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Cultural and socio-economic determinants of energy consumption on small remote islands

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Abstract

In this cross-country analysis of four small and remote islands, we integrate multiple dimensions of socio-economic demographic data, such as population, land area, remoteness, tourist arrivals and earnings, export earnings, financial support, average incomes, fuel and electricity prices, penetration of renewable energy sources, and motor vehicle usage; we compare these characteristics with per capita use of energy carriers such as electricity, petrol and diesel. From these characteristics, we identify key determinants of energy consumption in the islands. Whereas we focus on energy, our analysis also applies to emissions of carbon and energy-related pollutants. Our results indicate that cultural and social contexts are at least as relevant for policymaking as economic and technological aspects. We suggest that in small island developing States there is scope for policymaking to at the same time: reduce economic vulnerability due to dependence on imported fossil fuels; reduce environmental impact; and progress sustainable development. Such progress can be implemented through peer-to-peer learning programmes facilitated by targeted international cooperation and partnerships.

Keywords: Energy determinants; energy consumption; small remote islands; SIDS; socio-economic demographic data; per capita use of energy.

1. Introduction

Small remote islands are among the locations most vulnerable to the effects of climate change, despite their populations mostly consuming less fossil energy carriers than people in mainland communities (Schandl *et al*., 2011). The international literature contains a wealth of information on energy supply technologies on islands (Yu *et al*., 1997; Weisser, 2004a). This is especially true for renewable energy sources (Yu and Gilmour, 1996; Yu and Taplin, 1997a; 1997b; 1998; Weisser, 2004b), because the high energy prices and cost of fossil energy carriers (typically 20% of budgets) usually found on islands make renewable technologies more economically feasible than elsewhere. Wind and photovoltaics are among the most prevalent renewable energy technologies installed on remote islands (Carta *et al*., 2003; Schandl *et al*., 2011), although stored hydrogen is also being considered (Duic and da Graça Carvalho, 2004; Gazey *et al*., 2006). There is, however, much less information on the patterns of energy consumption on islands, especially those that are small and remote.

In this study we collect and examine a range of socio-economic, demographic and energy-related data for four islands — Norfolk, Niue, Yap and Cocos/Keeling (Figure 1)[1] — such as population, tourist arrivals and earnings, export earnings, financial support, use of liquid

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[1] A more detailed description of the islands can be found in on-line Appendix B. An attempt was made to include the islands of Pohnpei and Kosrae in the Federated States of Micronesia, however comprehensive and specific energy data were unavailable for these islands. Nevertheless, we have used evidence from Pohnpei and Kosrae to support results gained for the island of Yap.

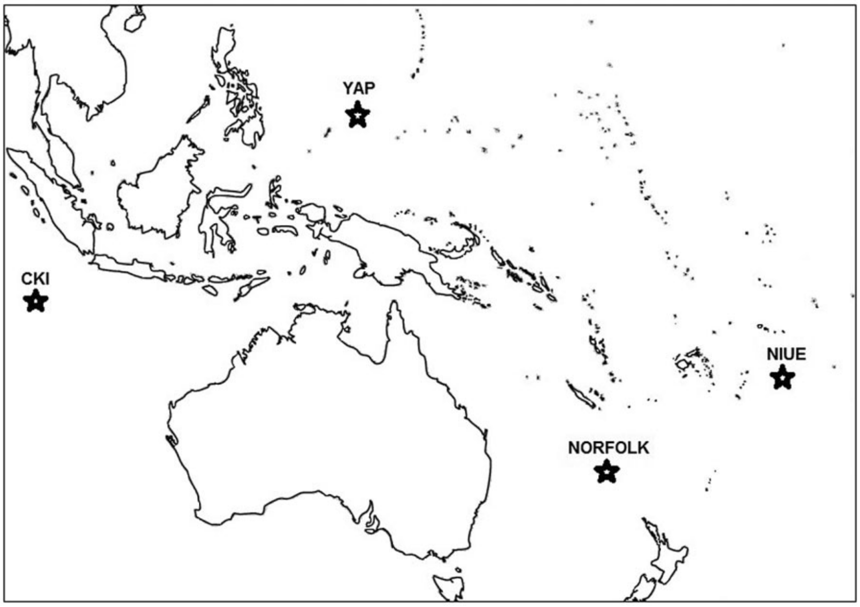

Figure 1. Location of the four islands examined in this study.
Source: Authors' drawing.

energy carriers (such as petrol and diesel), motor vehicle usage, electricity generation and consumption, average incomes, fuel and electricity prices, and penetration of renewable energy sources. Based on the data collected, we identify key determinants of energy consumption on the islands.

There is a large body of research on factors influencing energy consumed by households. Abrahamse and Steg, 2009) state that energy use is mainly determined by socio-demographic variables, whereas changes in energy use, which may require some form of cognitive effort, are related to psychological variables. Interestingly, a large number of authors (Kempton, 1993; Lutzenhiser, 1993; Stokes *et al*., 1994; Gatersleben *et al*., 2002; Poortinga *et al*., 2004; Vringer *et al*., 2007; Hertwich, 2008; Holden and Linnerud, 2010; Whitmarsh *et al*., 2011), have shown that pro-environment attitudes and values are often not translated into lower energy consumption. In this study we concentrate on socio-economic-demographic variables that may play a role in explaining energy consumption. As in previous studies (see overviews by Guerin *et al*., 2000; Wier *et al*., 2001; Lenzen *et al*., 2006; Hertwich, 2010) we utilize regression analysis in order to find out where statistically significant relationships exist.

The four islands in our study were selected because they share important geographical features and the challenges that accompany them (see Tables 1 and 2[2]). They are all small (smaller than 250 km^2) and hence experience a lack of indigenous resources and skills. They are all remote (more than 500 km to land, and more than 1,000 km to the next city), and hence face difficult transport logistics and high commodity prices. They differ from each other with regard to their culture, political status (ranging from sovereign to overseas territory), per capita income (from US$ 3,000 to US$ 26,000), population density (between 5 and 100 people per km^2), and intensity of tourism (from 0.5 to 16 annual visitor arrivals per capita). The inclusion of the Cocos (Keeling) Islands (CKI) is partly motivated by the existence of two distinct ethnic groups — one largely Australian-born and English-speaking, and one largely Cocos-born and Malay-speaking — which live almost exclusively on two separate islands of the atoll — West Island and Home Island. One objective of this work was hence to determine whether the cultural and socio-economic differences between these two groups would give rise to any differences in energy consumption.

The vast majority of existing studies deals with islands that are larger than and not as remote as the islands in our study. An exception is a report by Schandl *et al.* (2011), who give an overview of knowledge and data for the economy and natural resources sectors of several small island states, such as the Cook Islands, Kiribati, Marshall Islands, Nauru, and Palau. As far as we are aware, energy data for the four islands in our study have never been published (as in compendiums such as EIA, 2011; IEA, 2011), let alone a comparative study on their energy metabolism with implications for policymaking for sustainable development. Section 2 provides a detailed analysis of the islands' energy supply and demand in Section 3. Section 4 discusses the findings and concludes.

[2] Further details on the data item 'Renewable capacity' are given in Appendix B.

Table 1. Overview of geographic, demographic, economic, and energy characteristics of Yap, Niue, Norfolk and the Cocos (Keeling) islands

	Yap	Norfolk	Niue	Cocos (Keeling)
Geographic/demographic				
Political status	Member of the Federated States of Micronesia	Australian Territory	Sovereign nation in free association with New Zealand	Australian Territory
Distance to next land (km)	470 (Palau) 844 (Guam)	740 (New Caledonia) 750 (Northland/NZ)	430 (Vava'u/Tonga)	980 (Christmas Island) 1,200 (Java)
Distance to next cities (km)	1,950 (Manila) 2,430 (Taipei)	770 (Noumea) 1,080 (Auckland)	1,250 (Suva/Fiji) 2,500 (Auckland)	1,280 (Jakarta) 1,690 (Singapore)
Area (km^2)	73	35	259	14
Population	11,400[e]	2,000	1,500	600
Population density	119[f]	59	5.9	42
Visitors/resident ratio (%)[d]	0.5	36	6[i]	15-20[j]
Economic				
Per-capita income/GDP (US$)	3,000	26,000[b]	7,600[a]	23,900[c]
Financial support (% total island inc)	27	0[h]	50	85[l]
Tourist arrivals/resident	0.5	19	3	5-10[k]
Air services	2/ wk (Guam) 1/ wk (Palau)	5/wk (Auckland, Brisbane, Sydney)	1/wk (Auckland)	3/wk (Perth)
Supply ship services	2/ wk (Eurasia) 1/6 wks (Kyowa)	1/6 wks	1/mth	1/4-6wks (Zentner)[m]
Vehicles per capita	0.15	1.3[q]	0.55	0.47[p]
Energy supply and use				
Total energy use per capita (GJ)	20	70	50	120
Fuel price (at pump, US¢/L)	160-180	250	120-160	200
Fossil generation capacity (MW)	6.6	4	1.4	2.5[o]
Renewable capacity (kW)	47.6[g]	1,350[r]	52	0[n]
Electricity use per capita (MWh)	1.0	2.4	1.8	4.7
Electricity price (US¢/kWh)	45	71	40-50	20

