownership towards. It also plays on the norms surrounding solar energy's relative advantages related the sun's longevity versus the nation's finite fossil fuel reserves.

RETs like the current '10% by 2021' would require specific input from the energy Ministry and T&TEC. Chapters 7 and 8 show that the design of renewable portfolio standards (RPSs), which are different to RETs, work in Hawaii primarily because the utility companies are private entities that are held accountable by the State. In Trinidad however, the T&TEC is government-owned. Therefore there would be an issue with accountability if the T&TEC does not meet the legally-stipulated requirements under a policy like RPSs since it would essentially be one State-institution holding another accountable.

This is why Trinidad should set and commit to RETs. However these RETs should have a dedicated quota for solar power and the targets need to be well-publicized. The targets should be included in State energy documents, Ministry websites, and the T&TEC's publications. For example the RETs can be included on the T&TEC's bills where a line and/or graphic that states/shows that the nation is working towards the specified target for that period ('10% by 2021' in the case) is provided. Having the targets well-publicized not only aids awareness-raising but can build the public pressure which can foster social accountability - this is important because unlike RPSs, RETs are voluntary commitments.

Linking the RETs (and its solar power quota) to the national greenhouse gas emissions

reduction ambitions of '15% by 2030', and '19% by 2040' in the power generation sector under the Intended Nationally Determined Contributions and Carbon Reduction Strategy respectively can bolster the broad niches for solar energy. This linkage plays on the sustainability-related motivators for adopting solar energy as well as the norms surrounding solar power's relative advantages that relate to climate change mitigation.

This means that support can come from institutions like the Environmental Policy and Planning Division, and Multi-lateral Environmental Agreements Unit - in addition to the energy Ministry; Regulated Industries Commission; T&TEC; and proposed Renewable Energy and Energy Efficiency Agency (see Chapter 7).

The RETs and emissions reduction targets can be linked because solar power generation contributing to the RETs under the dedicated quota abates emissions that would have otherwise come from fossil fuels (see Chapter 8). Therefore through proper institutional and technical accountability achieving RETs will be reflected in the emissions reduction targets.

9.2.2. Determining What Types of Policies Should Be Implemented

Table 28 in Chapter 8 (page 300) summarizes the solar energy policy environment in Trinidad but the energy cultures results from Chapters 5 and 6 show that there is the particular need for education and awareness-raising; capital cost and performance-based incentives; technology and industry standards; and certification and accreditation policies.

9.2.2.1. Education and awareness-raising

There is no significant adoption of solar systems in Trinidad despite the existing incentives. This is particularly important because even though there may be policies supporting solar energy, if adopters are unaware of them or the supported technologies then the policies' efficacy will be limited.

Chapter 6 showed that the Trinidadian respondents' energy culture has a more rudimentary understanding of solar water heating than Barbados'. Their understanding of it also includes references to photovoltaics and misconceptions about how both technologies work. There is therefore a need to fill these knowledge gaps.

The MEEA[2] and MEEA[3] (2018) outline that there is currently a national programme to educate the public and raise awareness. The MEEA[2] states that there is a renewable energy and energy efficiency education pilot project in 25 schools across the country. The MEEA[3] also outlines that the energy Ministry rolled out a national public awareness campaign entitled 'My Energy, My Responsibility'.

The campaign has three phases: Phase 1 is 'My Energy: From where does it come?', Phase 2 is 'Energy Efficiency begins with me', and Phase 3 is 'Renewable Energy: the Power of Nature'. It is currently in its second phase through a lightbulb exchange initiative to promote the use of fluorescent over incandescent bulbs according to the MEEA[3]. The MEEA[3] states that the program has been undertaken using television, radio and newspaper advertisements as well as school outreach events, display booths and online content.

There however needs to be a more targeted approach. The thesis' energy cultures insights can be used to drive Phase 3 of the aforementioned campaign. The key information that would

help largely relate to solar energy technologies and the industry. For example technological information includes brands and types of solar energy systems available as well as their lifetimes and reliability. Information about the industry particularly includes the installation, maintenance and standard warranties that should be offered for instance.

Provided that the Renewable Energy and Energy Efficiency Agency is consolidated (see Chapter 7) and is able to build a registry of renewable energy businesses in Trinidad based on the Renewable Energy Committee's (2011) advice, then this information can be disseminated as well. The registry should however be based on national accreditation and certification schemes (this will be looked at in subsection 9.2.2.4.).

Disseminating the information should use the culturally salient information channels like those in Appendix J e.g. the internet and one-on-one professional consultations which were the two most salient options. The internet is an example of a mass communication platform and the latter is an interpersonal channel.

Rogers (1995) and Rogers et al. (2009) outline that mass communication creates a more effective space to develop knowledge about innovations but interpersonal channels are more effective in stimulating changes in attitudes and the decision-making associated with adopting an innovation. Therefore education and awareness-raising needs a multi-channel communication strategy.

The information published online should be up-to-date and access to the online interface/portal should be user-friendly. In the case of interpersonal interactions with professionals this can be through mobile educational caravans that demonstrate how solar systems work. There can be interactive information sessions with the technologies (e.g. using

smaller-scaled replicas) inclusive of small giveaways such as small solar lights as part of the public engagement. This would be useful since several respondents, e.g. *Respondents 01FTTD* and *16FTTD*, based their understanding of solar energy on references to such smaller-scaled solar technologies (see Chapter 6).

Education and awareness-raising policies will directly impact the culture by helping build the niches for solar energy described in the last subsection; it specifically influences the norms about solar energy and the technologies. The education and awareness-raising programme will particularly need the support of the energy, planning and sustainable development, and education Ministries; solar energy technology retailers; and non-governmental and non-profit organizations.

9.2.2.2. Capital cost and performance-based incentives

Renewable energy targets can support the broad niches for distributed residential solar energy outlined in subsection 9.2.1. However they do not directly address cost-effectiveness at the household level. This is important because the Trinidadian respondents particularly value cost and are especially motivated by cost-effectiveness. It is also important because the Trinidad and Tobago Electricity Commission's (T&TEC) rates are subsidized (see Appendix E). These notions are also related to the belief that using photovoltaics can be more economic than the electricity provided by the T&TEC. These considerations therefore point towards a need for fiscal interventions. Such policies can be capital cost-oriented or performance-based.

Several of the Barbadians claimed tax credits on their solar water heaters which reduced the capital cost of the systems. But the policy was not an organic or salient part of the

respondents' energy culture as shown by Chapter 5 and 6's results. The more culturally impactful policy would be a grid-connected programme like Trinidad's intended feed-in tariff (FiT). Policies like these are examples of performance-based incentives.

FiTs are likely to be more culturally impactful because they have longer lifetimes compared to one-off tax incentives. Policies are external influences on energy cultures and the FiT is likely to particularly affect the cost domain of the respondents' perceptions of household energy (based on Chapter 5 and the types of features listed in Table 38 in Appendix H).

This does not mean that addressing capital costs is unimportant. The Barbadians' norms and practices involved in adopting solar water heaters (see Chapter 6) show that it is important to have policies which support flexible payment schemes in addition to Government-led policies such as tax credits e.g. rent-to-own plans from retailers.

These will be important for widening the adoption audience since options such as tax credits for instance only benefit taxpayers. Flexible capital cost payment plans do not necessarily reduce the capital costs of solar systems but they mitigate the impact of upfront costs and make payments more manageable.

The Trinidadian respondents value convenience and practicality amongst others as adoption motivators. So the fiscal policies should be built around these motivators. For example rent-to-own plans which mitigate the full impact of upfront capital costs will be more practical for many adopters in terms of making payments versus paying the full cost at one time. This also applies to how these payments are made where automated payments from a customer's bank account to the retailer through a mobile app may be more convenient than personally visiting the retailer or bank to make regular payments for instance. The administrative elements of

accessing incentives like tax incentives, the FiT and flexible payments e.g. completing and submitting application forms also need to be tailored to the culturally salient adoption motivators.

These sorts of policies would be largely dependent on the parties involved in the purchase (namely retailers and/or financers and customers) since making payments to a retailer for a system purchase is based on the agreement between the customer and business at the time. However a State-level policy that can encourage flexible payment schemes can be a national best practice guide for retailers and households that highlights the benefits of such financially flexible options amidst other items like national technology and industry standards (these will be discussed in the next subsection).

There is currently no direct financing scheme or low-interest loan facility for solar in Trinidad (Gardner, 2011). So there can be demonstration programmes through State-owned financial institutions such as the First Citizens Bank (FCB) which can provide preferential loans that cover the system's capital cost but paid back through flexible yet guaranteed installments. As a State-owned entity, using the FCB to pilot flexible solar financing programmes also plays on the importance of the Government setting the example (Renewable Energy Committee, 2011; Marzolf et al., 2015).

There are several appliance, furniture and electrical retailers in Trinidad. One of the most popular is Courts. In Barbados retailers similar to Courts sell solar water heaters so they are examples of non-manufacturer retailers - versus companies like Solar Dynamics who manufacture and retail solar water heaters (see Chapter 6).

If retailers like Courts sell solar water heaters then it can be incorporated into existing flexible

payments schemes such as their 'Ready Finance' programme where customers can sign-up and essentially design a payment plan that is tailored to their needs i.e. deposits and installments, length of payment plan and choosing the store's branch most convenient to make payments (Courts Trinidad and Tobago, 2018). The current 'Ready Finance' programme allows Courts customers to make purchases at Solaris Energy Limited, one of the solar energy retailers on the island (Courts Trinidad and Tobago, 2018) - but subscription is expected to be quite low as suggested throughout the thesis with regards to the wider solar energy adoption in Trinidad.

Developing the fiscal recommendations for the national best practice guide for retailers would require input from solar energy retailers; home appliance, furniture and electronics retailers; the energy Ministry; banks; and the Renewable Energy and Energy Efficiency Agency provided that it is consolidated.

9.2.2.3. Technology and industry standards

The Trinidadian respondents' salient information needs and adoption motivators (see Chapter 6) can be used to design technology and industry standards. The norms that led to the number of adoption pathways observed for solar hot water in Barbados e.g. non-manufacturer retail, door-to-door sales and direct manufacturer retail (see Chapter 6) show that there should be a multiplicity of adoption pathways. Having standards will ensure that the technology and retail service quality is maintained especially where non-manufacturer retailing is allowed (considering the risk of inferior systems and services entering the market).

The MEEA[4] (2018) states that there are technical standards for the designing and installation

of solar water heaters which include system performance, operation and maintenance, safety, reliability and durability. But this should be expanded to include photovoltaics and the industry as a whole using the other culturally salient information and motivators brought up in Chapter 6.

The energy Ministry, retailers and the Trinidad and Tobago Bureau of Standards' (TTBS) input would be important for expanding the standards. The last institution is particularly important because it has the vested mandate to oversee the quality of goods and services (except food, drugs and cosmetics) being traded in the country under the Standards Act No. 18 of 1997 (TTBS, 2018).

9.2.2.4. Certification and accreditation schemes

National standards should be supported by certification and accreditation schemes. These schemes would ensure that retailers are skilled enough so that a minimum acceptable service standard guided by national industry and technology standards can be set. The schemes can also be part of being enrolled in the registry of renewable energy businesses that the Renewable Energy Committee (2011) advises should be vested with a proposed national Renewable Energy and Energy Efficiency Agency (REEEA) (see Chapter 7).

Other benefits that can come from certification and accreditation include publicity, branding and status for certified and accredited retailers which can be used for marketing their products. The certification and accreditation should be supported by training and capacity building programmes to build a minimum and standardized skill-level in the industry.

Institutions such as the Trinidad and Tobago Bureau of Standards; education Ministry; National Training Agency; Accreditation Council of Trinidad and Tobago; National Examinations Council; MIC Institute of Technology; and University of the West Indies and University of Trinidad and Tobago's input will be required to develop the programmes' content and delivery.

To illustrate how the above can link to the need for education and awareness-raising initiatives raised at the beginning of the section, an example can be using the REEEA's website (or the energy Ministry's in the interim) to host a portal that has a map of Trinidad containing the basic information of certified and accredited retailers (e.g. name, address, phone number) so online users can see their nearest retailer and get in contact.

This would be useful because one-on-one consultations with professionals is a salient means of getting information (see Appendix J) and several respondents, e.g. *Respondents 07MTTD* and *08MTTD*, were unaware of where they could locate experienced professionals. This website information can also be passed on via pamphlets at educational caravans' stops or through newspaper advertisements.

9.2.3. Advising Policy Design: An Example Using Trinidad's Feed-in Tariff

Chapter 8 detailed the recommendations for Trinidad's feed-in tariff (FiT). But the energy cultures results particularly help with the considerations around metering and using a generation and/or export tariff in the FiT pilot.

Solar power exported to the grid can be either estimated or metered. Chapter 8 showed that the FiT should use separate generation and consumption meters because the imported and exported electricity will be priced differently, and the FiT-supported solar power generation can contribute to the national renewable energy and greenhouse gas emissions reduction targets; the generation meters allows for technical accountability in the case of the latter.

Appendix G shows the Trinidadian respondents' various perceptions of household electricity costs. These perceptions determine whether householders believe their electricity bills are either too high or too low. There were no overwhelming consensuses driving the rationales. But four rationales stood out because of two underlying beliefs: the Trinidad and Tobago Electricity Commission (T&TEC) determines the costs of electricity bills by zoning households based on an urban-rural municipality divide, and the electricity bill is calculated remotely versus reading the household's actual electricity meter. Whilst these are perceptions and not statements of fact, they point towards there being a belief that the utility's metering is flawed and there is mistrust in the T&TEC's billing.

This may affect the understanding of the metering and crediting for FiT-supported solar. So having a separate generation and consumption meter (versus a bi-directional meter as in net energy metering (NEM)) would be a better fit; it is likely to be a clearer design for adopters (WEC, 2016). The proposed Renewable Energy and Energy Efficiency Agency (REEEA) (see Chapter 7) can be the ideal institution to do the metering and crediting determinations because it is independent of the T&TEC.

Chapter 5 showed that consuming solar energy in the home is a norm in the Barbadian respondents' energy culture i.e. solar energy self-consumption. This is important because it

diversifies the household energy mix and gives the household a greater sense of ownership over their energy resources. Encouraging solar self-consumption can be a cultural policy goal; policy goals will be discussed in the next subsection. This particular goal helps with the FiT's generation/export tariff design since different designs encourage self-consumption.

As Chapter 8 outlined, homes can be paid for either generating their solar power and/or for exporting it - and if the export tariff rate is higher than the utility's retail rate then exporting power is more profitable but when the export tariff is lower it encourages self-consumption. This suggests that a solar power generation tariff, or export tariff that is lower than the T&TEC's retail rates should be used for Trinidad's FiT.

But there is a subsidy which artificially lowers electricity rates in Trinidad (see Appendix E); the retail rate is USD $0.04 per kilowatt-hour (kWh) for the first 400 kWh used, $0.05 USD per kWh for the next 600, and above this 1000 kWh, $0.06 per kWh (Espinasa and Humpert, 2016). This suggests that a FiT tariff will likely be higher than the T&TEC's rates provided that the current fossil fuel subsidy remains in place.

Using a generation tariff means that any solar power exported to the grid is done freely and the T&TEC would benefit from free power. Therefore solar self-consumption is in the household's best interest. But whilst a generation tariff encourages solar self-consumption there is the risk of adopters increasing their energy consumption to avoid exporting it freely if there is a surplus e.g. leaving the air conditioning on for longer periods of time; Appendix K gives insight into the implications of such feedbacks through NEM in Hawaii.