Notes: Information refers to years between 2008 and 2011, unless otherwise stated. Local currencies were converted into US$ using average exchange rates of 1 US$ = 1.1 A$ = 1.5 NZ$.
[a] SPC PRISM (2009); [b] Community Survey (2011); [c] ABS (2011); [d] calculated as annual arrivals × average length of stay / 365 / number of residents; [e] 7,400 on Yap Proper and 4,000 people on outer islands; [f] 348 for outer islands; [g] PV mini-grids at Asor and Fadrai outer islands; [h] Until 2010, when its political and financial circumstances changed, Norfolk Island received assistance mainly for its airport and pier (JSC, 2005 §§2.44-2.47; DOTARS, *Federal assistance provided to Norfolk Island*, http://www.dotars.gov.au/terr/norfolk/fed_assistance.aspx); [i] assuming 1 week average stay; [j] ABS 1999; Attorney General's Department 2006; [k] average between 65 visitors (2001) every two weeks and 115 visitors (2006) every week (Attorney General's Department 2006); [l] derived from breakdown of hours worked by industry (ABS 2006); [m] Australian Government (2010c); [n] Four 20-kW wind turbines produced about 10% of electricity as of 2010 (Australian Government 2010b), but ceased functioning because of salt water spray and ensuing technical problems; [o] derived from daily automotive diesel oil (ADO) intake of 4,200 l and CEC (2012); [p] derived from 3.26 average household size and 1.54 vehicle per household (Attorney General's Department 2006); [q] Administration of Norfolk Island 2011a; McNeil (2011); [r] photovoltaic cells, mostly post-2010.

2. Energy metabolism

Data were mostly collected during more than one hundred informal interviews[3] with operators of power plants, fuel depots, ferries, petrol stations, island co-ops, hotels, restaurants, farms, airports, schools and hospitals, as well as customs officers and government staff. Most of the information exists only as unpublished printed material such as bills, tariffs, inventories, tourist arrival records, maintenance reports, or custom declarations, sometimes in handwritten form. In some cases, we measured energy consumption ourselves, by compiling inventories of gas bottles, measuring methane flow from digesters, monitoring ferry engines and household meters, or by transferring handwritten power house logbooks to electronic files. In exceptional cases (for example, population statistics) information existed on-line, and this is referenced throughout this article. The fact that the data reported here have never been documented makes our study so unique.

2.1. Fuel mix and energy balance

As explained in the introduction, the islands in our study face challenges in meeting their energy needs, due to their small size and remoteness. Virtually all energy consumed on the islands for transport, electricity, business and households is imported, mostly in the form of diesel, petrol

[3] All people interviewed were informed of the purpose of the study and consented to providing information. On Norfolk Island the study was publicised through a local newsletter (http://www.econorfolk.nf). On Niue the study was announced on national TV (http://www.isa.org.usyd.edu.au/research/documents/NiueTV.mov).

Table 2. Sources of income for the four islands

	Yap	Norfolk[i]	Niue	Cocos (Keeling)[b]
Local industries	65% — Marine products (fish, crabs, lobsters, trochus shell and handcrafts) 8% — Betelnut	2% — Agriculture, forestry and fishing 14% — Manufacturing, construction, maintenance, dwellings 36% — Tourism, retail and hospitality 7% — Social services (education and hospital) 17% — Finance, banking, accounting and insurance 7% — Arts and recreation and other services	25% — Taro, fish, noni[f], honey, vanilla	10% — Tourism 4% — Retail trade, workshop services, gardening and cleaning[d] 1% — Fishing
Taxes, licenses, duties		12% — used for Government Business Enterprises (electricity and water assurance, lighterage, airport, other transport, postal and warehousing, information media and telecommunications) 4% — used for Public administration	15%[g]	
Subsistence			25%	
External support	27% — CFAT[a]	0[c]	35% — NZ Gov't[h]	85% — Australian Government[e]

Notes: [a] The Federated States of Micronesia (FSM) receives economic assistance from the United States under the Compact of Free Association Treaty (CFAT). Under the original terms of the Compact of Free Association, the US provided $1.3 billion in grant aid during the period 1986-2001. The Amended Compact of Free Association (2004-2023) with the US guarantees the FSM approximately $14 million annual aid through 2023 and establishes a Trust Fund into which the US and the FSM make annual contributions in order to provide annual payouts to the FSM in perpetuity after 2023. Each state government within the FSM receives approximately $^1/_4$ of the total share; [b] derived from breakdown of hours worked by industry (ABS 2006); [c] Prior to 2011; [d] Australian Government (2010a); [e] Administration, education, health and local government services, provided through the Cocos Islands Cooperative Society Ltd. and the Shire Council (Australian Government 2010a); [f] Noni (also known as nonu) is a medicinal plant called *Morinda citrifolia*; Niue exports the juice derived from the fruit; [g] fishing licenses and import duties (Pihigia 2006); [h] New Zealand is the largest bilateral donor to Niue, with other donors including Australia, the EU and China (NZMFAT 2011); [i] ACIL Tasman (2012).

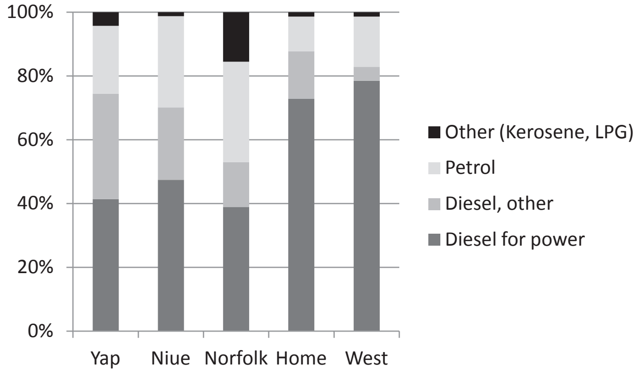

Figure 2. Breakdown of energy use by fuel and purpose.
Source: Authors' elaboration from unpublished material such as power plant records, customs declarations, and interviews with owners of supermarkets, restaurants and hotels.

and liquefied petroleum gas (LPG) (Figure 2). Some islands have a small port tank farm and can accept supplies by tanker; others receive bulk fuel in REEF tank-tainers. Petrol is used for transportation purposes (both road and water) and for small household equipment such as lawnmowers and chain saws. Diesel is used for running the generators at the power utilities and, to a lesser extent, for passenger ferries, freight shipping, and commercial fishing. Major power users are supermarkets, food shops and tourist accommodation. We exclude imports and usage of aviation fuels such as Avgas and JetA1, first because of the varying degree to which such usage would be attributable to island residents, and second because an unknown part of aviation fuel usage would be reported at the connecting airport, and not on the islands. Similarly, the usage of biomass such as firewood is excluded due to a lack of quantitative information, even though firewood usage can be substantial on some islands.[4]

The importance of diesel for power is especially surprising for the Cocos (Keeling) Islands where road vehicle use is limited because of the islands' small size. Given the high cost for importing diesel fuel, it seems astonishing that more than 50% of the fuel's energy content is lost via waste heat (losses in Figure 3).

[4] Personal communication, Jim West, CSIRO Ecosystem Science, 27 June 2011. Biomass is used on Niue on a small scale for drying crops such as copra.