Householders may also not care whether or not they export power freely to the T&TEC's grid since they are being paid for their solar power no matter where it is consumed. This is because

the norms which will likely develop around the FiT may be insensitive to differences between generation and export tariffs - the fact that adopters are paid for their solar power is the most salient feature.

In order to reconcile solar self-consumption with the incentive to adopt photovoltaics under an exportation scheme, the export tariff should be geared towards surplus solar power generation and remunerated at a rate lower than the retail electricity tariff. So the fact that adopters are paid for surplus export means that they need to consume their solar power and there is an incentive to reduce consumption so that more power could be exported. This allows the home to consume their solar power, reduce energy consumption and still benefit from the export-oriented payments.

But reducing electricity consumption is only one dimension of energy usage. There is still going to be a disparity between peak solar power generation and peak energy demand. Based on the respondents' perceived peak demand (see Appendix F), the T&TEC will get more free power during weekdays unless there is behavioural change. Appendix F shows that the Trinidadians' perceived peak energy demand include a consensus on the most electricity being consumed between 6:00PM and 8:00PM. Marzolf et al. (2015) also show that the technical peak energy demand occurs between these times.

This warrants thinking about demand-side management (DSM) interventions aimed at load shifting to encourage solar power self-consumption during its peak generation times. Appendix F provides more detail on the drivers of the perceived peak demand but a significant driver is the fact that householders are not home during the day which is when solar generation is at its peak. This means that there will be solar power exported during the

day since it is not being consumed.

Practices such as cooking and showering, and material culture like televisions and air conditioners are more specific drivers of the perceived evening peak demand. Specific and flexible features can be identified and used as targets for behavioural change through load shifting. Load shifting involves moving peak demand load to off-peak periods (Sinha and De, 2016). For example doing the laundry is a salient driver of the perceived peak demand. Weekends were also part of the respondents' framing of a 'typical' day. So households can be encouraged to do their laundry during peak solar energy generation hours on weekends.

An example of a common strategy used to achieve load shifting is time-of-use rates where different rates apply to different times of day and the highest rates apply during peak demand times (Sinha and De, 2016). This incentivizes householders to consume electricity during the day when solar power generation is at its highest and reduces the household's overall demand from the grid.

These considerations do not exclusively point towards choosing between a generation, and export-oriented FiT for surplus power. They do however put forward considerations that are important for planning Trinidad's FiT pilot and a full FiT programme pending the results of the pilot.

The FiT pilot can be funded through an increase in retail rates but this perpetuates the inequity issues from Appendix K. The Appendix also shows that the Green Fund could be used but its financing is not guaranteed and is very restrictive with respect to accessing funding. However based on the REEEA's proposed remit (see Chapter 7) it should be setup to be eligible for accessing the Green Fund so that it can access ad hoc financing.

The current subsidy that hydrocarbons benefit from should be used to fund the FiT pilot. But as indicated by Chapter 4 and Appendix E, this would require institutional and legislative reforms because the subsidy is funded by oil companies and the Government, and is guided by the Petroleum Production Levy and Subsidy Act - and this would be in addition to the reforms associated with the T&TEC and Regulated Industries Commission needed to accommodate solar in the first place.

The last institution will be particularly important for setting future tariffs after the FiT pilot since consideration can be given towards reducing the hydrocarbon subsidy in the electricity sector so that the commodity reflects its true cost more accurately (and its diversion into the FiT as well?). The subsidy reduction will result in higher tariff rates for all ratepayers and improve the cost-effectiveness of residential solar under a FiT.

Recalling that the most impactful policies will affect energy usage and its costs, a subsidy reduction in tandem with a FiT can be impactful. But this introduces the (in)equity issue so a mechanism to mitigate this will need to be part of the long-term solar energy strategy. This shows that the long-term success of a full FiT in Trinidad will be dependent on the future of the subsidy on the T&TEC's rates and the incumbent tariff design. This is because it will affect the FiT's rate determinations that include the actual rates set and generation and/or export tariff designs.

Li and Cannetti (2016) state that fossil fuel subsidies create inequities because wealthy consumers benefit from them the most. This means that integrating distributed residential solar would perpetuate the existing inequity even without rate-increases to fund a FiT.

Restructuring the incumbent rising block electricity tariff to one that is more sensitive to the

timing of energy demand, timing of solar power generation, and equity of electricity access may be a way of addressing this as part of a longer-term strategy (which ties into the DSM through load shifting brought up earlier). This will mean that rate revisions and/or restructuring to a completely new tariff design may be worth considering.

9.2.4. Guiding Policy Goal-Setting: An Example Using Trinidad's Feed-in Tariff

The development of new norms and practices, and acquisition of new material culture marks an energy cultures shift (Stephenson et al., 2015). Policies can directly and indirectly (through the supported technologies) catalyze such shifts.

The education and awareness-raising strategy outlined in subsection 9.2.2. is an example of a policy that will have a direct impact on the energy culture and tax credits are an example of a policy that will have an indirect impact because it is mediated by the photovoltaics or solar water heater systems they support.

A feed-in tariff (FiT) however is an example of a policy that will have both direct and indirect impacts on the energy culture (see Table 30 on the next page). The direct and indirect impacts are based on comparing the changes that would be likely to occur with stand-alone photovoltaics versus FiT-supported photovoltaics. This helps make the distinction between impacts due to adopting the technology versus adopting the policy and technology.

CULTURAL POLICY GOAL	GOAL TYPE	POLICY DESIGN IMPACT ON ENERGY CULTURE
To integrate the photovoltaic system (primarily solar panels) as material culture	Material Culture	Indirect
To integrate an added electricity generation meter as material culture	Material Culture	Direct
To promote the application for planning permits as a practice	Practices	Indirect
To promote the application for grid interconnection permits as a practice	Practices	Direct
To promote the adoption of photovoltaic systems as a practice	Practices	Indirect
To promote the adoption of a generation meter as a practice	Practices	Direct
To continue paying a household electricity bill as a practice	Practices	Indirect
To introduce collection of cheques/payments for the solar power exported and sold as a practice	Practices	Direct
To normalize the belief, aspiration and expectation that solar energy is being used in the home	Norms	Indirect
To normalize the belief, aspiration and expectation that using solar energy reduces the costs of electricity	Norms	Indirect
To normalize the belief, aspiration and expectation that using solar energy reduces the consumption of electricity	Norms	Indirect
To acknowledge that the weather impacts the household's solar energy generation as an external influence	External Influence	Indirect
To acknowledge that the contracted residential solar tariff rate determines the household's costs of electricity as an external influence	External Influence	Direct

Table 30 showing the key energy cultures policy goals for Trinidad's feed-in tariff

Note: The direct and indirect impacts are based on comparing the changes that would be likely to occur with stand-alone photovoltaics versus grid-connected photovoltaics.
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The FiT will be an external influence on the energy culture. So as an external influence it would make solar panels new material culture (indirect impact); a new norm would be that adopters expect and believe that the amount of solar power generated affects their electricity bill (indirect impact); and a new practice would be collecting cheques/payments for generating and/or exporting solar power to the grid (direct impact) for example.

These changes are part of the energy cultures shift and can be framed as goals that policymakers can design the FiT to achieve. Integrating distributed solar into Trinidad's residential electricity regime will make its regime more complex (see Chapter 7) and the energy culture will become more complex as well (see Chapters 5 and 6). Linked to this is the formation of energy subcultures due to policy interventions. Stephenson et al. (2015) state that there can be nested energy cultures i.e. energy subcultures within an energy culture. So policies can create energy subcultures provided that they develop defining norms, material culture and practices.

In Trinidad there could be a broad solar energy culture but there would be a subculture influenced by solar water heating (like Barbados' explained in Chapters 5 and 6), and one influenced by photovoltaics under the FiT. Examples of defining practices between both energy subcultures would be the adoption of solar water heaters versus photovoltaics and a generation meter, and collecting FiT payments for instance.

9.2.5. Informing Retail Marketing

Solar energy technologies are innovations but their supporting policies will be innovations as well. Comparing stand-alone photovoltaics to tax credit-supported and/or photovoltaics under a feed-in tariff (FiT) for instance are different innovations being presented to the adopter because the policies' affect the technology's relative advantages and the information presented to an adopter. There will likely be more uncertainties associated with policy-supported solar technologies because they are arguably more complex innovations.

For example using stand-alone photovoltaics will reduce the amount of electricity consumed

from the grid and the costs of consuming it. However FiT-supported photovoltaics allow homes to further reduce their household energy costs by being paid for the solar power they generate and/or export to the grid. This therefore affects the economic relative advantages of FiT-supported photovoltaics over stand-alone photovoltaics or consuming electricity from the grid.

Retailers can use the insights on desired adoption information (e.g. maintenance), motivations (e.g. practicality) and information channels (e.g. professional one-on-one consultations) to sell their products and packages under the supporting policies to customers. Table 31 (next page) shows an example of how this could be done using the adoption motivators from Chapter 6 for photovoltaics.

Retailers can use the information from Chapter 5 and Appendix H's features to ground their marketing. Several of the culturally salient material culture in Trinidad are not necessarily the most consumptive (e.g. refrigerators and lights) so combining cultural salience with the conventional backing of technical salience can be strong selling points if a retailer needs to present customers with system design.

For example air conditioning is the most salient feature according to the Trinidadian respondents' codes presented in Appendix H. It also accounts for approximately 22% of households' bi-monthly energy consumption (Renewable Energy Committee, 2011). Air conditioning is also likely to be used by higher-income households (Marzolf et al., 2015) so these sorts of defining material culture can be used to create customer-groups for marketing purposes; Figure 62 on page 371 shows the Trinidad and Tobago Electricity Commission's customer distribution and the portion likely to be using air conditioning as a reference.

MOTIVATION	IMPORTANCE	MARKETING POINTS EXAMPLES
Cost-effectiveness	* * * * * *	1. Claiming your tax credits reduce the upfront costs of the system 2. Your bi-monthly payments from the FiT earns your household money
Convenience	* * * * *	1. Your solar panels require low maintenance 2. Your solar system does not require you to manually operate it
Practicality	* * * *	1. Your home will still have electricity at night when the sun is not shining 2. Your grid-connected solar system can still power important appliances e.g. televisions
Social status	* * *	1. Solar panels can increase your home's property value 2. Solar panels are an aesthetic home improvement
Choice on the market	* *	1. Solar energy under the incentive scheme is an alternative to the current arrangement with the Trinidad and Tobago Electricity Commission 2. There are different brands and designs of solar panels to choose from
Durability	* *	1. Solar panels last 20 years or more 2. Solar panels can withstand storm conditions
Sustainability	*	1. Solar energy is consumed in the home 2.. The home's greenhouse gas emissions are reduced
Safety	*	1. There are interconnection standards and codes of practice to guide electricians 2. The Trinidad and Tobago Electricity Commission assesses the installation

Table 31 showing an example of the marketing points for adopting policy-supported distributed residential solar energy in Trinidad based on the Trinidadian respondents' motivators from Chapter 6

Note: The marketing importance is based on Figure 45 from Chapter 6

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This means that there is specific material culture that can be targeted for efficiency improvements or usage reduction to maximize the benefit from the solar system as part of its adoption marketing - and these can even be aligned with the demand-side management strategies mentioned in subsection 9.2.3. such as time-of-use rates. This notion also applies to norms and practices but material culture was the best example to use here given its tangibility.

The image showing the Trinidad and Tobago Electricity Commission's 2010 customer distribution originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Marzolf, N. C., F. C. Cañeque and D. Loy. 2015. A Unique Approach for Sustainable Energy in Trinidad and Tobago. Inter-American Development Bank. Website: http://www.energy.gov.tt/wp-content/uploads/2016/08/A-Unique-Approach-for-Sustainable-Energy-in-Trinidad-and-Tobago.pdf (accessed 12th January, 2017)

Figure 62 showing the Trinidad and Tobago Electricity Commission's customer distribution for 2010 and those particularly likely to be using air conditioning

Note: The black and light blue lines are the mean and median energy consumption.

Extracted from Marzolf et al. (2015; 276)

This subsection's ideas on retail marketing can be another element included in both editions (household and solar retailer) of the national best practice guide for residential solar energy mentioned in subsection 9.2.2. For example the solar retailer edition of the guide can include recommendations for retailers to use cultural considerations to improve their marketing. The household edition of the guide can provide recommendations that residents should consider to adjust their energy consumption practices to maximize their benefits from adopting solar.

9.3. Policy Recommendations for Trinidad's Residential Solar Energy Mainstreaming Strategy

This brief section puts forward the explicit recommendations that Trinidad's Government can

consider to mainstream residential solar energy. But before doing so, it is worth remembering that Trinidad's residential electricity regime is unusual by small-island standards (see Chapter 4). The regime's evolution from its incumbent orientation to a state that has more widely integrated distributed residential solar energy will be a prolonged process due to the barriers raised in Chapter 4, and especially so because of the subsidy that currently lowers electricity rates (see Chapter 4 and Appendix E).

But this is not a reason for pessimism and is instead a call to use this time wisely for planning the energy transition (ET). So Trinidad's ET planning should be approached as an opportunity to redefine the regime by regarding time as an asset instead of a liability. By regarding 'time' as an asset it particularly:

- Allows the Trinidad and Tobago Electricity Commission and Regulated Industries Commission to evolve at more institutionally sustainable rates relative to the learning around solar energy integration, rate-setting and adjustment determinations, and revenue and/or profit outlooks.

- Can be used to consolidate the supporting institutional architecture for renewables such as the Renewable Energy and Energy Efficiency Agency (REEEA).

- Enables the institutional and legislative structures supporting the existing subsidy on conventional energy to be revised and realigned to fit an agenda that broadens the national approach energy (even diverted into renewable energy subsidies).

- Allows for the periodic revision of policies and programmes to accommodate changing conditions (considering that too many revisions can create uncertainty).

- Allows the solar industry to grow more sustainably and avoid 'boom-and-busts'.

There was no real sense of what the current policy environment for solar energy is like in Trinidad so interviews with policy officials were conducted as outlined in Chapter 8. Trinidad has implemented several policies and some of which are pending (see Chapter 8). The wider discussion using the cultural results from Chapter 5 and 6 showed that Trinidad's Government needs to consider more than the incumbent policies. There are ten policy options worth highlighting to answer the second research sub-question: *"What are the Government's State-level residential solar energy policy options in Trinidad?"*

- Publishing, more widely publicizing and committing to national renewable energy targets (RETs). These RETs should have a specified quota for solar energy. They should also be more explicitly linked to the national greenhouse gas emissions reduction targets.

- Expanding the incumbent tax credits scheme to include photovoltaics.

- Expanding the incumbent standards for solar water heaters to include photovoltaics and the solar energy industry as a whole.

- Developing national certification and accreditation schemes for the solar energy industry.

- Integrating a more targeted education and public awareness-raising strategy that fills knowledge gaps linked to the use of solar energy technologies, the local industry, and supporting policies through more effective channels like one-on-one consultations in addition to online content.

- Encouraging retailers and financial institutions to develop/adopt fiscal policies which offer flexible capital cost payment plans for solar system purchases.

- Implementing a formal pilot programme for a feed-in tariff (FiT) that uses fixed-rates; a generation, and/or export tariff for surplus power exported; levelized/avoided costs; a separate generation and consumption meter; guaranteed contract rates; bi-monthly crediting/billing; and system and programme caps. The pilot should be funded through the financing that is used to subsidize the conventional electricity rates. The FiT-supported power generation should contribute to the national RETs and emission reduction targets (hence the use of generation meters).