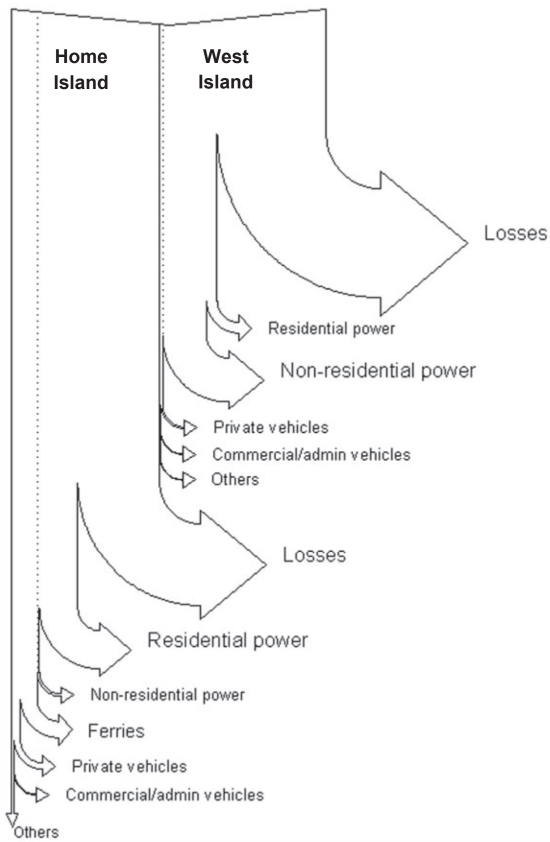

Figure 3. Energy balance for the Cocos (Keeling) Islands
Notes: Incoming primary energy amounts to 44,400 Gigajoules. Non-residential power on West Island is for supermarket, motels, resorts, airport, light industrial area, school, health centre, administrative block, water pressure, vacuum sewerage disposal, street lighting, radio station, transmitter sites, and the fuel tank farm, among others.
Source: Authors' elaboration, from the Cocos Islands Co-op records, fuel pump sales receipts, and interviews with owners of restaurants, the ferry operator, and the power plant operator.

2.2. Energy supply and demand trends

It is interesting to see that both Norfolk Island and Niue feature a relatively stable level of fuel imports over time (Figure 4), despite their very different population trends (Figure 5). Even more unexpected is the substantial decrease in fuel imports recorded for Yap, once again despite an increasing population. This trend is not due to efficiency improvements, since thermal efficiencies of generators have stayed fairly constant (Figure 4). Trend data for the Cocos (Keeling) Islands were unavailable.

Per capita fuel use trends confirm these observations (Figure 6): In the mid-1990s, people on Yap and Niue consumed energy at comparable levels (around 30 GJ/cap/year), however after this, energy demand rose on Niue (to around 50 GJ/cap/year) to almost the level on Norfolk Island (around 70 GJ/cap/year), while energy demand on Yap decreased to 20 GJ/cap/year. Similarly, in 1990, annual electricity consumption in Yap and Niue was 1.2 MWh/cap, but by 2009 this had increased to 1.8 MWh/cap in Niue and decreased to 1.0 MWh/cap in Yap (Figure 6). In the following sections, we will examine more detailed evidence in order to explain these trends.

2.2.1. Yap

Fuel imports into Yap have showed a rapid short decline between 1995 and 1997 and have showed a slow, steady decline since 2000 (Figure 4, left panel). This decline was primarily due to Micronesian Petroleum Company, one of two petroleum companies in the State, halting most of its fuel imports following the closing-down of at least four major commercial customers (two garment factories, Kingtex and Micronesian Knitting; Yap Fresh Tuna; and Penta Ocean Construction Company). Yap Fresh Tuna and the State's own vessel reduced the number of voyages between islands owing to the poor condition of the ship. The Yap State Public Service Corporation (YSPSC)[5] fuel demand, as well as kWh billed to residential, commercial and government customers decreased during this period (Figure 4, right panel).[6] In addition, the two typhoons that struck the island in 2003 and 2004 had devastating effects: 80% of the conductors were damaged and more than 90% of service drops (servicing approximately 2,000 customers) were damaged or destroyed. The transport sector has not shared these declines: vehicle imports are still increasing despite the high cost of fuel. Because it is cheaper to import older used cars, most of them are not energy-efficient. Additionally, the practice of "car-pooling" is uncommon.

Contrary to the decline in power production, the number of metered customers increased significantly after 2000 (Table 3). Interestingly, the substantial increase in the number of customers between 2004 and 2008 (Table 3) was not accompanied by a corresponding increase in electricity consumption: On a per capita basis, electricity consumption decreased significantly during the same period (Figure 6, right panel).

This decrease can potentially be assigned to two trends: First, YSPSC's demand-side management (flyers encouraging energy conservation, progressions in tariffs, and energy efficiency actions)[7] started to bear fruit. Second, and more importantly, the decrease was accompanied by a sharp increase in the prices of all major fuels (Table 3). This price increase, combined with the impact of the global

[5] Electricity is provided by the YSPSC, a public authority governed by a board appointed by the governor and confirmed by the state legislature. The YSPSC operates plants and distribution grids on Yap Proper and three locations on outer islands ever since it took over from the Department of Public Utilities and Contracts in 1996.
[6] Personal communication, YSPSC, 28 September 2012.
[7] Maintenance of the existing stock of air conditioners, refrigerators and freezers, and the exchange of older, less efficient equipment for higher efficiency units, for example replacing them with high-EER air-conditioners, using higher efficiency motors on pumps and switching to CFLs from incandescent lamps. On Pohnpei and Kosrae, the authorities started distributing cash-power meters.

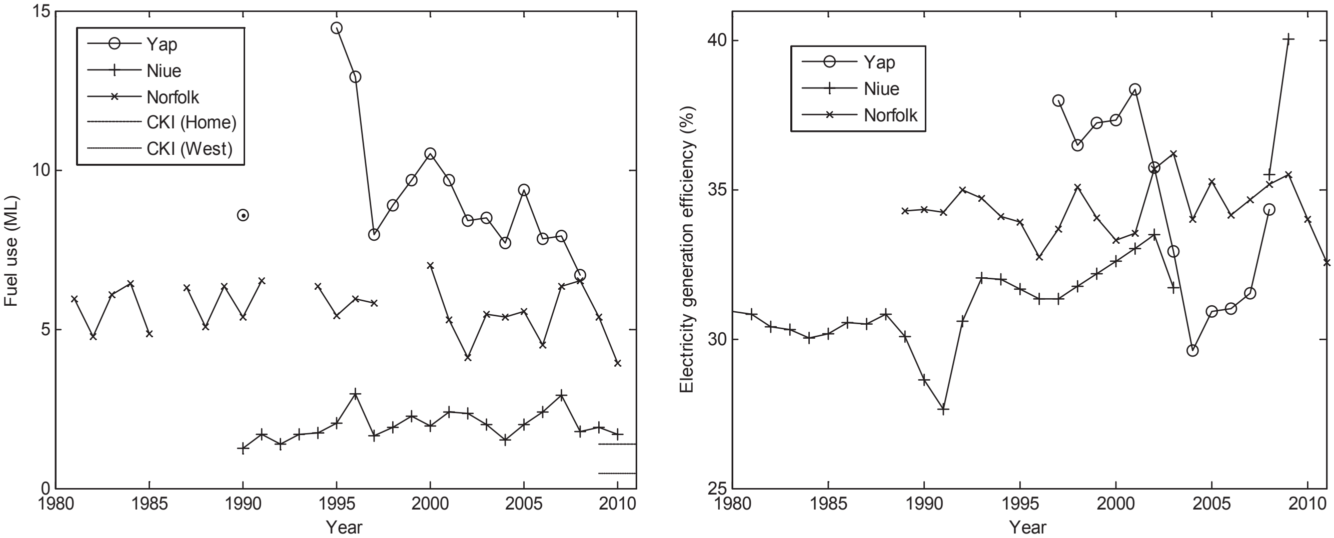

Figure 4. Total fuel imports and thermal efficiency of electricity generation over time

Note: Fuel use (including diesel, petrol, LPG and kerosene) is in units of megalitres ((ML), left panel; Fuel import data for Yap is based on records from the Division of Transportation for the whole Yap State) and electricity generation is in units of $MJ_{ADO,in}/MJ_{electr,out}$ (right panel); ADO = automotive diesel oil. Efficiency data for Niue include an estimated 13% distribution loss (SPC 2009).

Source: Authors' elaboration from unpublished, often handwritten supply ship, customs and power plant records.