- Considering load shifting strategies such as a time-of-use electricity tariff design to complement the FiT's cultural policy goal of allowing solar power self-consumption. This may even extend to completely restructuring the incumbent rising block tariff to account for energy equity issues and the effect of the energy subsidy on this and designing a competitive FiT rate.

- Encouraging retailers to sensitize their marketing to the culturally salient details e.g. information needs, motivators, and factors believed to affect energy usage and its costs.

- Publishing and circulating national best practice guides for residential solar energy (household and retailer editions) that includes items such as technology and industry standards, certification and accreditation guidance, and fiscal best practices.

9.4. Critiquing Mainstreaming and Culture as Elements of Energy Transitions

9.4.1. The Usefulness of Mainstreaming as a Concept in the Multi-Level Perspective of Socio-technical Energy Transitions

The Multi-Level Perspective (MLP) illustrates the vertical structure of energy transitions (ETs). The socio-technical regime is the mainstream structure of the MLP and mainstreaming refers to a niche-innovation evolving out of its niche(s) and becoming part of the regime by being more widely adopted (see section 2.2. in Chapter 2). Chapters 4 to 8 had concluding subsections that qualitatively characterized mainstreaming through a series of points that can be arranged as pre-requisites for, facilitators of and pseudo-indicators of mainstreaming.

Pre-requisites for mainstreaming:

It must be understood that in the context of the MLP mainstreaming:

i. Is tied to the adoption of technologies.

ii. Needs adopters to have a basic awareness of the technology being adopted, its service(s), and the incoming resource(s) powering the technology.

iii. Requires reducing uncertainty about the technology and satisfying a need for more detailed pre-adoption information.

Facilitators of mainstreaming:

During mainstreaming:

i. There are certain properties that make a technology more easily adopted - cost-

effectiveness is one of the most important.

ii. A technology is more readily adopted when it satisfies the culturally-valued motivators for adopting it.

iii. A technology is more readily adopted when it fits non-disruptively into adopters' routines and habits.

iv. Incentivization policies can improve the adoption rate of a technology.

Pseudo-indicators of mainstreaming:

Once an innovation enters the regime of the MLP:

i. There will be varying degrees of resource and technological substitutions.

ii. There will be new practices and norms emerging in the energy culture because of the adoption of the technology as material culture.

iii. There will be multiple adoption pathways established which means that the technology's original adoption niche is outgrown.

iv. There will be new actor-institutions introduced into the regime's institutional multi-actor network accompanied by new inter-actor relationships as well as actor-agency and actor-power changes.

v. There can be industrial, policy, cultural, scientific, market, and technological transitions.

vi. There will be systems-level feedbacks linked to the adoption of the technology.

These characterizations are useful because they itemize a visually and theoretically complex space in Figure 17 (page 67). So given the multiplicity of tenets, the term 'mainstreaming' is useful because it acts as an umbrella terminology.

Mainstreaming could be potentially quantified but quantifying ETs is hard so absolutely quantifying mainstreaming is also expected to be difficult. Several elements are also too fluid to be readily quantified and one in particular is culture. This is because quantification implies that there is a threshold and once it is crossed an innovation can be deemed as mainstreamed.

Nevertheless Chapter 2 showed that there may be a theoretical pseudo-threshold of 16% in an adopting system based on the diffusion of innovations theory - and the work in Chapter 6 and 7 showed that Barbados and Oahu have respectively mainstreamed solar water heating and photovoltaics since the market penetration of these technologies are significantly beyond this 16% figure.

9.4.2. Evaluating the Efficacy of Studying Culture in Socio-technical Energy Transitions and in Trinidad

9.4.2.1. Critiquing the value of studying culture in energy transitions

In the context of the vertically-structured socio-technical theory such as the Multi-Level Perspective (MLP) of socio-technical energy transitions (ETs), culture represented a gap in its understanding of transitions. Therefore studying culture marked a novel undertaking.

But behaviour is a fundamental element of the 'socio' in socio-technical studies and culture is but one way to approach behaviour. Culture is so complex that it transcends the planes of the

MLP so culture is also vertically-structured. This is a particularly useful way to approach behaviour since it means that culture's roles in socio-technical ETs can be studied holistically.

More critically, in terms of culture's explicit inclusion in the MLP's regime, it seems to be a term used to represent the social and more human elements of the structure. Therefore since culture is but one expression of this; is hard to grasp conceptually; and behaviour is at its root, 'culture' could be potentially replaced with 'behaviour'.

However when considering the element of time and the systems-level context of the regime in the MLP, 'culture' is likely a better concept because it acknowledges a collective system of integrated behaviours (versus solely behaviour which can refer to one action). Using the Energy Cultures Framework was useful for illustrating this through the interactions of norms, practices, material culture. Its consideration for an external context is also particularly useful because it essentially sets this 'culture' and its behaviours in the wider external context of the regime.

9.4.2.2. Critiquing the value of studying culture in Trinidad

The thesis shows that the regime's six elements transition at different rates over varying timescales. This implies that a regime's elements do not have equal importance or influence on an energy transition (ET). Culture may play an influential role in other geographies but in Trinidad culture might not be the most influential element of an ET since many of the energy culture's most influential dimensions (based on the respondents interviewed) are rooted in the economics associated with the cheap electricity made possible by the island's energy subsidy. When put in the context of Trinidad's energy history (see Chapter 4), it may be likely that the

regime's other elements may be more influential than culture e.g. the energy subsidy may make the ET an economics-oriented process.

One reason for this is that in Trinidad, culture's reactive role(s) will likely be more strongly expressed given the incumbent energy culture from Chapter 5. This notion is also linked to Trinidad's culture creating very broad niches for photovoltaics. The same could be said for Barbados. But the fact that solar water heating has already been adopted means that the niche(s) for solar energy is more defined because of the energy culture's more detailed suite of solar energy norms and practices. It is also bolstered by norms and external influences linked to the international oil market as well as the lack of competition due to a monopoly on the electricity market for example.

Another reason is that the thesis looked at the relationships between culture and policy in a location where the latter is largely absent in terms of its effective implementation. There are more thoughts on this particular dimension in section 9.6. as part of the thesis' limitations. But the current state of Trinidad's policy support for residential solar and studying Trinidad's energy culture showed the need for more than solely fiscal policies (recalling the economic background from the first point).

9.5. Contributions of the Thesis

9.5.1. Contributions to the understanding of energy transitions

The thesis has both general and specific practical contributions. Considering the number of small islands in the world and their defining characteristics, the thesis' takeaways are highly

replicable. More specifically, the thesis bettered the understanding of the residential energy transitions (ETs) occurring in Barbados, Oahu and Trinidad.

Perhaps its greatest contribution in this regard however comes through studying the island of Trinidad. Trinidad is a small, tropical island that is unusually well-endowed with oil and natural gas by islandic standards so it is a unique energy case study. This work can therefore possibly act as a foundational advisory resource for the Government of the Republic of Trinidad and Tobago in planning the national ET roadmap - particularly because there is no literature that concretely documents the application and potential of renewables in Trinidad (Solaun et al., 2015).

Academically, the thesis improves the spatial understanding of the Multi-Level Perspective (MLP) by applying it to not one but three case studies. Beyond this, by being applied to small, tropical islands, it represents a highly specific geographic application that is rather novel. Small, tropical islands are also amongst the most vulnerable geographies relative to the repercussions of energy insecurity and climate change. So this islandic research on residential solar energy is a valuable contributor to understanding the mainstreaming of alternative energies in these marginal geographies.

The final and most significant academic contribution of the thesis however, is its exploration of the roles of culture in ETs which is coupled with the academic application of mainstreaming as a concept to consider in the MLP (versus its more pronounced featuring in the diffusion of innovations work). The thesis determined that culture has proactive and reactive roles during an ET. However relative to the MLP, these roles transcend the landscape, regime and niche planes of the theory. The niche-creation, technological

selectivity, resistance to changes and lock-ins, reaction to changes, and adaptive capacity outlined in section 9.1. play out in different degrees across the MLP's three planes.

9.5.2. Contributions to the understanding of energy cultures

The Energy Cultures Framework (ECF) was presented in Stephenson et al.'s 2010 research and modified in a 2015 paper. Therefore the ECF is a relatively young theory/framework. So by using the model, the thesis automatically contributes to the growing body of literature on energy cultures and the model's applications.

It also specifically contributes to its application in socio-technical energy transitions work (see the next subsection). This comes especially through studying the energy cultures surrounding innovation adoption. This is important since niche-level culture did not explicitly emerge in the ETs literature review from Chapter 2, and the ECF caters for energy subcultures' existence which is likened to niche-level culture in the Multi-Level Perspective.

Beyond this the thesis' analyses shed light on linking behavioural interventions to residential solar energy policies - and should prove useful to the Government of the Republic of Trinidad and Tobago's plans for residential solar energy.

9.5.3. The theoretical links between the Multi-Level Perspective and Energy Cultures Framework

In addition to the contributions outlined in the last two subsections, integrating the theories is a specific academic contribution. The Energy Cultures Framework's approach to behaviour is

versatile enough to address culture's vertical integration in the Multi-Level Perspective (MLP) of socio-technical energy transitions (ETs). This was however due to the fact that the MLP and ECF share several theoretical links that are predicated on the fact that culture has a role in ETs and transcends the planes of the MLP:

- The MLP's socio-technical regime is a co-evolutionary structure made up of scientific, industrial, cultural, market, technological, and policy elements which suggests that a change in one dimension would catalyze a change in the others. In the ECF, a change in its norms, practices or material culture would spur a change in the other elements because of the consonance of the model and culture.

- Material culture in the ECF can be akin to technology in the MLP. Therefore a technological change in the MLP can translate into a change in material culture in the ECF - and this extends to the associated elements' changes in each model based on their respective degrees of interconnectedness.

- The ECF was developed to help with policy interventions and 'policy' is an explicit feature of the MLP's socio-technical regime.

- There are links between the nature of the MLP's landscape-forces and ECF's external influences - though regime-level features can also be external influences on the energy culture of interest.

- The existence of nested energy cultures within a wider energy culture of the ECF are linked to the nature of adopters in the niche-innovation plane of the MLP.

However there are two key limitations to integrating the theories:

- The MLP extends consideration for the socio-technical regime affecting the socio-technical landscape. However the ECF does not give detailed insight into how norms, practices, and material culture affect external influences - considering that landscape and regime forces can be external influences.

- Cultural evolution as a process is not addressed in the ECF since the model does not consider time which would have been quite useful given the importance of time to ETs and the MLP's processes.

9.6. Limitations of the Study

The main limitation surrounds the use of the three case study islands (Oahu, Barbados, and Trinidad). Whilst the research conducted in each island is valuable in its own right, in terms of looking at the more explicit interactions between policies and cultures, comparing two islands would have perhaps been more effective.

Barbados was used as a case study because its wider cultural context is largely comparable to Trinidad's e.g. demography and history so it keeps the cultural variables as constant as possible for the comparison. Barbados has been a Caribbean leader in solar energy for the last 40 years and after being ranked amongst the global top five 'installed solar hot water heaters per capita', the island is now transitioning into the solar power industry (CEIS, 2015; IEA-ETSAP and IRENA, 2015). Therefore Barbados' policy experience with photovoltaics, the key solar energy technology of interest, is more limited than Oahu's hence why the latter was used as the policy comparator.

As shown by the energy cultures' comparison in Chapters 5 and 6, the Barbadians and Trinidadians' energy cultures are quite similar (except for the impact of solar water heating) which meant that theoretically, the wider cultural contexts were not factors that explicitly affected the nature of the energy cultures of interest. But this is not to say that they cannot hence why Oahu was not used as a cultural comparator during the initial research design. Nevertheless based on the underlying structure of the energy cultures, any perceived wider cultural differences between Oahu and Trinidad may not have had any substantive impact on a comparison between both islands.

The use of Barbados' solar water heating limited the deductions that could have been made surrounding the cultural impacts of photovoltaics which is arguably the more important given its popularity and the dominance of electricity in modern energy systems. Given that Oahu has been undergoing a transition through distributed residential photovoltaics for just over a decade, the technology's prominence on the island meant that by default the institutional interviews were going to connect with residential solar energy policies that are linked to the deployment of photovoltaics.

So considering the fact that Oahu has widespread residential photovoltaics, using Oahu to make the energy cultures comparison with Trinidad may have retrospectively been a better technological (or rather material culture) comparator than Barbados; based on the above two retrospective insights, solely comparing Oahu and Trinidad would have made the thesis' comparisons more consistent and focused.

Another perspective that emerged as a limitation is the use of Oahu as the policy comparator. This set the available suite of policies that could be looked at to only those implemented in

the island. So even though Oahu's policy options were used on the island to mainstream solar it does not meant that they are the most effective policies to be considered in Trinidad.

For example looking at countries like India which has subsidized electricity (similarly to Trinidad) and aggressive solar energy ambitions or even Norway that has significant fossil fuel reserves (similarly to Trinidad) and high renewable energy deployment may have been better case study comparators. But Oahu was used to keep the islandic comparisons constant especially since culture was the main element being studied and Barbados and Trinidad were the two islands being looked at.

This also meant that the interactions between policies and cultures were limited to those used in the study. Therefore there may be other policies that have more visible or influential relationships with culture but may have been omitted because they were not implemented in Oahu or thought about in Trinidad.

Also using Oahu and Trinidad as case studies meant that fiscal policies would be the most likely to show up as drivers of solar energy given their backgrounds. Both are extreme cases of island energy systems by small-island standards; Trinidad has an abundance of oil and natural gas and cheap electricity, and Oahu is the most isolated archipelago with expensive electricity so it can be expected that 'cost' will be a key element in their regimes.

This is linked to the critique of studying culture in Trinidad in subsection 9.4.2.2. One can question whether culture will be that influential especially if it supports a fiscal policy that could have been implemented without considering culture. However this assumes that there is a capacity for seamless policymaking - and in a country like Trinidad and Tobago, a Small Island Developing State, any useful inputs into policymaking will go a long way.

9.7. Opportunities for Further Research

9.7.1. Short to Medium-term Projects

Technological transitions and Energy cultures: There is an opportunity to study the cultural impacts of an energy culture that has undergone a technological transition from solely residential solar water heating to adopting both residential solar water heating and distributed residential photovoltaics. Such a project can be conducted with households in Barbados and Oahu and comparing the findings from both islands can help build confidence in the anticipated changes that result from the transition.

Photovoltaics and Energy cultures: Worthwhile projects would be researching both grid-connected and off-grid distributed residential photovoltaic systems and their impact on the adopting energy cultures. In terms of the grid-connected solar, given that solar water heating was the technology looked at in the thesis' energy cultures comparison and was used to make policy-based deductions for photovoltaics, it is only logical that an explicit study be done to investigate the impact of supporting policies like feed-in tariffs (FiTs), net energy metering, or other location-specific examples such as Hawaii's customer grid-supply.

In the case of off-grid photovoltaics, this can look at battery-integrated designs or even stand-alone photovoltaics that directly power several household appliances. This would be an important project given that batteries are becoming prominent global socio-technical elements (see Figure 63). Battery storage also works well with photovoltaics when the notion of satisfying evening peak demand with solar power is concerned (Blechinger et al., 2014; Szabó et al., 2015). It would tie in well to this study given that the proposed FiT design allows

residents to consume their solar energy and opens up avenues for looking at storing this solar power for later use.

The image showing the global grid-connected stationary battery storage capacity by country from 2006 to 2016 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Renewable Energy Policy Network For The 21st Century. 2017. Advancing the Global Renewable Energy Transition: Highlights of the REN21 Renewables 2017 Global Status Report in Perspective. Website: http://www.ren21.net/wp-content/uploads/2017/06/GSR2017_Highlights_FINAL.pdf (accessed 25th April, 2018)

Figure 63 showing the global grid-connected stationary battery storage capacity by country from 2006 to 2016

Extracted from the Renewable Energy Policy Network For The 21st Century (2017; 139)

Such research may even extend to the adoption of electric vehicles given that this is another globally emergent socio-technical development (see Figure 64) and using the solar power from the proposed FiT in Trinidad to charge the vehicles may be a useful application to look into as it pertains to load shifting.

The image showing the global passenger electric vehicle market 2012 to 2016 originally presented here cannot be made freely available via ORA because of copyright. The image was sourced from:

Renewable Energy Policy Network For The 21st Century. 2017. Advancing the Global Renewable Energy Transition: Highlights of the REN21 Renewables 2017 Global Status Report in Perspective. Website: http://www.ren21.net/wp-content/uploads/2017/06/GSR2017_Highlights_FINAL.pdf (accessed 25th April, 2018)

Figure 64 showing the global passenger electric vehicle market (including PHEVs) from 2012 to 2016

Extracted from the Renewable Energy Policy Network For The 21st Century (2017; 145)

Geography and Energy cultures: A study that looks at the impact of the geographic factors that create urban, peri-urban, and rural distinctions between energy cultures will be useful considering increasing urbanization and energy consumption. Such a study targets value systems and practices as shaped by geographic location. Another can be looking at the impact of specific environmental factors as external influences. For example the cooling demands of people near the coast or on a highland area would be different to other regions because the temperatures that drive the need for cooling is strongly moderated by sea breezes and elevation respectively.

Isolated practices: Given that energy cultures involve assemblages of practices, isolating the most salient or energy-intensive amongst them and studying them through other theories such as social practice theory for instance may give individualistic insight into the each practice. Based on the thesis' work, explicit practices that can be looked at in more depth are the use of air conditioning (culturally salient and consumptive), refrigeration (culturally salient), and hot

water (consumptive).

Institutional multi-actor network: This relates to the multi-actor network of socio-technical regimes undergoing an energy transition. This can include both quantitative and qualitative studies that look at actor-power, actor-agency, strength of association between actors, and actor-dependence metrics for instance. Small islands are traditionally serviced by a single electricity utility company so an interesting case study would be investigating the utility's changing actor-dynamics during transitions - and Oahu would be a particularly good case study given the rate at which its transition developments have been occurring.

Energy cultures driving transitions: A study which specifically looks at energy cultures as the driving agents of change during an energy transition can give more insight into the proactive role of culture during transitions. Oahu may be a useful case study given the strong public voice involved in Hawaii's energy developments.

9.7.2. Long-term Projects

Cultural drift and Energy cultures: There is an opportunity to do long-term studies on the cultural drift of the features that appear within a given energy culture. Such a study will provide insight into if there are feature-migrations due to changes in perceived salience; their entry and exit patterns; lag times in response to stimuli such as policies or technology adoption; and their rates of migration based on the saliences of the cultural features being observed over time.

Renewable energy transitions and Nested energy cultures: There is room to do a long-term

and a large-scale study that looks at the energy subcultures that may exist as part of a socio-technical regime's wider energy culture which has undergone an energy transition through a mix of renewable energy resources, technologies and policies.

Appendices

Appendix A: The Energy Cultures' Sampling Parameters

Household member: If a household figurehead could be identified then they could be the primary contact for energy interventions (Seebauer and Wolf, 2017). The heads of households were the target audience and were elected by each respective household.

Age: The age of the respondents was decided using the household heads' age distribution from the CSO's (2011) data which show a broad peak between ages 15 to 80. The CARICOM Secretariat's (2009) data also show that 25 to 44 is the peak urban age bracket. This set the lower age boundary to 25. The lifetime of a solar panel is roughly 20 years (Lombardo, 2014). The solar panel lifetime was subtracted from the above age of 80 to set the upper limit at 60.

This was done since it is assumed that the heads may be more likely to invest in solar if they can see some fruition of their investment within their lifetime; Trinidad's average life expectancy is between 68 and 75 years of age (WHO, 2018). The national retirement age in Trinidad is also 60 (NIBTT, 2014) so the 20-year solar panel lifetime was a well-placed consideration.

Gender: It was important to have a gender balance amongst the respondents since gender roles in the home can differ based on the householder e.g. a housewife may be more familiar with the household's energy services whilst her husband may be more aware of their costs if he pays the electricity bill.

Household size: The household size can affect the results since the number of energy users will affect the amount and types of energy services used as well as may change the

household's decision-making dynamics. The household size was left unrestricted.

Homeownership and Housing type: There can be privately-owned and rented, single-unit as well as multi-unit homes. The privately-owned, single-unit homes were the target. This was because they are the largest segment of Barbados and Trinidad's residential sectors. The rented and multi-unit households also complicate the study. For instance since the landlord does not live in the same household as the tenants consuming the energy, there can be a mismatch between the willingness to adopt solar and what energy dynamics unfold in the home it will be installed on.

Geography: The households were grouped according to the islands' administrative districts. Households from the most rural, peri-urban and most urban communities were selected.

Figure 65 (next page) shows the energy cultures investigated through the 33 structured interviews conducted in Barbados and Trinidad. Two features worth pointing out are: 1) both islands' samples were male biased (9:7 male to female ratio in Trinidad and 9:8 in Barbados), and 2) several Barbadian respondents were residents of rented and multi-unit housing though the majority resided in privately-owned, single-unit homes.

The average respondent's age in Trinidad was ≈50 with the eldest being 67 and the youngest 27. In Barbados, the average age was ≈51 with a 68 to 30 spread. Only 1 person in Barbados and 3 in Trinidad lived all their lives in their present home; the average residence length was ≈25 years in Trinidad and ≈40 in Barbados. At the other end, 1 Barbadian reported living in their present home for just 2 years whilst in Trinidad, 2 respondents had 5-year residencies.

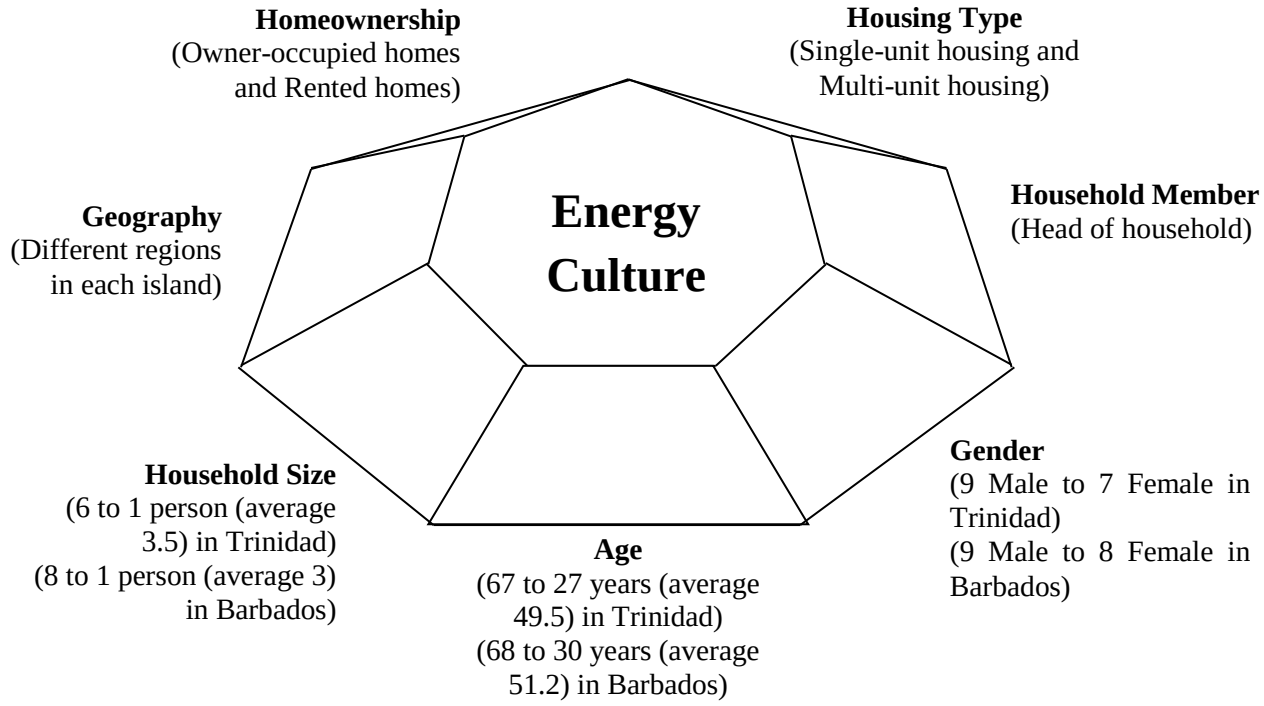


Figure 65 showing the boundaries used to frame the Barbadians and Trinidadians' energy cultures samples and the resultant information from the field

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The Barbadians' owned systems for as long as 33 years with others as short as 2 years - the average was between 12 and 14 years. 7 respondents have also lived in their current residences as long as they have owned their solar water heaters. These residence and adoption figures put the average age at the time of adoption around 38 with the eldest being 56 and the youngest, 17.

Appendix B: Barbados' Structured Interview Questions

Question-sheet

Section A: Energy Supply

1) How does your household get energy?

Section B: Energy Costs/Payments

2) In your opinion, what specific factors influence how much you pay for energy?

3) Do you think you pay too much for electricity?

4) Why do you think so?

Section C: Energy Demand

5) In your opinion, what specific factors influence how much energy is used in your home?

Section D: Considering Solar

6) Can you define what solar energy is?

7) How do you think a solar water heater works?

8) What was the best way(s) for you to receive information about solar water heating?

9) What specific information did you look for when you were thinking of getting solar water heating for your home?

10) What made you get solar water heating for your home?

Section E: Solar Water Heating

11) How did you go about getting your solar water heater?

12) How does having solar water heating affect your energy usage in the home?

13) How does having solar water heating affect the cost(s) of your energy bill(s)?

Short Questionnaire

Gender: _____ Age: _____yrs Household size: _____persons

How long have you lived in this residence? _____ years/months

Roughly how much is your household's average electricity bill? _____ USD

When do you think your household uses the most energy on an average day? (Circle all that apply)

AM
12-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8–9 9-10 10-11 11-12

PM
12 -1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-11 11-12

What specific factors made you choose those times?

Can you list the first 8 household activities that come to mind when you think of how energy is used in your home during your chosen times?

Does your household own any of the following?

OWNERSHIP (✓/X)	ITEM
	Electric water heater
	Air conditioner
	Refrigerator
	Clothes dryer
	Freezer
	Computer laptop/desktop
	DVD player
	Fan
	Iron
	Kettle
	Microwave oven
	Television
	Washing machine
	Stereo
	Incandescent lights
	Water pump

When did you get solar water heating? _____

How much did your solar water heating system cost? $_____USD

How long did your solar water heater take to install? _____

What size (tank capacity) of solar water heating system do you have? _____

How long is your solar water heater's warranty (if it had one)? _____years

What are your household's main hot water uses?

Appendix C: Semi-Structured, Key-Informant Interview Examples

Oahu: The Hawaii State Legislature topic guide

Institutional Concept Diagram

Which of the actors/relationships do you think has the most influence in the network?

Why do you think so?

What's the role of the Legislature?

Innovation and Solar Energy

What are some of the traits that an innovation needs to have in order to become mainstreamed?

What sort of distributed solar technologies has Hawaii mainstreamed?

When did solar become 'mainstreamed' in the State?

Solar Energy Industry and Policies

What are the State's main residential solar energy strategies?

Are any of these supported by legal guidance?

What factors would you say made Hawaiian residential solar such a growth-industry?

Legislation Development

Can you describe the process of making legislations?

What are some of the hurdles associated with making legislations?

How long does the law-making process usually take?

How are legislations amended?

How long do amendments take to enter into effect?

What's the review/revision cycle (if any) for legislations?

What are the legislations that govern energy in Hawaii?

Trinidad: The Sustain T&T topic guide

Institutional Concept Diagram

Which of the actors/relationships do you think has the most influence in the network?

Why do you think so?

Which actor(s) do you think should be central in promoting and implementing solar energy?

Characterizing Innovations

What are some of the traits that a technology has to display in order to be considered an innovation?

What are some of the traits that a technology has to display in order to be considered 'mainstreamed'?

Solar Energy Industry

Which solar energy technology is most suited to Trinidad?

Do you think solar fits well with the future outlook of Trinidadian energy?

Do you think there is a demand for residential solar energy in Trinidad?

What sort of support would Trinidad's private solar energy retailers need to emerge from their niche operations?

Institutions and Policies

How would you describe the government's response to sustainable energy issues?

What are some of the State's residential solar energy strategies that should be implemented?

What are some of the barriers to solar energy?

Which of these barriers are the most resistant?

How do you think they can be overcome?

Has the NGO engaged with the country's energy authorities on sustainable energy issues?

What strategies do you think would be effective in engaging society on using solar energy?

What role do NGO's such as Sustain T&T play in Trinidad's sustainable energy future?

Appendix D: Coding Matrices

The inductive coding matrix sample

CODING STRUCTURE					
THEME	**EXAMPLES OF EACH CODING CLASS**				**EXTRACTED TRANSCRIPT EXAMPLES**
	CATEGORY	**SUB-CATEGORY**	**CODE**	**SUB-CODE**	
Energy supply	Electricity	Electricity is a domestic energy input	A single electric utility company provides electricity to homes	Homes use electrical energy	Energy comes from electricity which comes from T&TEC which comes from gas.
	Liquefied petroleum gas	Liquefied petroleum gas is a domestic energy input	Liquefied petroleum gas provides heat energy for specific energy services	Homes combust liquefied petroleum gas for heat energy	There's also gas cylinders that are purchased from RAMCO.
Energy usage	Appliance usage time	Length of time appliance is plugged in			If it's not running all the time, then the bill would not go up.
	Energy demand	Appliance usage	Specific appliance usage	Refrigerator	Washing; dryer; refrigeration; lights at night.
Energy costs	Energy consumption	Energy demand	Environmental factors	Rainy season	Use of certain appliances such as the air conditioner and clothes dryer - especially drying clothes during the rainy season and using the air conditioning during the dry season.
	Retail electricity costs	Institutional electricity design	Institutional leverage	Fuel adjustment legislation	The price fluctuates with the oil price under a fuel adjustment clause.
Solar energy	Solar energy resource	The sun's light is a natural form of energy available to the earth	The sun's light provides energy	The energy source is the sun	The power from the sun.
	Solar energy technology	Technology is necessary to convert solar energy through a solar collector surface into others forms of energy that can be practically used	A solar collector surface is needed to harness solar energy	A solar water heater has a solar collector	There is a glass dish that is put out in the sun to store current and has a plug that attaches it to a converter as well as a cable which connects it to the household so that the various household appliances can be used.
Solar water heating	The system converts sunlight into thermal energy	The sun's light is the energy input	Direct and indirect sunlight can power the system	Sunlight is made up of different light wavelengths	The energy transmitted by all the various wavelengths from the sun.
	Solar water heating impacts the costs and usage of energy	Using the solar water heater electrical backup switch affects the electricity bill and consumption	Electricity bill and consumption increase	Switching to the electrical backup increases electricity bill	It keeps it lower because the switch isn't used at all since it doesn't get cold enough to require using the switch to enable electrical heating of the water when solar energy is limited.