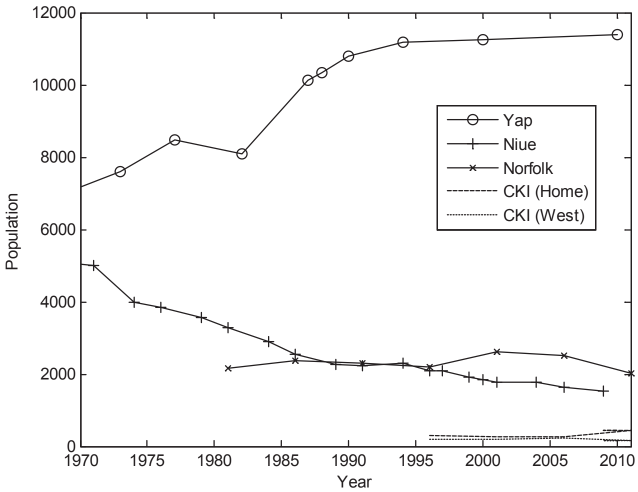

Figure 5. Population trends for the four islands in our study.

Sources: ABS (2006; 2011); Community Survey (2011); Statistics Niue (2013); Yap State Government unpublished records.

economic recession and the energy sector's ability to provide reliable electricity, has resulted in households changing their consumption habits by sharing of appliances (such as freezers and refrigerators) in the extended family systems in order to limit the usage of energy and save money. Similar trends can be observed for Pohnpei and Kosrae.

2.2.2. Niue

Despite a population decrease (Vaha, 2005), Niue's energy use shows an upward trend due to increases in imports of electronic and electrical appliances as well as vehicles, and due to increases in demand for pumped water. Notable spikes in Niue's fossil fuel imports occurred in 1996 and 2007 (Figure 4). The spike in 2007 was caused by the economic activity generated by the Niue Fish Processing Factory that opened in 2004. Electricity used by the factory, in particular automotive diesel oil used by vessels for refueling, contributed greatly to the increases in Niue's fossil fuel imports. When the factory closed in 2007 there was a considerable drop in the total imports of fossil fuels for Niue. Improvements in electricity use from raising consumer awareness and conservation efforts contributed to the slight reduction seen in the per capita use of electricity on Niue in 2002-2003 (Vaha, 2005). Improvements in total energy use also came partly from reductions in the use of electricity for pumping and the reticulation of water for the island, which in 2008 accounted for 8% of Niue's energy consumption (Ambroz, 2011).

The mid-2000s saw a strong trend towards improving energy use and efficiency in Niue through EU-funded projects aimed at reducing electricity demand, for example by distributing solar water heaters and gas ovens at a subsidized price. However, most homes did not use electrical water heaters for showering anyway, and the introduction of gas ovens had only a moderate effect on overall energy use.

2.2.3. Norfolk Island

Energy consumption and demand has been slightly increasing over the last few decades, with per capita electricity consumption increasing by 70%. This is reflected in a combination of increasing fuel imports and improving

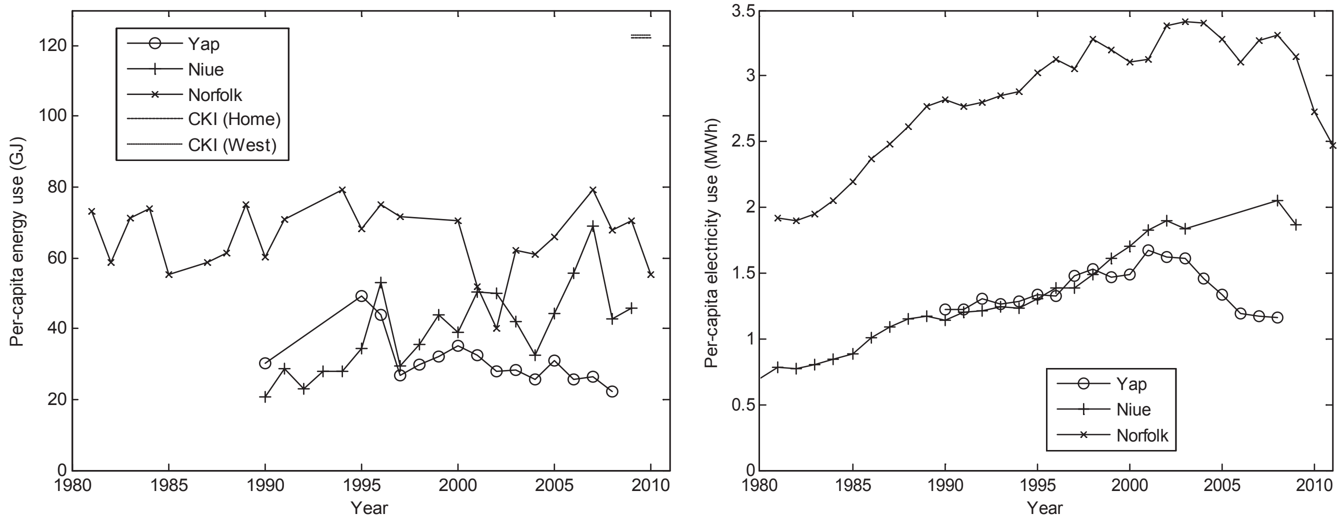

Figure 6. Per capita energy consumption and per capita electricity consumption over time.

Note: Energy consumption in units of Gigajoules (GJ, left panel), and electricity consumption is in units of Megawatt-hours (MWh, right panel). Power production data for Yap is based on the data from Yap State Public Service Corporation (YSPSC) power station on Yap Proper. A number of years are missing in the time series of power generation for Niue. This is due to the building housing the generation records having been damaged or destroyed by a cyclone in 2004, and by a fire in the powerhouse in 2006.

Source: Authors' elaboration, compiled from information contained in Figure 4, by conversion of volumetric and mass units into energy units, and dividing by population counts.

Table 3. Price and customer number trends of YSPSC

	Gasoline price	Automotive diesel oil price	Kerosene price	Electricity production cost	Number of metered customers			
		(US$/gallon)		(US¢/kWh)	Residential	Business	Gov't	Total
1995	1.23	0.76	1.54					
1996	1.28	0.88	1.54					
1997	1.39	0.89	1.58	0.07				
1998	1.26	0.77	1.46	0.07				
1999	1.07	0.99	0.88	0.08				
2000	0.94	0.95	0.99	0.11				
2001	1.00	1.10	0.85	0.11				
2002	1.02	0.67	0.79	0.08				
2003	0.91	0.83	1.29	0.19				
2004	1.04	0.90	1.29	0.28	861	268	70	1,199
2005	1.30	1.51	2.10	0.29	1,043	305	84	1,432
2006	2.08	1.94	4.37	0.35	1,331	354	124	1,809
2007	2.04	2.15	3.03	0.34	1,322	360	130	1,812
2008	2.99	3.23	4.84	0.56	1,346	378	143	1,867
2009	2.27	2.24	3.32	0.45	1,359	385	143	1,887
2010	2.80	2.83	4.38	0.50	1,373	398	137	1,908

Source: Personal communication, YSPSC, 28 September 2012.

plant efficiency (Figure 4). Triggered by the global financial crisis and the ensuing collapse of the island's tourist market, energy consumption has been in rapid decline since 2007. Fuel price increases have had a significant effect on the cost of living, directly through on-Island fuel costs and indirectly through the cost of electricity. The remoteness of Norfolk Island played a crucial role in these trends: the Norfolk Island retail price index for "household operations" (including electricity) increased by 65% since 2002, compared to a 57% increase on the Australian mainland. During the same period, transport costs increased by 66% compared to 27% in Australia. As a result, in 2009,

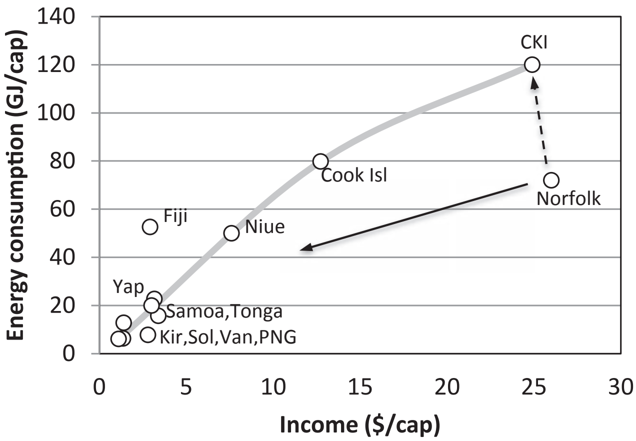

Figure 7. Per capita energy and electricity consumption.
Notes: CKI = Cocos(Keeling) Islands, Kir = Kiribati, Sol = Solomon Islands, Van = Vanuatu, PNG = Papua New Guinea.
Source: Data for Yap, Niue, the Cocos (Keeling) Islands and Norfolk Island from this study, remainder from Schandl *et al*. (2011).

the Norfolk Island Government allowed privately-owned Government-subsidized[8] photovoltaic (PV) systems.