Table 32 showing the 5 main themes/concepts in the inductive thematic content analysis of the Barbadians and Trinidadians' energy cultures comparison as well as examples of the lower-tier coding labels used

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The deductive coding matrix sample

CODING STRUCTURE					
THEORY	**THEME**	**CATEGORY**	**EXAMPLES OF EACH CODING CLASS**		**EXTRACTED TRANSCRIPT EXAMPLE TEXT**
			SUB-CATEGORY	**CODE**	
Multi-level Perspective of socio-technical energy transitions	General case study	Solar niche			The T&TEC has two PV grid–tied systems: one at the Mt. Hope office and another at the University of Trinidad and Tobago's Omera Campus.
		Energy history			1970 was a great development period for the Trinidad oil industry.
	Multi-actor network	Niche	Agency	Solar technology retailers	So they supply PV and that's basically what they do. So you could buy a PV outfit from them and put it up on your house.
		Regime	Agency	Regulated Industries Commission	The RIC is a watchdog agency.
	Transition vision	Regime	Overarching aims		So that's two fold: going to a cleaner fuel and reducing our reliance on fossil fuels.
	Niche to regime migration	Solar strategies	Grid-connected policies	Feed-in tariff	A feed-in tariff policy is supposed to be in the works by the Government.
		Innovation traits	Technology	Technically efficient	An innovation needs to operate efficiently, e.g. solar panels operate at between 15 - 20% efficiency which is more than enough for someone thinking about investing in it.
		Mainstreaming	Regime entry date	Timestamp	I would say at least 5 years before all those barriers are solved at least.
	Resistance during transitions	Niche	The Green Fund	Financing	So first challenge is trying to understand what they want to use the money for, and related to that is the capacity to align budgets with activities and outputs.
		Regime	Economics	Expensive	You need to have some kind of economic incentive to cut down the cost of the technology to make it economically feasible or favorable for the residents to put it in.
	PRESET LABELS		**EMERGENT LABELS**		

Table 33 showing the 5 main themes/concepts in the deductive thematic content analysis of the energy officials' transcripts for Oahu and Trinidad's comparison as well as examples of the lower-tier coding labels used

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Appendix E: Oahu and Trinidad's Energy Orientations

Petroleum imports and cost recovery in Oahu

Hawaii's fuel importation costs are passed on to ratepayers (see Figure 66 on the next page). The oil prices' impacts on the retail tariffs are enabled through an Energy Cost Adjustment Clause (ECAC) which allows the risks associated with fluctuant oil prices to be passed directly onto consumers (HELCO, 2001; Pintz and Morita, 2017).

The ECAC increases or decreases based on the oil price fluctuations since the last time the fixed Base Energy Charge was set (HELCO, 2001) and *Informants OH03* and *OH09* were of the opinion that following a change in oil price there is usually a 2 to 3-month lag before these costs are reflected in the retail rates.

Informant OH11 believed that the retail electricity rates are determined by the fuel costs and electricity-provisioning costs. *Informant OH09* thought that though the process for determining the retail rate is quite methodological and formulaic, the high bills that are prevalent in Hawaii are due to the fuel costs. The HELCO (2001) also states that the fuel costs transferred to customers are the actual costs and not 'hiked-up' prices.

The Research and Economic Analysis Division (2014), and Morita (2014) give more detail by stating that 60 to 70% of Hawaii's electricity costs are due to the fuel and purchased power costs, and their related taxes; the increase in Hawaii's electricity tariffs seen in Figure 67 (page 403) was predominantly due to these fuel and purchased power costs (Research and Economic Analysis Division, 2014). Morita (2014) also presents Figure 68 (page 403) which illustrates the cost recovery per kilowatt-hour on an average bill, and again, the fuel and purchased power costs are the most significant and account for nearly 65% of the rate.

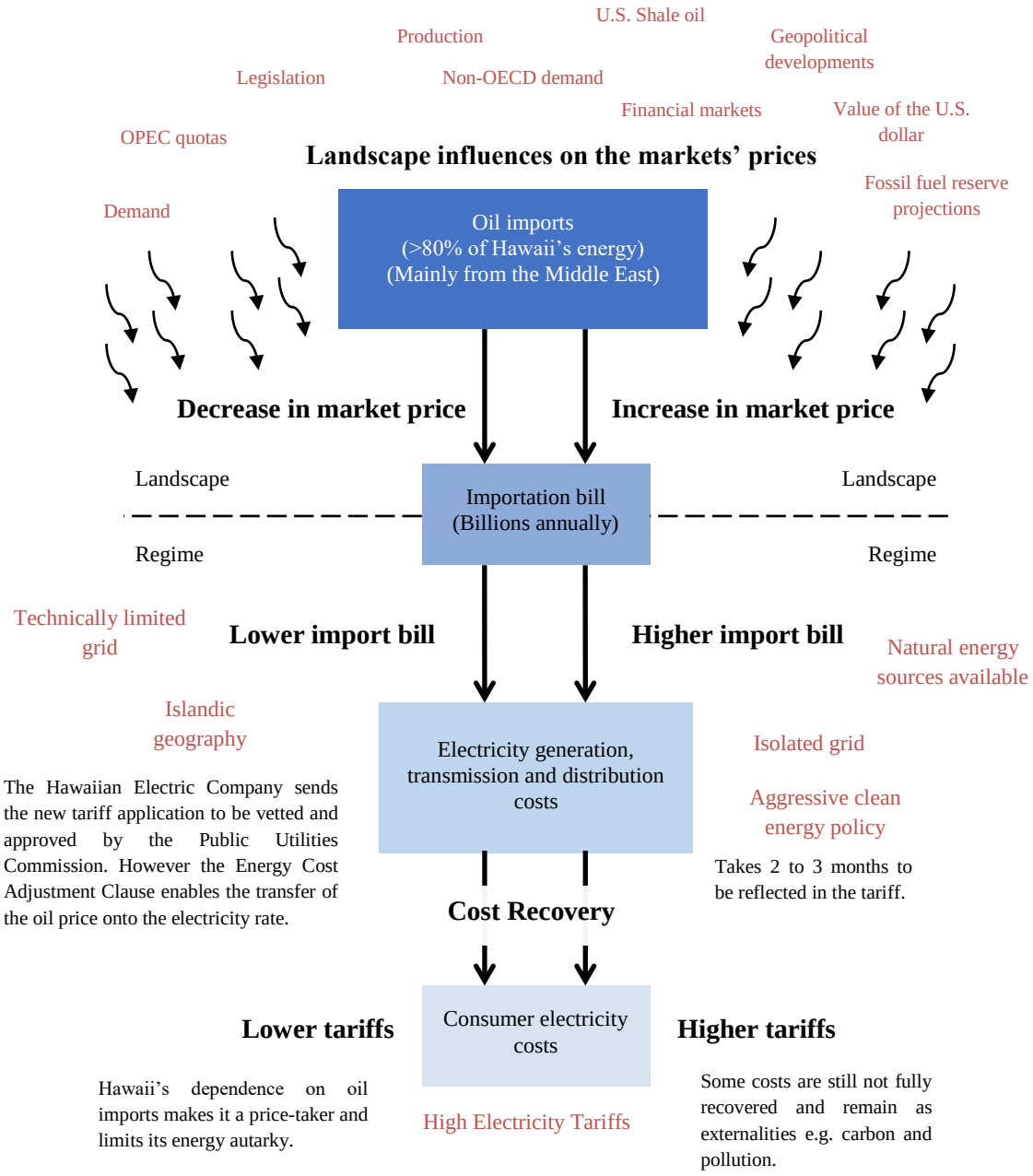


Figure 66 showing the import-oriented nature of Oahu's energy system

Generated by the Author using Microsoft Word

The image showing the State of Hawaii's per kilowatt-hour elecrcity costs from 1990 to 2012 originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Research and Economic Analysis Division. 2014. State of Hawaii Electricity Generation and Consumption in 2013 and Recent Trends. Hawaii Economic Issues. Department of Business, Economic Development and Tourism, State of Hawaii. Website: http://files.hawaii.gov/dbedt/economic/data_reports/reports-studies/ElectricityTrendsReport2014.pdf (accessed 30th August, 2015)

Figure 67 showing the per kilowatt-hour electricity costs in United States cents in Hawaii from 1990 to 2012

Extracted from the Research and Economic Analysis Division (2014; 43)

The image showing the Oahu's per kilowatt-hour elecrcity costs breakdown for a typical bill originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Morita, H. M. 2014. State Examples of Innovation & Stakeholder Engagement. Hawaii Public Utilities Commission. Utility business models that align with State Clean Energy Goals. National Governors Association Workshop, Washington D.C., United State of America, 23rd September, 2014. Website: http://nga.org/files/live/sites/NGA/files/pdf/2014/1409UtilityBusinessModelsStateCleanEnergyControl_Morita.pdf (accessed 1st August, 2015)

Figure 68 showing the per kilowatt-hour breakdown of costs recovered by a typical customer's bill in Oahu

Generated by the Author but adapted from Morita (2014; 10) using Microsoft Word

Fossil Fuel subsidization in Trinidad

Informant TD13 believed that the current retail rates in Trinidad are determined by the power generation costs; cost of the natural gas feedstock; the prices stipulated in the power purchase agreements (PPAs) between the utility and independent power producers; foreign exchange rates; replacement costs; grid network costs; and rate of return for the invested parties.

As in Oahu, the fuel costs are important because they are passed through directly to the consumer in Trinidad (RIC, 2006). But *Informant TD02* was of the opinion that a fuel subsidy plays out at the power generation level through natural gas' fuel costs. The utility company, the Trinidad and Tobago Electricity Commission, procures the natural gas for the independent power producers at a preferential low price set by the Government (McGuire et al., 2007) - and nearly USD $20 million of the $300 million-dollar subsidy benefits the electricity sector (Iwaro and Mwasha, 2010). Therefore the most important feature in Figure 69 (next page) is the subsidy.

Electricity is amongst the most commonly subsidized household energy resources (Dzioubinski and Chipman, 1999). Governments tend to subsidize electricity along more than one point in its value chain (Kitson et al. 2011) so many subsidies are hidden in economic and public infrastructures (de Moor, 2001; Iwaro and Mwasha, 2010); subsidies should instead be transparent (Borlick and Wood, 2014). de Moor (2001) also suggests that recipients of hidden subsidies prefer it because the subsidies are often overlooked during fiscal reformations.

de Moor (2001), Iwaro and Mwasha (2010), and Kitson et al. (2011) describe a subsidy as an intervention that keeps consumer-prices below the market's, producer-prices above the market's, or reduces the costs incurred by either party. Kitson et al. (2011) add that there is

also a distinction between consumption and production subsidies.

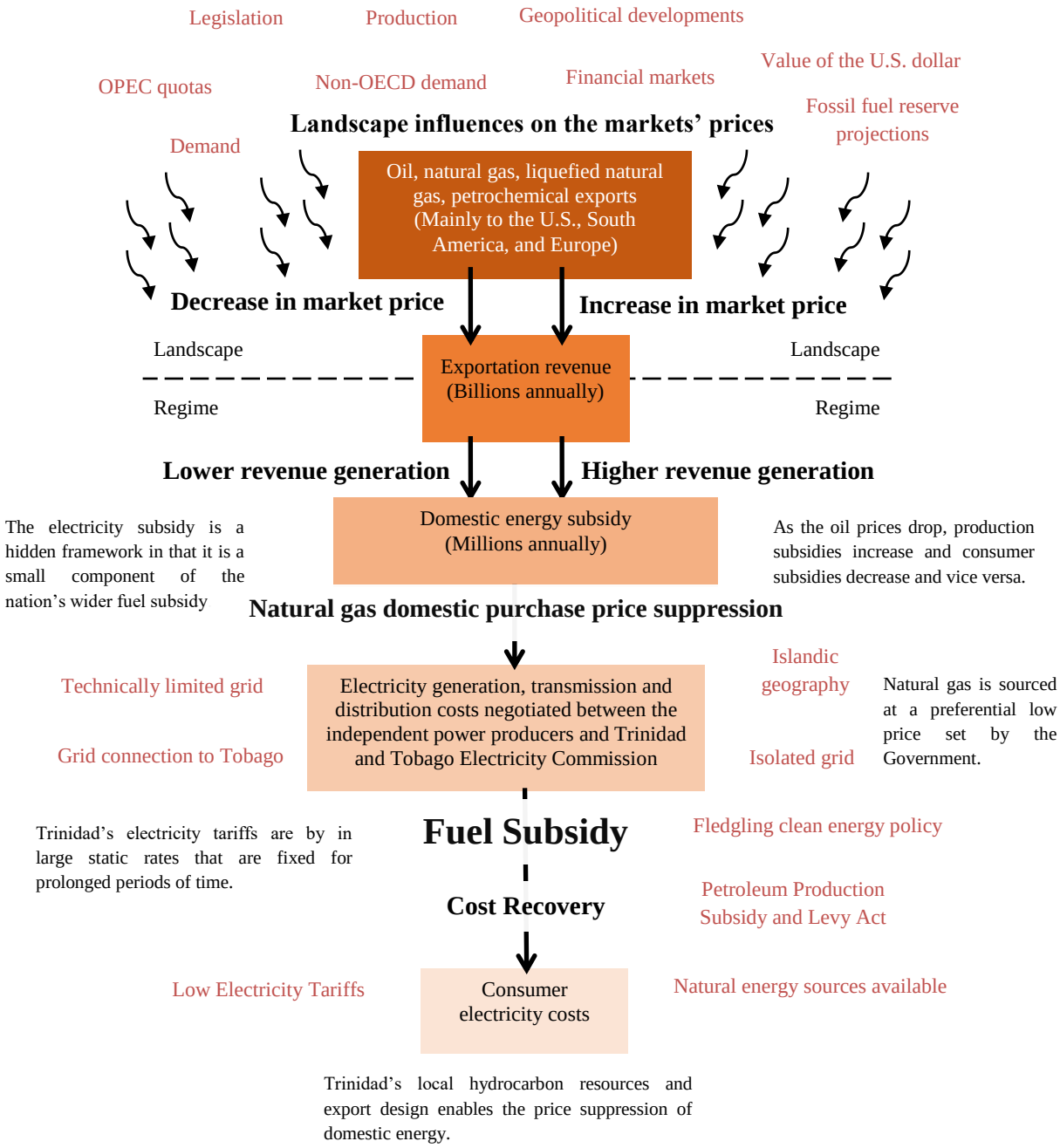


Figure 69 showing the export-oriented nature of Trinidad's energy system

Generated by the Author using Microsoft Word

Borlick and Wood (2014) explain that the purpose of a subsidy is to incentivize the system to

adopt a favourable public policy. However the use of 'desirable' offers no insight as to its desirability for whom. Trinidad's energy subsidy was instituted to stimulate economic growth but since policies, societies and economies evolve over time, what was desirable then may not necessarily be desirable now.

Based on Badcock and Lenzen's (2010) work, Trinidad benefits from financial and externality-oriented subsidies - these create a series of transfers through market mechanisms (de Moor, 2001). Griegg (2011) outlines that the subsidy's financing comes from the Government and energy companies operating in Trinidad. The latter contributes through a levy imposed under the Petroleum Production Levy and Subsidy (PPLS) Act.

It stipulates that oil companies producing more than 3,500 barrels of oil per day will contribute 4% of their gross incomes whilst the Government will stand the remaining costs should the total subsidy amount to more than these corporations' contributions (McGuire et al., 2007; Iwaro and Mwasha, 2010; Griegg, 2011; Li and Canetti, 2016). The Government's contributions usually come directly from its Consolidated Fund and in recent time has accounted for 71% of the subsidy bill (Li and Canetti, 2016).

The subsidy skews end-user prices compared to those in a competitive market (Iwaro and Mwasha, 2010) and incentivizes consumers to continue their 'business-as-usual' attitudes (Myers, 2000). de Moor (2001) further states that by keeping prices below that of the international markets' governments incentivize over-consumption, and by keeping production prices at the minimum above international prices, encourage resource depletion.

Additionally public subsidies are causative agents of unsustainable development; are economically inefficient, expensive and inequitable; and increase the climate impact of fossil

fuel consumption (de Moor, 2001; Iwaro and Mwasha, 2010; Li and Canetti, 2016).

de Moor (2001) states that energy production is primarily subsidized in industrialized countries whilst developing countries focus on consumer subsidies. de Moor further outlines that as the oil price drops, producer subsidies increase whilst consumer subsidies decrease and vice versa. Iwaro and Mwasha (2010), and Greigg (2011) suggest that Trinidad's subsidies are both consumer and producer-oriented and Table 34 highlights them.

The table showing the energy subsidy elments in Trinidad and Tobago originally presented here cannot be made freely available via ORA because of copyright. The information was respectively sourced from:

Iwaro, J. and A. Mwasha. 2010. Towards energy sustainability in the world: the implications of energy subsidy for developing countries. International Journal of Energy and the Environment, 1(2): 705 – 714. Website: http://www.ijee.ieefoundation.org/vol1/issue4/IJEE_13_v1n4.pdf (accessed 27th October, 2014)

Table 34 showing the nature, category and effect of governmental energy subsidies

Generated by the Author but adapted from Iwaro and Mwasha (2010; 709) using Microsoft Word

Appendix F: The Barbadians and Trinidadians' Perceived Peak Energy Demand

When do households perceive they use the most energy?

Electricity demand is a complex system of factors and each factor could itself be thought of as a system of like complexity (Buys et al., 2015). Engle et al. (1992), Hong et al. (2013), and Buys et al. (2015) list appliance usage, household demographics, culture, weather and climate, and retail electricity rates as examples.

Demand varies between and within any given day or season, and is made up of a baseload i.e. a demand level that is always present and peak demand i.e. an increased demand that results from higher consumption based on society's collective energy activities (Rallapalli and Ghosh, 2012; Dahlke and McFarlane, 2014/2015).

Peak demand is a sign of synchronisation within society (Torriti, 2017). It is made up of two primary factors: the amount of energy and the timing of when this energy is used (Yarbrough et al., 2015). Chapter 5 explored the factors that affect the first and this Appendix focuses on the second because time is a key element of energy services (Sorrell and Dimitropoulos, 2008).

As outlined above, given that time is important to energy consumption, the respondents in Barbados and Trinidad were asked: '*When do you think your household uses the most energy on an average day?*' They were provided with 24 hour-long timeslots to select all that applied. Figure 70 (next page) shows the results as the number of respondents who selected each hour-long timeslot.

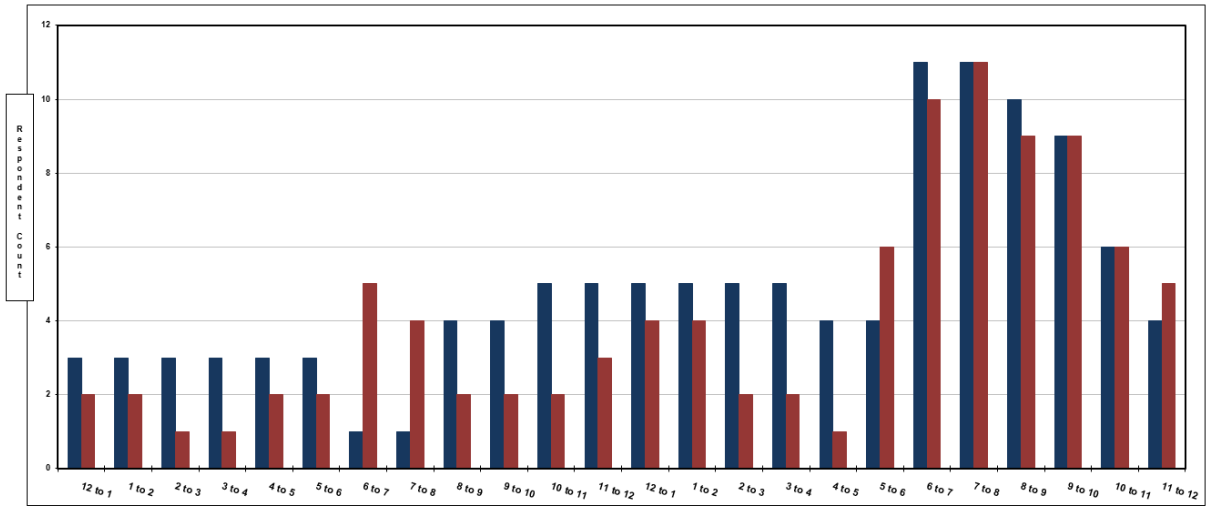


Figure 70 showing the perceived peak energy demand times of Trinidad (blue bars) and Barbados' (red bars) energy cultures

Generated by the Author using Microsoft Excel

The graph shows that there were variations in when respondents thought the most energy was being used in their respective homes. This variation was due to lifestyle diversity e.g. respondents worked from home, commuted to and from work, were retired, and/or were students. The family makeup also played a role since respondents mentioned the impact of their family members' goings and comings to and from the home or their particular energy uses as factors that affected their time selections. The variation was also due to the respondents being able to answer the question using what they personally believed to be a 'typical' day in their household i.e. weekday versus weekend 'typical' days.

Table 35 (next page) shows the explicit practices that drive the time selections in Figure 70. A caveat is that many respondents simply stated that their selections were based on generic energy uses that were not specific e.g. the need for cooling at the hottest times of day, and these are not represented in Table 35.

TRINIDAD		BARBADOS	
FREQUENCY	**PRACTICE**	**FREQUENCY**	**PRACTICE**
8	Lighting	2	Refrigerator use
7	Television use	2	Deep Freezer use
5	Laundry / Washing	2	Television use
4	Air conditioning	1	Computer use
3	Fan use	1	Radio
3	Cooking	1	Washing
3	Ironing	1	Baking
2	Clothes drying	1	Ironing
2	Showering	1	Gas stove use
2	Electric water heater use	1	Commercial sewing machine use
2	Computer / Laptop use	1	Cooking
2	Radio use	1	Lighting
1	Cleaning	1	Fan use
1	Refrigerator use		
1	Water pump use		

Table 35 showing the explicit practices driving the Barbadian and Trinidadian respondents' perceived peak energy demand time selections from Figure 70

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
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The data on the respondents' perceived peak energy demand led to four takeaways.

Firstly, there was a cross-cultural acknowledgement that energy is constantly being used in the home by various appliances whether they technically use power all day e.g. refrigerators and deep freezers, or people think they use these appliances enough to warrant them believing so e.g. televisions, air conditioners and computers - hence another reason for the erratic data during the day in Figure 70 (previous page).

Second is that there are energy activities happening in the home throughout the day. They are a mix of active and passive practices. Examples of active practices are cooking, washing and showering. The passive practices largely referred to the latent ones that can be deduced from the continuous use of material culture - though latent practices can also be active. Both show

that the design and use of domestic appliances influence the sequence and duration of activities, and the timing of demand (DEMAND Centre, 2016). But the fundamental difference between active and passive practices is the human presence in the home to perform the practices.

An example of a latent, passive practice is refrigerator usage. Simply leaving it plugged in means that its services are used independently of the household being present in the home; they still use and benefit from it storing and chilling their produce/goods. A latent, active practice would again draw on material culture as a proxy and television usage is an example where it is switched on to view aired programmes. A manifest, active practice example is coming home after the day's work to cook dinner. Many different appliances e.g. electric/gas stove, blender, and/or microwave oven would be used to prepare the meal so cooking requires direct and sustained use of material culture to perform the practice.

The third point is the most visible in Figure 70 (page 409). There was consensus relative to when the respondents' perceived peak energy times occur. The broad peaks recorded in Trinidad occurred between 6:00PM to 11:00PM. In Barbados it occurred between 5:00PM to 11:00PM. The specific peak times observed were selected by 11 respondents each; Trinidad's was 6:00PM to 8:00PM and Barbados' was 7:00PM and 8:00PM. These can also be compared to the technical peak demand times that occur roughly between 6:00PM to 8:00PM in Trinidad (Marzolf et al., 2015), and roughly between 9:00AM to 4:00PM and again from 6:00PM to 8:00PM in Barbados (Hohmeyer, 2015; Rogers, 2016).

The respondents' sense of time is not tied to monitoring timepieces but rather to their immersion in routines and habits. Habits and routines are observable performances and the

patterning of stable practices which are recurrent, non-reflexive and culturally-shared (Gram-Hassen, 2008; Southerton, 2012). Routines sustain everyday life as well as its wider socio-cultural and technological structures which means that routines have an inertia (Gram-Hassen, 2008).

Habits are defined by their frequency of repetition and are somewhat automatic because past and future actions are linked and suggest that people maintain traditions (Aarts and Dijksterhuis, 2000; 53). Present practices are therefore predisposed to continue in the future (Wilhite, 2013; Wallenborn and Wilhite, 2014), and they may be likely repeated at the same times on any given day as well (Torriti, 2017).

The perceived peak demand times show that the material, infrastructural and institutional environments can make practices recurrent and non-reflexive (Gram-Hassen, 2008; Southerton, 2012); they support the materialization of energy through the way in which individuals use and access matter as routine undertakings (Sheller, 2014), and make energy a daily part of life (Muhammad-Sukki et al., 2014).

The fourth and final point is that the perceived peak demand timings are largely based on daily lifestyles. But there was sensitivity to weekly and even annual timeframes in both islands. These timeframes were a result of external institutions' e.g. schools and workplaces influence on people's presences in their homes. This shows that the demand rhythm is not solely an in-house product (DEMAND Centre, 2016). These external institutions are also examples of external influences in the Energy Cultures Framework and the landscape in the Multi-Level Perspective.

Detailing the drivers of perceived peak energy demand

There are everyday practices that are grouped together based on their daily importance in people's lives and these practices are created, sustained and transformed through everyday life (Strengers, 2010). To put the last subsection's data into more explicit context and to link with the energy usage domains' lead question from Chapter 5, the respondents were asked: '*Can you list the first 8 household activities that come to mind when you think of how energy is used in your home during your chosen times?*'; 'chosen times' referred to their personal peak demand time selections in Figure 70 (page 409).

There were 46 different explicit items recorded in Barbados and 36 in Trinidad. Of the items listed ≈88% were appliances in Trinidad and ≈70% in Barbados. Refrigerators were the most salient in both islands. The remaining items were a mix of practices such as cooking and showering. This means that the respondents' material culture (and by extension the practices associated) were the most salient features driving the perceived peak energy demand.

Figure 71's information (next page) for an average home's consumption breakdown (in Trinidad) is also included in Table 36 (page 415) to show how these appliances' saliences (via free-listing) compare to their technical consumption. The Table shows that the most consumptive material culture are not necessarily the most socio-culturally salient e.g. electric water heaters. This is because householders have skewed perceptions of their energy demands and underestimate the energy consumption from heating water (Sovacool, 2009; Lockton et al., 2013).

If hot water is not culturally visible in Trinidad as inferred by the salience of electric water heating in Table 36, then technologically transitioning to solar water heating would not be in

households' direct line of sight regardless of the potential to reduce their electricity bills and consumption. Therefore increasing the visibility of socially invisible services is paramount for sustainable end-user behaviour (Pink, 2011; Anda and Temmen, 2014).

The image showing the electricity consumption breakdown for a home with and without air-conditioning originally presented here cannot be made freely available via ORA because of copyright. The image and information were respectively sourced from:

Renewable Energy Committee. 2011. Framework for Development of a Renewable Energy Policy for Trinidad and Tobago: A Report of the Renewable Energy Committee. Ministry of Energy and Energy Affairs. Website: http://www.energy.gov.tt/wp-content/uploads/2014/01/Framework-for-the-development-of-a-renewable-energy-policy-for-TT-January-2011.pdf (accessed 18th October, 2013)

Figure 71 showing the electricity consumption breakdown in an average home with air conditioning (a), and without air conditioning (b) in Trinidad

Extracted from the Renewable Energy Committee (2011; 41)

PROPORTIONAL BI-MONTHLY ENERGY USAGE (%)	APPLIANCE	SALIENCE RANK OUT OF 20
45-58	Electric Water Heater	7
22	Air Conditioner	4
11-13	Refrigerator	1
8-10	Clothes Dryer	12
6-8	Freezer	Was not listed
5-6	Computer Laptop / Desktop	8
	DVD Player	19
	Fan	13
	(Hot) Iron	10
	(Electric) Kettle	13
	Microwave Oven	5
	Television	2
	Washing Machine	6
	Stereo	19
2-3	Incandescent Lights	3
1-2	Water Pump	9

Table 36 showing the proportional consumption and saliences of 'typical' household appliances in Trinidad based on Figure 71's information and the interviews carried out with the respondents in Trinidad

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Relating cultural salience to appliance-ownership and technological transitions

The appliance list provided in Figure 71 (previous page) was used to ask respondents if they owned each one. This was done to check whether or not respondents were listing appliances that they owned. The only notable observation was the lack of electric water heater ownership in Barbados. In Trinidad refrigerators, computer laptop/desktops, fans, (hot) irons, televisions and washing machines were owned by all 16 respondents. In Barbados, refrigerators, DVD players, (hot) irons, televisions and washing machines were owned by all 17.

When put into context of their energy cultures, it shows that the appliances that make up their material culture are those that are owned versus respondents having knowledge that these appliances can impact their energy usage and/or costs even though they are not owned.

Other data that arose organically indicated that there were technological transitions in the household. Statements converged on a lighting transition from incandescent lighting to either a mix of fluorescent and incandescent (reported by 6 Trinidadians and 4 Barbadians); a mix of light emitting diode (LED) and fluorescent (3 Barbadians); all fluorescent (8 Trinidadians and 3 Barbadians); or all LED fixtures (1 Barbadian). This observation showed that homes experience technological transitions which provide the same service (in this case lighting) but through different technologies (incandescent versus LED or fluorescent lighting).

Appendix G: The Respondents' Perceptions of Household Electricity Costs

The 17 Barbadian and 16 Trinidadian respondents were asked: '*Roughly how much is your household's average electricity bill?*' and Table 37 shows their responses. This was an interesting question to ask because having some cognitive quantities to look at whilst exploring the factors that affect households' energy usage and their costs helps better frame the accounts given in Chapter 5. It was also asked in this way because people can recall averages better than the actual quote or kilowatt-hour rate because the latter are unfamiliar metrics.