2.2.4. Cocos (Keeling) Islands

At the time of writing, the two power stations on West and Home Island were being managed and maintained by the Water Corporation of Western Australia under the auspices of the Indian Ocean Territories Power Authority. In February 2005, four 20-kW wind turbines at a total cost of US$ 3.6 million were installed on Home Island (Powercorp, 2012) in order to supplement four 320-kW diesel generators (CEC, 2012). Comprehensive time series data on the fuel and electricity metabolism were unavailable.

3. Discussion

3.1. Trajectories and explanatory determinants of energy consumption

A comparison of per capita energy consumption with other Pacific islands shows that most islands are on development trajectories that ultimately lead to Cocos/Keeling (CKI)-type energy metabolisms (grey curve in Figure 7).

The different stages of development in Figure 7 are perhaps best illustrated by quoting from Niue's statistical release (Vaha, 2005):

> *"There are a lot of things to consider when we look into this. For instance, in the early 60s when the population was estimated to be above the 4,000 heads the demand for electricity was low as a lot of them were living in the outer villages where there was no electricity. The concentration of the demand then was in Alofi, hence, the production and supplying was low. Towards the 70s and 80s, the government then decided to take the electricity to the outer villages which resulted in the demand for electricity soaring followed by the production and supply. The rate of increasing was in the range of 6.8% to 37% from 1974 to 1981, peaking in 1978. Not only that the households demanded for electricity for domestic use but other commune requirements such as pumping of water from the underground lenses and to the homes and lighting for the roads and sea tracks were added to the equation. Therefore, even in the event of the population decreasing the services required by them that consumed electricity were on the rise, and this was the same for the electrical appliances obtained and used by individual homes."*

Norfolk Island is an exception, because islanders consume less energy at a wealth equal to CKI. Dividing per capita energy consumption by per capita income yields a measure of energy intensity in units of megajoules per dollar. Whereas most islands require between 5 (CKI) and 9 (Fiji) MJ to satisfy an average $ of consumption, Norfolk Island gets by with only 3 MJ/$. In other words, the Norfolk Island economy is more energy-efficient than other island economies (see Lenzen, 2008 for concrete examples).

We undertook a number of regression analyses in order to quantitatively investigate whether a statistically significant relationship exists between per capita energy consumption on the one hand, and socio-economic-demographic characteristics on the other. The details of our regressions (underlying data and regression forms) are described in Appendix A. Guerin *et al*. (2000), Wier *et al*. (2001), Lenzen *et al*. (2006) and Hertwich (2010 list many studies that contain multiple regressions of energy consumption against socio-economic-demographic explanatory variables, and hence we will refer our comparisons to these reviews. We use the terms "determinant" and "determine" in order to indicate power of a variable in explaining energy consumption. Strictly speaking, results of regression exercises do not reveal anything about the direction of causation. However, the general view in the literature is that energy consumption is chosen as the explained variable, and hence this choice fixes the direction of explanation. We follow this view in our work.

Our regressions showed that most of the potential determinants of energy consumption — tourist arrivals and tourist income, land area, vehicle ownership, fossil and renewable generation capacity — had insignificant relationships with per capita energy consumption. The distance to the next land showed a significant positive relationship, which is unexpected since the more remote an

[8] AU$ 5.1 million in 2009-10 in rebates was provided to Norfolk Island residents under the Renewable Remote Power Generation Programme.

island, the higher the prices and the fewer the consumption opportunities. Indeed, testing the distance to the next city (where some of the goods potentially consumed would come from) showed a negative relationship, albeit insignificant. Hence, geographical remoteness as an explanatory factor for per capita energy consumption is inconclusive. Next, we see that connectedness, expressed as the frequency of air or ship services, is similarly inconclusive. Whereas both variables are significant at the 67%-level of confidence, their influence is exactly opposite, and once these variables are expressed as a combined service frequency, the relationship becomes insignificant. Next, both fuel pump prices and power rates, as well as their combination into an energy price per megajoule, are insignificant.

Interestingly, population size comes up as a significant determinant of per capita energy consumption, with larger populations exhibiting lower per capita consumption. A similar result was found at the household level by Brandon and Lewis (1999) for the UK, by Yust *et al*. (2002) for the US, and by Lenzen *et al*. (2006) for Australia, Brazil, Denmark and India. This trend is interpreted in the literature (see Lenzen *et al*., 2006; Hertwich, 2010) as an effect of larger households sharing more appliances, vehicles, etc. than smaller households. Although we do not have information on average household size, we know from the islands examined in this study that sharing behaviour occurs beyond the individual household, so that this effect can also be seen at the total population level.

Finally, income is a highly significant determinant of energy consumption. Indeed, there are a number of international studies that have measured energy consumption as a function of income. These differences in energy consumption reflect different standards of living, which are reflected in various levels of per capita incomes. Examples from the literature abound: Lenzen *et al*. (2006; Hertwich (2010) and Wier *et al*. (2001) list a large number of studies featuring income as the most important explanatory variable in regression analyses of energy consumption. Similarly, in their extensive review, Guerin *et al*. (2000) find income among the most frequent predictors of energy consumption behaviour. The energy-income relationship applies both to domestic and transport energy. For example Newcombe (1979) reports income as the main factor leading to increases in domestic energy use in Hong Kong, and Carlsson-Kanyama and Lindén (1999) state income as the main determinant of travel patterns in Sweden.

Our findings are confirmed in a study of energy use in the Netherlands by Abrahamse and Steg (2009), who found income and household size to be the two most important determinants of energy use. Interestingly, our linear regression showed that the part of income originating from external financial assistance explains energy consumption with an even higher significance than total income. Examining the evidence assembled so far, we conclude that remoteness, land area, renewable energy sources, tourist arrivals, and connectedness are not sufficient to explain Norfolk Island's outlier position regarding levels of per capita energy consumption. Similarly, energy prices do not explain cross-island differences. Our data suggest that per capita financial assistance and population size are the two main determinants of per capita energy consumption.

Considering this evidence for a combined trajectory of assistance/wealth and energy consumption, the question arises of how Norfolk Islanders were able to live less energy-intensively than fellow islanders, as a result of their not receiving financial assistance. In the following section we present evidence that this is due to the social and cultural context of Norfolk Islanders; Islanders were able to implement drastic measures to cut the dependence on imported fossil energy carriers.

3.2. Social and cultural contexts influencing energy consumption on Norfolk Island

The idea that social and cultural context matter for energy consumption is not a new one (Lutzenhiser, 1992; 1993; Wilhite *et al*., 1996). In our study we observe a typical evolution of islands' energy metabolisms by looking at the progression of Yap —Niue — CKI. On Yap (27% of income is assistance, 20 GJ/cap), traditional lifestyles prevail, and the society has been relatively independent of energy needs and resilient to energy price increases, by reverting to communal lifestyles. Similar observations can be made for the Micronesian islands of Pohnpei and Kosrae. On Niue, with its higher levels of assistance (50%, 50 GJ/cap) such resilience has partly disappeared, as communal structures have partly broken down in exchange for individual affluence made possible by financial assistance. On CKI, the Australian Government is required to uphold Western Australian rural living standards (85% assistance, 120 GJ/cap), and electricity prices are kept at the Australian mainland level. Despite the vastly different cultural origins of the two ethnic groups occupying CKI, we observe that energy consumption behaviour is virtually identical. This evolution towards higher living standards goes hand in hand with prospects for a more convenient lifestyle made possible by outside assistance.

Evidence to explain the circumstances that led Norfolk Islanders to remain below the "trajectory of convenience" can be found in reports of a Joint Standing Committee (JSC) on Norfolk Island's future financial sustainability (JSC, 2005; 2006, aptly entitled "Sink or Swim"). In essence the Committee's mandate was to examine Norfolk Island's capability to raise revenue sufficient to uphold "adequate services and acceptable infrastructure". The Committee concluded that that challenge had become "too great for the Norfolk Island Government alone to confront and resolve". Using a very explicit reference to wealth, it recommendedthat Norfolk Islanders pay income taxes in return for assistance on infrastructure[9] (JSC, 2005:iii):

> "*The pathway to increased prosperity will not be easy and will not be quick. The Committee has recommended that Norfolk Island should come under the income taxation and welfare systems of the Commonwealth*."