TRINIDAD RESPONDENT IDENTITY	BI-MONTHLY ELECTRICITY BILL (USD)	BARBADOS RESPONDENT IDENTITY	MONTHLY ELECTRICITY BILL (USD)
Respondent 01FTTD	150	Respondent 01MBDS	100
Respondent 02MTTD	Doesn't know	Respondent 02MBDS	140
Respondent 03FTTD	50 to 67	Respondent 03MBDS	80
Respondent 04FTTD	42	Respondent 04FBDS	60
Respondent 05FTTD	43 to 47	Respondent 05MBDS	65
Respondent 06MTTD	67 to 83	Respondent 06MBDS	100
Respondent 07MTTD	42	Respondent 07FBDS	65 to 75
Respondent 08FTTD	50 to 83	Respondent 08FBDS	40 to 45
Respondent 09MTTD	<42	Respondent 09MBDS	175
Respondent 10MTTD	75 to 83	Respondent 10FBDS	85
Respondent 11MTTD	67	Respondent 11FBDS	100
Respondent 12FTTD	93	Respondent 12MBDS	112.5
Respondent 13MTTD	73	Respondent 13MBDS	100
Respondent 14MTTD	183	Respondent 14MBDS	65
Respondent 15MTTD	42	Respondent 15FBDS	25
Respondent 16FTTD	150	Respondent 16FBDS	50
		Respondent 17FBDS	25 to 30

Table 37 showing the perceived electricity bills of the 17 Barbadian and 16 Trinidadian respondents

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The figures in Table 37 are cognitive representations of the householders' electricity bills and are comparable despite each island's per kilowatt-hour rate being island-specific. To give the

Table's figures meaning, the respondents were also asked: '*Do you think you pay too much for electricity?*' So doing gives some qualitative sense of what these costs mean to people.

The responses largely fit into answers that could be described as affordable and reasonable cost perceptions (i.e. the costs of electricity are not too high, are reasonable, and are more affordable than before); high cost perceptions (i.e. the costs of electricity are too high and are too high sometimes); or being unsure if the costs are too high.

The first observation is that in Trinidad most of the responses revolved around the fact that the costs of electricity are either too high or not. In Barbados, responses showed a more recognizable distribution across the perception coding categories. This is likely because Trinidad's retail tariffs are non-fluctuant (unlike Barbados') so there is an established cognitive baseline relative to respondents' 'average' bills.

The two variables are household energy consumption and the retail rate. So in Trinidad constant consumption levels over subsequent months would produce a similar bill. In Barbados however, the fluctuant global oil price and retail rate means that even though household consumption may remain constant, it does not mean that the bill will be.

The second observation is at the individual level. Sometimes a person's response acknowledged more than one reason driving their perception(s). For example *Respondent 16FTTD* who thought that their bill was too high believed so because they compared their electricity bills to their other utility bills but also because of the type of oil that they believed was used for generating power (and oil is not used for power generation (see Chapter 7)). Another example was *Respondent 15FBDS* who was of the opinion that their bill was more reasonable than before because the oil and gas prices plummeted but also because the number

of people using energy in their home decreased.

The third observation was that the drivers of perceptions can be interpreted differently by individuals such that there are opposing views emerging from the same reason(s). In Trinidad for example the perceived geographic billing designations illustrated this. Respondents thought that electricity billing was done based on location (not metering) and urban households would generally have a higher bill than rural homes; *Respondent 09MTTD* from the sample's rural respondents viewed their bill as not too high whilst *Respondent 14MTTD* from the urban respondents thought it was too high (see Table 37 on page 417 for their cognitive bills).

In Barbados the number of persons in the household was also recorded as an 'on-the-fence' observation; *Respondent 08FBDS* thought that their bill is too high regardless of the number of energy users in the home versus *Respondent 15FBDS* who was of the opinion that less energy users equates to a lower bill (see Table 37).

A fourth observation was that unlike the other energy cultures dimensions investigated, there was no overwhelming consensus during the analysis. This is likely the result of the highly personal nature of perceptions playing out in the interpretation of electricity costs by householders.

In Trinidad, singular responses predominantly drove the perceptions of electricity costs as being high except for 2 respondents who believed the costs are high due to the generic cost of living e.g.:

"Relative to the cost of living, the rate per unit of electricity i.e. kilowatt-hour [kWh] is too high." (*Respondent 10MTTD*)

2 others also viewed the country's perceived wealth and its indigenous natural gas resources as reasons that electricity should be a free commodity. So they believed that the current costs are too high e.g.:

"We have natural gas; that's (i.e. electricity) supposed to be free." (*Respondent 11MTTD*)

Whilst there same could be said for Barbados in terms of the singularity of responses, there was some rudimentary convergence of the fact that:

"there is a lack of competition" (*Respondent 02MBDS*)

in the electricity sector where the:

"Barbados Light and Power is the only utility company - there is no other that would do it [i.e. provide electricity] so [there is] no competition." (*Respondent 03F*BDS)

Respondent 02MBDS also went on to make a telecommunications market comparison where there was only one company operating on the island but with the entry of several others, they believed that prices became more competitive and consequently cheaper for consumers.

Also coupled to the above was the notion that the fuel costs are rather high e.g.

"The type of oil is also costly." (*Respondent 06MBDS*)
"Because the bill went up due to an increase in the fuel rate." (*Respondent 12MBDS*)

This is set in a wider appreciation for the relationship with international oil markets where one thought that their bill:

"depends on the price of oil since the market price fluctuates." (*Respondent 09MBDS*)

Another even thought that:

"the oil prices have been falling all over the world but the rate in Barbados is increasing." (*Respondent 14MBDS*)

Affordable/reasonable price drivers in Trinidad revolved around the belief that the respondents' energy costs were commensurate with their usage:

"because it [i.e. electricity] is used all the time." (*Respondent 01FTTD*)

The costs of electricity were also perceived as affordable/reasonable by several respondents because in comparison to their peers' bills, theirs were cheaper. In Barbados, the only element worth mentioning was once again the oil market where one believed that there was a fall in oil and gas prices.

The main takeaway from these series of cognitive prices and cost perceptions is that the Trinidadians' perceptions of their electricity costs are seemingly more polarized than the Barbadians' because of the non-fluctuant retail rates. The Barbadians' perceptions of electricity costs are led by an appreciation for the impact of global oil prices whether it is perceived as too high or affordable/reasonable. In Trinidad, there is however a more generic connection to its cost as part of the costs of living and whether the costs of energy are commensurate with the amount of electricity used.

Appendix H: The Energy Cultures' Sub-code Tables

These tables relate to Chapter 5's energy cultures comparison. The red rows affect energy usage and costs, the yellow affects either, and the grey affects either but has a frequency of 1.

SUB-CODE		FREQUENCY		
		USAGE	COSTS	TOTAL
1	Air conditioner	10	5	15
2	Length of time appliance is used	6	4	10
3	Refrigerator	4	3	7
4	Lights	3	3	6
5	Types of appliances used	2	4	6
6	Washing machine	3	3	6
7	Water pump	4	1	5
8	Number of appliances used	3	1	4
9	Electric water heater	2	1	3
10	Computer	1	1	2
11	Microwave	1	1	2
12	Heating or cooling appliances	1	1	2
13	Amount of energy used	0	5	5
14	Clothes dryer	0	4	4
15	Number of energy users	0	4	4
16	Retail tariff rate	0	2	2
17	Appliance isn't owned but they are aware it can affect energy demand	3	0	3
18	Different energy user lifestyles	2	0	2
19	Freezer	2	0	2
20	Hot iron	2	0	2
21	Television	2		2
22	Fuel costs	0	1	1
23	Gas stove	0	1	1
24	Utility's geographic billing method	0	1	1
25	Institutional cost recoveries	0	1	1
26	Institutional policies	0	1	1
27	Other customer charges	0	1	1

Table 38 showing items 1 to 27 of the 41 different sub-codes that emerged in the Trinidadians' energy usage and costs domains

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
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SUB-CODE		FREQUENCY		
		USAGE	COSTS	TOTAL
28	Power tools	0	1	1
29	Rainy season	0	1	1
30	Steel cutter	0	1	1
31	Wasting energy	0	1	1
32	Dry season	0	1	1
33	Arc welding plant	1	0	1
34	Costs of electricity	1	0	1
35	Electric stove	1	0	1
36	Energy efficiency	1	0	1
37	Energy service demand underestimation by household	1	0	1
38	Tropical heat	1	0	1
39	Being present in the home	1	0	1
40	Utility cost recovery	1	0	1
41	Utility reliability	1	0	1

Table 38 continued showing items 28 to 41 of the 41 different sub-codes that emerged in the Trinidadians' energy usage and costs domains

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
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SUB-CODE		FREQUENCY		
		USAGE	COSTS	TOTAL
1	Refrigerator	7	6	13
2	Length of time appliance is used	7	4	11
3	Television	6	4	10
4	Washing machine	1	7	8
5	Number of appliances used	3	5	8
6	Lights	4	4	8
7	Types of appliances used	3	2	5
8	Clothes dryer	2	2	4
9	Type of energy user	3	1	4
10	Computer	1	2	3

Table 39 showing items 1 to 10 of the 50 different sub-codes that emerged in the Barbadians' energy usage and costs domains

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
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SUB-CODE		FREQUENCY		
		USAGE	COSTS	TOTAL
11	Fan	1	2	3
12	Air conditioner	1	1	2
13	Appliances always being plugged in	1	1	2
14	Radio	1	1	2
15	Tropical heat	3	0	3
16	Wasteful energy practices	3	0	3
17	Lifestyle lock-ins	2	0	2
18	Different energy user lifestyles	0	2	2
19	Freezer	0	2	2
20	Hot iron	0	2	2
21	International oil market	0	2	2
22	Climate change	1	0	1
23	Cable box	1	0	1
24	Compressor	1	0	1
25	Energy conscious appliance installation location	1	0	1
26	Energy consumption misconception	1	0	1
27	Water availability	1	0	1
28	Faulty appliance wastes energy	1	0	1
29	Being present in the home	1	0	1
30	Lack of education	1	0	1
31	Wasting energy is costly	1	0	1
32	Water pump	1	0	1
33	Way in which appliance is used	1	0	1
34	Energy-efficient appliances	0	1	1
35	Amount of energy used	0	1	1
36	Appliance efficiency	0	1	1
37	Electric utility injustice	0	1	1
38	Energy-saving appliances	0	1	1
39	Cloud cover	0	1	1
40	Fixed costs	0	1	1
41	Fuel adjustment legislation	0	1	1
42	Fuel cost	0	1	1
43	Gas stove	0	1	1

Table 39 continued showing items 11 to 43 of the 50 different sub-codes that emerged in the Barbadians' energy usage and costs domains

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.

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SUB-CODE		FREQUENCY		
		USAGE	COSTS	TOTAL
44	Government taxes	0	1	1
45	Phones	0	1	1
46	Solar water heater electrical backup	0	1	1
47	Switching off appliances	0	1	1
48	Tablets	0	1	1
49	Unplugging appliances	0	1	1

Table 39 continued showing items 44 to 49 of the 50 different sub-codes that emerged in the Barbadians' energy usage and costs domains

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code

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Appendix I: The Respondents' Water Heating Material Culture and Hot Water Practices

A look at the water heating methods used by Trinidad's respondents

Appendix F shows that electric water heaters, microwave ovens, and electric kettles are all appliances that are owned and could be used to heat water. But the Trinidadians were specifically asked: '*How do you heat your water?*' This was so done so as to more explicitly find out what were the water heating material culture used by the Trinidadians since they did not own solar water heating.

FREQUENCY	WATER HEATING MATERIAL CULTURE	POWERED-BY
5	Standing-tank electric water heater	Electricity
3	Showerhead electric water heater	
1	Wall-mounted electric water heater	
2	Electric kettle	
1	Microwave oven	
1	Electric stove	
3	Gas stove	Liquefied petroleum gas
1	Solar water heater	Solar energy

Table 40 showing the Trinidadians' water heating material culture

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code for the water heating material culture.
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12 Trinidadians reported using electric water heating and Table 40 shows the specifics. Technologies included standing-tank, showerhead and wall-mounted water heaters as well as kettles, microwaves and stoves. 3 respondents also indicated that they combusted liquefied petroleum gas (LPG) through their stove's burners to heat water - even the respondent in Table 40 who reported using an electric stove stated that it used LPG as well. A respondent owned a solar water heater and this was an unexpected observation during the interview.

This subsection showed that a transition towards solar water heating in Trinidad will involve the substitution of electricity-based and LPG-fired water heating for solar energy. The emergence of these two resources also confirms two key findings from Chapter 5: 1) LPG and electricity are household energy inputs, and as noted with the Barbadian respondents', 2) it is likely that using solar water heating will affect the use and costs of using electricity and LPG.

A look at how hot water is used by the respondents in Barbados and Trinidad

The last subsection's question focused on the material culture used in heating water. But this subsection's targets practices to help build a better understanding of what the hot water is used for (if at all). This was useful because material culture like an electric kettle can be used to heat water for making tea or even bathing where one mixes the hot water in a bucket with water at room temperature for instance.

Respondents were asked: '*What do you use hot water for?*' There was a limited suite of hot water practices found in both islands. Table 41 on the next page shows the practices recorded in Barbados and Trinidad. Showering/bathing and cooking were the only cross-cultural practices and showering/bathing is the most salient. This subsection's results confirm the findings in Appendix F which show that hot water use is part of the respondents' everyday routines. But considering its relatively low cultural visibility brought up in Appendix F there are 3 reasons worth outlining here.

FREQUENCY	TRINIDAD HOT WATER PRACTICE	BARBADOS HOT WATER PRACTICE	FREQUENCY
1	All pipes have hot water	All pipes have hot water	1
11	Showering / bathing	Showering / bathing	7
4	Cooking	Cleaning	2
4	Preparing tea	Washing laundry	3
1	Washing dishes	Cooking	1
		Washing hair	1

Table 41 showing Barbadians and Trinidadians' explicit hot water practices

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code for the water heating practice.
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Householders think that bigger appliances often consume more energy (Steg et al., 2015). So the first reason is that some of the water heating appliances mentioned in the last subsection are rather small e.g. showerhead electric water heaters. This is also coupled by the fact that the larger components of some appliances may be installed in a location that is not visible on a daily basis e.g. the storage tank for the standing-tank electric water heater.

A second reason is that electricity is not exclusively used for heating water nor is combusting liquefied petroleum gas (LPG). The material culture that use electricity are numerous and heating water is just one energy service amongst the others. So it is easy for water heating to be lost energy-wise. Relative to LPG use, heating water is often not the main activity e.g. combusting LPG for cooking and heating water is just part of the meal preparation.

The third reason is that there may be no actual or perceived hot water usage. 2 Trinidadian respondents said that they did not use hot water and their hot water use was minimal with statements like:

"What I have is what I need." (*Respondent 12FTTD*)

"There's no real hot water use." (*Respondent 14MTTD*)

Respondent 12FTTD's wider response implied that hot water is a luxury and not a necessity. In *Respondent 14MTTD*'s case, they used to own an electric water heater but with today's perceived high temperatures, they thought that taking cold showers is a comfort hence why they believed that their hot water usage was insignificant.

Appendix J: The Trinidadian Respondents' Solar Water Heating Information Channels

The types of information the Trinidadian respondents would want before adopting an innovation like solar water heating (see Chapter 6) was complemented by asking: '*What would be the best way(s) for you to receive information about solar energy technologies like solar water heating?*' This was important because the information desired would be gotten from various sources and the means of accessing these can give insight into the practices surrounding the knowledge phase of adopting an innovation; see Rogers (1983) for more on the innovation-decision process and the process of adoption.

Table 42 (next page) shows the responses via the coding structure for the wider information channels together with the sub-codes' frequency of occurrence. 9 of the 16 respondents provided only 1 information channel. With respect to the other 6 respondents, 4 listed 2 channels, and 2 gave 3 channels.