The rationale for this conclusion reads (JSC, 2005:iii):

> "*The Committee is of the view that all Australian citizens, irrespective of where they choose to reside in the nation, deserve competent government administration and service delivery to a standard no less than can be expected in any similar jurisdictions in other States or Territories [. . .] in the interests of fairness, equity and justice for all residents of Norfolk Island, as citizens of the Commonwealth of Australia*."

The report later mentions wages and salaries as a yardstick for equity (JSC, 2005:§2.19). Interestingly, the views of the Norfolk Island Government (NIG) at the time differed with those of the Committee on the definition of adequacy (JSC, 2005:§1.41, see also p. 91), arguing that:

> "*the JSC has fundamentally failed to realise the significant differences in the model of government in Norfolk Island from those of Australian [sic] jurisdictions. Current government structures and procedures in Norfolk Island are essentially different, not inadequate*",

and (JSC, 2006:§§1.27-1.31)

> "*The NIG believed Norfolk Islanders wished to maintain control of their own affairs. [. . .] Most of the Norfolk Islanders engaged by the Committee during its discussions appeared to concur with this point of view, even among those who felt that the NIG was underperforming. [. . .] Several individuals emphasised the benefits of the low level of business regulation; others highlighted the strength of family and community spirit on Norfolk Island as a more than adequate replacement for a formal system of social welfare.*"

Indeed, submissions by Norfolk Islanders to inquiry questioned the meaningfulness of the adequacy criterion (JSC, 2005:§2.55, §2.56):

> "*This does not mean that the Norfolk Community desires all of the services, nor services to the same levels, as [those] that [are] enjoyed by other Australians. Indeed, our aspirations as a community may well be less in some areas, and the majority of us do not feel 'second class' (as some would have us believe) as a consequence. [. . .] Persons who come to live in a remote and isolated location with an extremely small population, cannot expect to have the same standard of services as on the mainland.*"

Popular views held by the island population were that "*Norfolk can manage with what we have*" (JSC, 2005:88), and that "*[o]ur remoteness has led to an innovative people who pride themselves on their self-sufficiency*" (JSC, 2005: footnote 24). There was even "*widespread hostility to the introduction of mainland style unemployment benefits, which it was believed would undermine the work ethic of the community*" (JSC, 2006:§1.52).

These views also demonstrate the significance of Norfolk Island's historical roots:

> "*I think the Pitcairners and subsequent NI community have always been keen to do things for themselves as much as possible, to be as subsistence as possible. For example the battle for the NI community to remain independent has been [on]going since before Federation — in fact probably since the Pitcairners arrived at NI on the understanding that Queen Vic had given them the Island, but then land was granted to "outsiders" and the Pitcairners realised they didn't have the self determination that they thought they would have. On a broader note the Norfolk Islanders have traditionally been basically resourceful and conservative with resources, reusing old machinery and equipment to rebuild rather than buy[ing] new [ones], find[ing] many different ways to cook and us[ing] a particular fruit or vegetable when there is a surplus in season [. . .] those cultural traits and the mutiny mentality are still around today in many areas.*"[10]

These report extracts are central to understanding Norfolk Island's position in Figure 7. Although the JSC benchmarked adequacy on mainland Australian living standards, at least a part of Norfolk Islanders felt that their autonomous lifestyle was adequate, despite economic hardships brought about by their island's financial independence. These hardships spawned a number of remarkable achievements in terms of innovative business approaches to environmental sustainability (see examples in

[9] Social security, health and aged care services, national census and economic statistics collection, immigration, customs and quarantine, primary and secondary school education, vocational education and training, legal services and the courts, telecommunications, broadcasting, environment protection, hospital, roads, the school, power generators, a deep water harbour, and the airport.

[10] Personal communications on Norfolk Island, Jodie Quintal, compiled 26 February 2013. NI = Norfolk Island; Pitcairners are the community of 193 *Bounty* mutineers and their Tahitian companions from Pitcairn Island who arrived on Norfolk Island on 8 June 1856, after having been granted portions of land by Queen Victoria.

Lenzen, 2008), and ultimately led to Norfolk Island's society being less energy- and emissions-intensive than those of other islands.

The question of what constitutes an "adequate" island lifestyle is also at the heart of past and future development trajectories of other islands. Clearly, the residents of the Cocos (Keeling) Islands did not have a choice because living standards were set out in the UN contract, and as a consequence of power subsidies and other forms of assistance, CKI's energy intensity is the highest in our island sample (Figure 7). On Niue, "adequacy" is in the process of being re-defined as the younger generation cares less about traditional values but more about western-style convenience. As on Pohnpei and Kosrae, residents of Niue now feel more than ever entitled to financial assistance and expect to be cared for by governments. The situation in Yap is somewhat different. Despite the electrification of villages and outer islands (Table 3), an increase in per capita electricity consumption has not occurred, partly because the low level of financial assistance has not enabled development paths similar to those of Niue, and partly due to the unique cultural traditions and governance structures that exert a strong influence on Yapese lifestyle and hence consumption patterns. Anecdotal evidence suggests that cultural integrity plays a larger role than the lack of finances in keeping Yapese lifestyles "island-friendly".

3.3. *Policymaking for empowerment of islanders*

What implications do these findings have for policy strategies? We believe that double dividends such as those on Norfolk Island could be supported and strengthened by policies that emphasize financial independence and cultural identity, while at the same time make appropriate use of islands' limited natural resources settings. Such policies must focus on promoting general attitudes of self-reliance, independence, self-determination and resource conservation, and instil a sense of stewardship for future generations. Naturally, such policies would need to abandon comparisons with affluent continental lifestyles and individual aspirations but instead aim at building communities that take pride in their independence, strength and ingenuity.

Given the small size of many island States and their resource limitations, and the formidable challenges in achieving economic and resource sustainability, it would make sense to understand "community" to include and unite the populations of many islands, thus forming a greater skill pool from which to derive support and advice. Policy initiatives could focus on implementing measures that emphasize commonalities between islands in dealing with their contemporary development issues.

Initiatives that create and enhance inter-island relations and partnerships can play a crucial role in engaging small island residents in implementing policies and technologies that advance sustainable development. One example for an initiative aimed at empowering islanders is the Sustainable Islands programme funded by AusAID and administered by the University of Sydney and the EcoNorfolk Foundation.[11] The aim of this programme is to train leaders from small remote islands in the area of sustainable development in order to increase their capacity to deal with key regional environmental issues such as energy, waste, and marine resources. The programme is based on peer-to-peer knowledge exchange and management training, but includes specifically tailored academic units aimed at enhancing the trainees' understanding of the impact of a globalized interconnected world on the sustainability of their region. Through tailored courses designed for business and government professionals, guided teamwork, discussions, and practical training, islanders gain knowledge and practical know-how about carbon footprinting and other life-cycle approaches to environmental management, renewable energy sources and energy conservation, waste recycling, and strategies for managing fisheries and aquacultures as a sustainable export industry. The highlight of the training programme is a series of practical training sessions conducted on Norfolk Island.

One of the major revelations for previous groups during their peer-to-peer learning was that Norfolk Islanders had embarked on their initiatives without outside assistance. This experience provided a sense of empowerment — the vision of being able to create sustainable energy, waste and marine futures for one's own island using only island skills and resources, and living autonomously.

In a sense, these policy deliberations fall short of recommending concrete measures or schemes. This is mainly because the issue at hand is one of lifestyles, choices, and aspirations, an area that has traditionally been avoided by policymakers. Governments have largely avoided encouraging the public to question material affluence and the role of mass media (see Trainer, 1995; Trainer, 1997; Jackson and Marks, 1999; Lenzen and Smith, 2000; Brown and Kasser, 2005; Jackson, 2005; 2009; Jackson and Papathanasopoulou, 2008; Lenzen *et al.*, 2008; Druckman and Jackson, 2010; Lenzen and Cummins, 2013), let alone intervening in unsustainable lifestyles (Beekman, 2001). Indeed, the Joint Standing Committee on Norfolk Island echoes government viewpoints stating the right of all Australians to equal service delivery. In contrast, many commentators propose that this narrow view of welfare must be extended in order to include environmental quality and happiness (Gowdy, 2004; Ferrer-i-Carbonell and Gowdy, 2007; Government of Bhutan, 2012; OECD, 2012; Kubiszewski *et al.*, 2013). Even more, research has demonstrated that increasing income has diminishing returns in terms of well-being (Frey and Stutzer, 2002; Stutzer, 2004; Mayraz *et al.*, 2006; Abdallah *et al.*, 2008; Brereton *et al.*, 2008; Steinberger and Roberts, 2010). Such

[11] http://www.isa.org.usyd.edu.au/research/islands.shtml; http://www.econorfolk.nf.

findings lend support to questions as to whether the Committee's focus on restoring material standards and finances might have missed some crucial determinants for Norfolk Islanders' happiness. In any case, leadership needs to embrace a wider view of what constitutes desirable and adequate lifestyles, and needs to be creative in order to effect genuine progress. The example of the Government of Bhutan (2012) stating that gross national happiness is more important than gross national product indicates that chances for such leadership to be effective may be especially favourable in small communities such as islands.

4. Conclusions and outlook

The remoteness and limited resource base of small islands mean that financial independence and affluent lifestyles cannot be attained at the same time. Many island populations have opted for affluence and as a result are heavily dependent on external assistance. One consequence of this assistance is that energy prices are artificially low or energy budgets subsidized, so that energy consumption behaviour can largely ignore the islands' resource realities. In these cases, per capita energy consumption reaches levels similar to those of the populations on the resource-unconstrained mainland, as evidenced on the Cocos (Keeling) Islands. Once islanders have experienced convenient and relatively secure lifestyles, unequal framing of loss and gain makes it difficult for them to turn back to traditional values and lifestyle patterns that are more in tune with the islands' limitations. In many ways, Niue is in a transition between traditional values and globalized lifestyles as the younger generation takes over. It is an open question which way relatively traditional island societies such as those on Yap will evolve. Our data show that many Yapese are still sufficiently rooted in their cultural values and community ties that they would absorb energy price hikes unassisted.

Norfolk Island is different in many respects. For decades the island population has managed to uphold its income and community services infrastructure (roads, hospital, school, telecommunications) with virtually no outside assistance, which places it in a unique position among remote and small islands.[12] However, the island finds itself at a crossroads. Aspirations of some Norfolk Islanders for Australian mainland lifestyles and service levels do not tally with weakening economic prospects, meaning that some aspects of island life may have to give. In essence, it appears that there are two diverging development paths: either continuing political and cultural sovereignty but at service levels and living standards below those on the Australian mainland (solid arrow in Figure 7), or opting for convenience and security by integrating into Australian governance structures (dashed arrow) at the cost of self-determination and probably at the loss of the very individual resourcefulness and resilience that has enabled the unique environmental outcomes of the island's economy. Today, most island societies are on a trajectory towards a convenient and secure future but, depending on how far they have progressed on their trajectory, have lost a varying degree of independence, cultural integrity and identity, and resilience. Many Norfolk Islanders have a fierce desire for independence (see for example JSC, 2005: footnote 24 and p. 89), but were recently at economic breaking point. The following years will show which way the scales will tilt on Norfolk Island.

[12] This lasted until in 2010 when, faced with the combined adverse effects of price hikes, a volatile tourist market, and the global financial crisis, the Norfolk Island government decided to voluntarily cede administrative independence to the Australian Government in return for financial bail-out. At the time of writing, Norfolk Islanders found themselves in a climate of uncertainty about the consequences of possible arrangements with the Australian Government.

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Appendix A: Regression analysis

In order to identify relationships between the explained variable energy consumption and explanatory variables, we utilized univariate regression. Even though we have more than one explanatory variable, we are unable to apply multivariate regression because our sample size is not large enough to ensure an acceptable degree of freedom. We tested both linear and logarithmic regression forms. The following section A.1 describes the data underlying the regressions, and results are presented in section A.2.

A.1. Data

In addition to the data listed in Table 1 in the main text we compiled a number of derived quantities, such as per capita and percentage values (see Tables A.1.1 and A.1.2). The variables 'Financial support', 'Energy price', and 'Transport services' were combined from two primary explanatory variables, as explained in the notes to Table A.1.1, because the underlying primary variables relate to a similar characteristic (income, energy price and accessibility).

Table A.1.1. Explained variable (energy consumption per capita) and some explanatory variables

	Energy consumption (GJ/cap)	Financial support ($/cap)[a]	Population	Energy price ($/MJ)[b]	Transport services (/month)[c]	Total income ($/cap)	Indigenous income ($/cap)	Fuel pump price ($/L)	Power rates ($/kWh)	Air services (/month)	Supply ship services (/month)
Yap	20	810	11,400	0.09	12	3,000	2,190	1.70	0.45	4	8
Niue	50	3,800	1,500	0.08	5	7,600	3,800	1.40	0.45	4	1
Norfolk Island	70	0	2,000	0.13	12.7	26,000	26,000	2.50	0.71	12	0.7
CKI	120	20,315	600	0.06	13	23,900	3,585	2.00	0.20	12	1

Notes: [a] Financial support = total income — indigenous income; [b] Average energy price = [fuel pump price / 35 MJ/L + power rates / 3.6 MJ/kWh] /2; MJ = Megajoule; [c] Transport services per month = air services per month + supply ship services per month.

Table A.1.2. Remaining explanatory variables

	Distance to next city (km)	Distance to next land (km)	Tourist income (%)[a]	Tourist income ($/cap)[a]	Tourist arrivals (/cap)[a]	Tourist arrivals[a]	Land area (sqkm)	Financial support (%)	Vehicles /cap	Fossil generation capacity (MW)	Renewable generation capacity (kW)	Renewable fraction (%)
Yap	1,950	470	0	0	0.5	5,700	73	27	0.15	6.6	47.6	0.7
Niue	1,250	430	0	0	3	4,500	259	50	0.55	1.4	52	3.7
Norfolk Island	770	740	36	9,360	19	38,000	35	0	1.3	4	1350	33.8
CKI	1,280	980	10	2,390	7.5	4,500	14	85	0.47	2.5	0	0.0

Note: [a] Annual values.

A.2. Linear univariate regression results

In the following we present standard results for regressions of energy consumption per capita = $m \times$ explanatory variable + *const*, where m and *const* are the slope and intercept of the linear relationship, respectively. R^2 is the standard goodness of fit, that is, the proportion of the variance in per capita energy attributable to the variance in the respective explanatory variable. The Student's t statistic can be derived from the regression slope and its standard error according to $t = m/\sigma_m$.

Table A.2.1. Linear regression results for some explanatory variables

	Financial support	Population	Energy price	Transport services	Total income	Indigenous income	Fuel pump price	Power rates	Air services	Supply ship services	Distance to next city	Distance to next land
Regression coefficient m	3.76E-03	–6.44E-03	–4.34E+02	3.63E+00	3.00E-03	4.38E-04	3.79E+01	–9.57E+01	7.50E+00	–8.47E+00	–4.57E–02	1.52E–01
Standard error σ_m	1.63E–03	3.73E–03	8.62E+02	7.43E+00	1.47E–03	2.58E–03	5.74E+01	1.26E+02	3.64E+00	5.77E+00	5.21E–02	4.35E–02
R^2	0.73	0.60	0.11	0.11	0.68	0.01	0.18	0.22	0.68	0.52	0.28	0.86
Student's t	2.30**	1.73*	0.50	0.49	2.04*	0.17	0.66	0.76	2.06*	1.47*	0.88	3.49***

Note: Regression coefficients are significant at the confidence levels of 67% (*), 90% (**) and 95% (***).

Table A.2.2. Linear regression results for remaining explanatory variables

	Tourist income (%)	Tourist Income ($/cap)	Tourist arrivals	Tourist arrivals	Land area	Financial support	Vehicles	Fossil generation capacity	Renewable generation capacity	Renewable fraction
Regression coefficient *m*	8.42E+01	3.03E–03	2.18E+00	1.38E–04	–1.66E–01	6.96E+01	2.44E+01	–1.06E+01	2.94E–03	1.02E+01
Standard error σ_m	1.64E+02	6.36E–03	3.28E+00	1.79E–03	2.38E–01	6.62E+01	5.86E+01	1.09E+01	4.51E–02	1.83E+02
R^2	0.12	0.10	0.18	0.00	0.19	0.36	0.08	0.32	0.00	0.00
Student's *t*	0.51	0.48	0.67	0.08	0.70	1.05	0.42	0.97	0.07	0.06

A.3. Double-logarithmic univariate regression results

In the following we present standard results for regressions of energy consumption per capita = *const* × (explanatory variable)^m, where *m* and *const* are the slope and intercept of a logarithmic relationship log(energy consumption per capita) = *m* × log(explanatory variable) + *const*, respectively. R^2 is the standard goodness of fit, that is, the proportion of the variance in per capita energy attributable to the variance in the respective explanatory variable. The Student's *t* statistic can be derived from the regression slope and its standard error according to $t = m/\sigma_m$.