It is clear from the Table that the most salient channel is using the internet to do personal research; personal internet searches was flagged 8 times together with using internet search engines which occurred twice. For example respondents said:

"Since I like technical things, the internet through sites like YouTube may be best since it has a lot of resources." (*Respondent 14MTTD*)

"In today's society, Google." (*Respondent 15MTTD*)

The other sub-code seen within the personal sub-category is related to the influence of social networks on acquiring information. This is worth mentioning since the respondent whose answer led to this sub-code, *Respondent 06MTTD*, is the Trinidadian respondent who owned

solar water heating (an unplanned coincidence) and their mother used to work at the energy Ministry so all the desired information was at their household's fingertips.

CODING STRUCTURE				SUB-CODE FREQUENCY
CATEGORY	SUB-CATEGORY	CODE	SUB-CODE	
Information Channels	Informational consultations	Professional Consultations	Community consultations on solar	1
			Professional consultation with retailers	4
			Professional consultations with experts	4
		Peer Consultations	Peer consultation with adopters in Barbados that have experience with solar water heating	1
			Peer consultations with adopters in Trinidad that have experience with solar water heating	1
			Peer consultations with adopters that have experience with solar water heating	2
	Personal	Internet	Personal internet searches	8
			Internet searches are a mainstream information platform	2
		Influence of social network on information acquisition		1
	Advertising	Business advertising	Private sector advertisements	1
			Retailer advertisements	2
		The media		1

Table 42 showing the Trinidadians' salient information channels and the coding structure that emerged from the inductive thematic content analysis of the respondents' answers

Note: The frequency is defined as the number of respondents' answers that were flagged with the associated sub-code.
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The others that emerged were peer and professional networks. In terms of the peer consultations, 2 respondents generically suggested that liaising with someone who has already adopted solar water heating would be a good information resource. But another, *Respondent 02MTTD*, suggested that their social network was such that they would:

"call up a friend that has had dealings with solar water heating in Barbados." (*Respondent 02MTTD*)

This observation is significant for two reasons: first, it shows that social networks are not

limited to intra-island locals but cultural connections exist between islands, and second, it specifically included Barbados, the energy cultures comparator in the thesis.

Another response under the peer consultation code came from *Respondent 16FTTD.* They thought that it would be particularly important to liaise with a person in Trinidad that has already installed and is using solar hot water since they had concerns surrounding technological standards in Trinidad where low quality products may enter the local market and not perform as desired versus abroad where product standards may be higher.

In terms of the professional consultations there were 3 sub-codes associated. *Respondent 03FTTD* suggested that hosting community consultations would be a good platform for disseminating information to a wider audience and led to the community consultations sub-code in Table 42 (previous page).

However consulting an experienced professional, tradesperson, retailer or the like was thought to be the most salient type of professional consultation. These sub-codes appeared a total of 8 times. This means that after internet usage, having some sort of interaction with experienced personnel was the next most significant information channel. Examples were:

"I would visit a supplier or consult with someone that has expertise like an engineer or someone who has experience with owning solar." (*Respondent 04FTTD*)

"Someone who knows about it - [someone who] has experience in the field." (*Respondent 08MTTD*)

Respondent 04FTTD's quote is also an example of a peer consultation reference. In addition *Respondents 13MTTD* and *16FTTD* specifically suggested that contacting a solar water heater retailer would be the best source for information. Interestingly despite *Respondents 07MTTD*

and *08MTTD* identifying the need to consult experienced persons, they were also unsure of where to find such persons. This illustrates that the industry, its knowledge and its services have not grown to an extent that it is readily accessible.

One way to address this came through the last observation worth pointing out from the Trinidadians' informational channels. There were 3 responses that led to 3 sub-codes relating to advertising; retailer advertisements appeared twice, and private sector advertisements and the media each appeared once.

Respondents 10MTTD and *13MTTD* specifically believed that solar energy retailers need to be part of the advertisement and *Respondent 13MTTD* outlined that they would particularly need to promote the technologies especially as it relates to their relative advantages over conventional means of heating water (like those outlined in Appendix I).

In this same trend of thought *Respondent 03FTTD* was of the opinion that:

"the media should also help inform the people of the advantages of solar over electricity, not to put the T&TEC [Trinidad and Tobago Electricity Commission] out of business, [but rather] so that people can have a choice; awareness is the key." (*Respondent 03FTTD*)

To echo *Respondent 03FTTD*'s sentiment above, *Respondent 07MTTD* further said that:

"education is important since people's knowledge is limited." (*Respondent 07MTTD*)

Appendix K: Considering the Social Costs of Residential Solar Energy Using Hawaii's Net Energy Metering as an Example

Energy consumption feedback through Net Energy Metering

Hawaii's net energy metering (NEM) programme is detailed in Chapter 8. It has an annual 'net-zero' sale cap where any solar power exported to the grid beyond this cap is so done freely. NEM is intended for customers producing electricity for self-consumption. *Informants OH06* and *OH10* thought that this design may have created cases where homes that have exported more power than consumed increased their energy consumption. It is suspected that increasing their consumption through NEM was done because they are not being compensated for this 'free' energy that they would have been providing the grid.

Since households' generation surpluses may be perceived as 'wasted' if they are not the ones using it, households may increase their consumption to benefit from increased consumption; *Informant OH06* thought that most residents have a community-based mindset but display self-interested behaviour. Related to this is price. If it is a marginal factor then the potential for rebound effects to occur is very unlikely (Hinchliffe, 1995). But as seen throughout the thesis, the high costs of electricity together with NEM make price/costs influential.

Informant OH10 suggested that energy efficiency measures should be adopted before renewable energy systems are installed to maximize the benefits - since renewables do not reduce demand but rather substitute how it is met. But based on NEM's design, mixing energy efficiency measures with photovoltaics may not be the most sustainable solution since increased energy efficiency would reduce consumption and so too the 'net-zero' target. This

therefore increases the generation surplus that can be accessed to increase the household's overall consumption to maximize its perceived benefits.

Informant OH04 believed that there is a high likelihood that individuals would invest in solar. But *Informant OH05* thought that higher-income households would be those more likely to invest in it, and more specifically, homeowners according to *Informants OH03* and *OH07*. Therefore wealthy households adopting solar energy can theoretically increase their energy demand - this feeds into a wider (in)equity discussion that will be looked at in the next subsection.

Increasing consumption post-NEM would require householders to establish a cognitive baseline of their generation versus consumption that enables them to make the choices that increase consumption. However another angle that may not be dependent on this comes with Mitchell (2015) identifying that there are misconceptions with respect to solar energy. For instance such misconceptions may drive increased consumption:

> "because a lot of people, when they get solar, frankly they start running their air conditioning more or they start using other power [consuming appliances] more because they think, well 'I've got solar now, I can start using more electricity'." (*Informant OH10*)

Households' solar providers usually take factors such as energy consumption records, roof space, and even shading factors into consideration so that the system being installed could help achieve NEM's 'net-zero' ambit. But there can be instances where systems are over-sized or consumers modify their behaviour post-installation such that there is a surplus generation that can be capitalized upon.

Provided that the price of electricity is geographically homogenous, as is in Oahu, then

increased electricity consumption coincides with increased electricity expenditures (Arthur et al., 2010). However these increased expenses can be moderated through NEM. If a net debit is registered for which the household has to pay the utility, provided that NEM moderates the debit enough, then the bill will still be less than the pre-solar bills; households benefit from increased energy consumption whilst still saving money (Scenario 3 versus Scenario 1 in Figure 72).

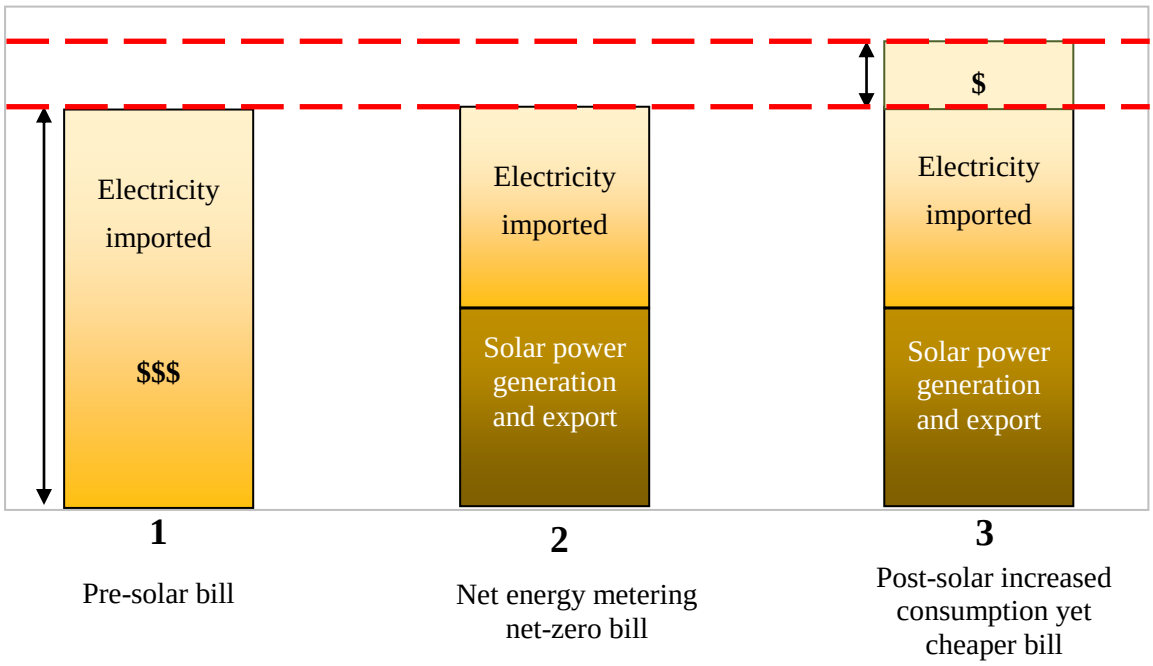


Figure 72 showing the potential impact of increasing household energy consumption through net energy metering-supported photovoltaics on electricity bills based on *Informant OH03*'s statements

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Though the residential sector's systems-level hydrocarbon-electricity usage and greenhouse gas emissions are being reduced through solar energy under NEM, there are other sustainability implications such as continued purchase of appliances and disposal of these

items after their lifetimes for example i.e. consumerism implications.

This is why there should be government policies that explicitly encourage energy conservation as opposed to solely one-sided conventional green energy generation solutions. Therefore combining solar installations with consumption reduction strategies should be considered when rolling out residential solar energy policies - *Informant OH10* pointed out that this would also reduce the size of individual solar systems needed and will be cheaper.

Exacerbating inequity through grid-connected residential solar energy

Having systems-level caps for Hawaii's net energy metering (NEM) was thought to effectively put neighbour up against neighbour as each 'competed' for a permit according to *Informant OH07*. This meant that successful applicants inadvertently formed a socio-technically exclusive cohort; wealthy households are likely to access solar energy technologies first so they form this cohort.

Informant OH04 and Guthrie (2014) outline potential increases in the property value of homes because of solar installations. Guthrie states that the solar system could be registered on a house's energy performance rating and could have some certification to verify its market value. Howell (1979) and Clark (2014) also document this effect. Clark outlines the results of a Lawrence Berkley National Laboratory survey in California which showed that for every 1 kW increase in rooftop solar, homes' market value increased by USD $5,911. But if higher-income homes make up the socio-technically exclusive cohort and increase in property value through solar, then the residential sector's inequity is increasing.

Based on the discussions thus far in this Appendix higher-income homes can potentially benefit from reduced electricity bills, increased energy consumption, socio-technical exclusivity, and higher property values. However the more significant dynamics of the social inequity comes through consideration for the utility's ratepayer base relative to the energy expenses of those who have installed solar and those without.

Many NEM programmes are believed to decrease profits for utility companies which consequently lead them to adjust their electricity tariffs to compensate (Eid et al., 2014) - and *Informants OH06, OH07, OH09, OH10,* and OH*11* touched on this dilemma in Oahu. They believed that since ratepayers are the financial base for a utility company, increasing retail tariffs would affect all those paying for the utility's services.

But households that have installed solar are not exposed to the full brunt of rate-increases since their bills can be offset by generating, and subsequently exporting and selling this solar power to the utility company. So provided that the conventional policy and diffusion of innovation models apply, this means that lower-income households face a proportionally larger financial burden of paying for the grid and programme.

In the case of Oahu's NEM, since NEM-households escape the full effect of the retail price-hikes, this means that non-NEM customers subsidize the costs of maintaining the grid for the NEM subscribers (The Electricity Journal, 2013; Eid et al., 2014; Page, 2015). Trabish (2015) reports that Hawaiian experts estimate that 88% of the utility's customer-base was subsidizing the remaining 12% enrolled in NEM.

With grid-connected solar every unit of electricity saved is one that can be potentially sold back to the grid (Goss, 2010). Therefore every kilowatt-hour (kWh) a solar homeowner

generates is a kWh that the electric utility loses money from (Cunningham, 2014). Beyond fuel costs, the utility is a fixed-cost company so when large amounts of kWh are sold, there is a growth in sales and the fixed-costs are spread out over a larger customer-base (The Electricity Journal, 2013). This reduces the per-unit cost across-the-board (The Electricity Journal, 2013). In Oahu's case it was thought that:

> "if customers who have PV [photovoltaics] aren't paying for those fixed costs it just means that somebody who doesn't have the PV has to pick up that extra share which was leading to the unfairness." (*Informant OH09*)

The integration of grid-connected solar may not decrease the utilities' customer-counts but the proportional revenue contributions from within the ratepayer-base changes. The Electricity Journal (2013) describes this increased inequity as the greatest implication of NEM's success.

These inequity considerations also apply to increasing retail rates to fund grid-connected programmes. One way of overcoming this is through specified funds. Chapter 8 highlighted the creation and use of specified funds to finance grid-connected solar. In Trinidad's context, *Informant TD13* was of the opinion that since its intended feed-in tariff (FiT) would not be competitive with Trinidad's present electricity rates (due to the subsidy detailed in Appendix E), there was consideration extended to funding it through The Green Fund (at least the initial investment).

According to *Informant TD03* this Fund's finances are stored in the Green Fund Account of the Central Bank to support remediation, reforestation, conservation, and education projects. *Informant TD03* explained that it is funded through a levy charged on private sector businesses (0.3% of their gross sales and receipts).

Informant TD03 continued by outlining that the Fund (at that time) is over USD $600 million but there are four types of entities that can access the Fund: organizations incorporated under their own legislation and not under the nation's Companies Act; organizations incorporated under the non-profit banner of the Companies Act; non-governmental organizations registered with either the Ministry of Community Development or the Tobago House of Assembly; and community groups registered with either of the two aforementioned institutions.

The utility, the Trinidad and Tobago Electricity Commission (T&TEC), is under the consolidation of its own Act of Parliament so may fall under the first category of eligible organizations. But it is also a profit-based company which conflicts with the second type listed. Therefore it may not have access to the Fund for a FiT. There is however the possibility of revising the eligibility criteria to increase its inclusivity according to *Informant TD03*. But the Renewable Energy Committee's (2011) proposed Renewable Energy and Energy Efficiency Agency (see Chapter 7) can be established to access the Fund.

Based on *Informant TD03*'s information on the Green Fund it is vulnerable to the influence of political agendas since its line Minister i.e. the Minister of Finance approves projects' funding. So approvals are hinged on the political agenda of the presiding Minister. Additionally, *Informant TD03* explained that during the fiscal year 2016, the Fund was tied-up with the country's national accounts and pledged to stand against the Central Bank's overdraft as collateral. So in terms of financing a FiT the funding is not necessarily sustainable.

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