Table A.3.1. Double–logarithmic regression results for some explanatory variables

	Financial support	Population	Energy price	Transport services	Total income	Indigenous income	Fuel pump price	Power rates	Air services	Supply ship services	Distance to next city	Distance to next land
Regression coefficient *m*	n.a.	–5.87E–01	–6.00E–01	2.13E–01	6.83E–01	2.81E–01	1.35E+00	–6.36E–01	9.69E–01	–5.93E–01	–1.27E+00	1.58E+00
Standard error σ_m	n.a.	1.21E–01	1.43E+00	1.15E+00	1.87E–01	4.45E–01	1.94E+00	9.03E–01	4.84E–01	2.14E–01	1.08E+00	7.92E–01
R^2	n.a.	0.92	0.08	0.02	0.87	0.17	0.20	0.20	0.67	0.79	0.41	0.67
Student's *t*	n.a.	4.86****	0.42	0.19	3.65***	0.63	0.70	0.70	2.00*	2.77**	1.18*	2.00*

Notes: Regression coefficients are significant at the confidence levels of 67% (*), 90% (**), 95% (***), and 99% (****). n.a. = not applicable because of zeros in the underlying data.

Table A.3.2. Double–logarithmic regression results for remaining explanatory variables

	Tourist income (%)	Tourist Income ($/cap)	Tourist arrivals	Tourist arrivals	Land area	Financial support	Vehicles	Fossil generation capacity	Renewable generation capacity	Renewable fraction
Regression coefficient *m*	n.a.	n.a.	4.14E–01	1.02E–01	–3.53E–01	n.a.	5.86E–01	–6.05E–01	n.a.	n.a.
Standard error σ_m	n.a.	n.a.	1.78E–01	5.10E–01	3.52E–01	n.a.	4.32E–01	6.80E–01	n.a.	n.a.
R^2	n.a.	n.a.	0.73	0.02	0.34	n.a.	0.48	0.28	n.a.	n.a.
Student's *t*	n.a.	n.a.	2.33**	0.20	1.00	n.a.	1.36*	0.89	n.a.	n.a.

Note: n.a. = not applicable because of zeros in the underlying data.

Appendix B: Portraits of Yap, Niue, Norfolk Island and Cocos (Keeling Islands) — Geography, economy, population, energy conservation and renewable energy sources

B.1. Yap

Yap, locally known as *Wa'ab*, is a cluster of islands that stretch about 900 km in the northwest Pacific Ocean, and is one of the four states of the Federated States of Micronesia (formerly the Caroline Islands). It includes Yap proper, a group of four continental islands lying within a fringing barrier reef, other islands and atolls that extend eastward, and one atoll about 130 km to the south. Yap is known as the island of stone money for the huge disks of stones that were once used as local currency.

The United States held Yap after World War II as the *Trust Territory of the Pacific Islands*, under a United Nations mandate, until 1986 when Yap became part of the independent nation of the Federated States of Micronesia (FSM) along with Chuuk, Pohnpei and Kosrae. Under the Compact of Free Association with the United States (Congress of the Federated States of Micronesia, 2005), the United States provides guaranteed financial assistance in exchange for full international defense authority and responsibilities. The Compact Agreement was designed to assist the FSM with infrastructure and the development of its economy. Infrastructure development has been successful, but the development of a self–sustaining economy has had only limited success. In fact, since 1986, the Compact has provided large external financial transfers to support operations of the Government of the FSM and substantial public sector investment at the State level.

Like that of other states in the FSM, Yap's trade is characterized by a wide gap between imports (US$ 19.7 million annual average between 1990 and 2008) and exports (US$ 6.3 million). The main export products of Yap include betel nuts, copra and marine products (Table 2). Yap also exported garments until 2005, when two garments factories closed their operations.

B.1.1. Energy issues

The Federated States of Micronesia (FSM) Department of Economic Affairs prepared a draft National Energy Policy in 1999 (FSM, 2000), but there has apparently been no work to further develop or finalize it since 2000. However, in 2008, the fluctuating fossil fuel prices have nearly led the FSM into a national emergency and this paved the way for the leadership to develop a comprehensive national energy policy in 2010 (FSM, 2010, Volume I:51), with clearly mandated national and State plans. Renewable energy, energy efficiency and conservation, and conventional energy are the three major components of the national policy framework. The main goal of renewable energy policy framework is to derive 30% of the energy supply from renewable resources by 2020, whereas energy efficiency and conservation policy framework envisages enhancing the supply side energy efficiency by 20% by 2015 and increases the overall energy efficiency by 50% by 2020. Within this national energy policy, Yap State has incorporated its action plans for 10 years, YSPSC being the principal stakeholder and implementing agency.

In the wake of 2008 fuel crisis, the YSPSC already began exploring alternative sources of energy and seeks grants from outside agencies to implement renewable energy projects that help lower the cost of power generation in the State. One such project is the electrification of Asor and Fadrai in Ulithi Atoll using mini grids powered by solar panels, the system of which are 19.5 kWp and 28.08 kWp in size respectively. This project was funded under a 9th European Development Fund (EDF 9) programme called 'Support to the Energy Sector in Five Pacific Island States' or REP–5 in short. Under the FSM Energy Policy Action Plans (FSM 2010, Volume II:83) YSPSC also adopted several action plans. Among this include plans to purchase fuel efficient 1.5 MW generators, conducting energy audits for YSPSC and government buildings, plans to electrify 7 outer islands with renewable energy and plans to install wind turbines. Very recently, the YSPSC received US$23,000 from the French Pacific Fund to implement a project titled "Supporting the development of wind energy in Yap." This project will develop the means to install wind farms across Yap Proper.

B.2. Niue

Niue is a single large raised coral atoll, with 14 villages spread around the coast of the island. It is a sovereign and self–governing nation with an exclusive economic zone (EEZ) of 390,000 km^2. Niue has been in free association with New Zealand since 1974, and all Niueans have New Zealand citizenship. Niue has had problems with population retention (Statistics Niue, 2013 and Figure 5) as about 20,000 Niueans are currently residing in New Zealand (Statistics New Zealand, 2011) — and more in Australia and elsewhere — to seek education and employment opportunities. Niue's policy of sending its young people for education in New Zealand may have exacerbated the outflow of people, as these young people did not return to Niue and chose instead to remain in New Zealand. This policy has now been changed to encourage the return of Niueans. In the Niue National Strategic Plan (NNSP) 2009-2013, the Government has set a target for a population growth rate of 1% per year (SPC, 2013), supported via health, education and social benefits, such as maternal leave with full pay.

Tourism has been identified in the NNSP as an important economic driver with the most potential for growth and development. In partnership with REEF, Niue established the Niue Fish Processing Factory in 2004 which processed fish caught in Niue waters for fresh and frozen export. However due to financial difficulties, the factory closed down.

B.2.1. Energy issues

The high reliance, volatility and high prices of international oil prices have motivated the Government to consider investment in renewable energy as a solution for Niue's future power needs. The Niue Environmental Declaration 2007 commits to pursuing a 100% renewable energy economy. Due to financial and technical constraints, Niue has outlined a phased approach for achieving the goal of renewable energy power supply increased to 20% by 2013.[13] The Niue National Strategic Plan (NNSP) 2008-2013 states that one of Niue's goals is to work towards grid stability of 20% renewable and alternative energy to total electricity power by 2013.[14]

Past experience with renewable energy technologies was limited mostly to solar water heating on government housing and hotels. A photovoltaic pumping system was installed in the mid-1990s, but the tracking system that was used for the PV panels broke down and the system became inoperable a few years after installation. A report for the Pacific Islands Renewable Energy Project for Niue, given current technological constraints, identified solar and wind as the most viable renewable energy sources for the Island. Given the protected status of forests and the lack of large plantations of economically useful tree crops, there is little opportunity for biomass to be a significant energy source.

[13] Niue Power Corporation, 2010, Niue PIGGAREP Project Activity Summary: Increasing the Impact of Grid-Connected Solar PV Generation.
[14] Niue National Strategic Plan 2008-2013 (Government of Niue 2013).

Biogas was also not considered a significant potential for emissions reduction given the population is dispersed over the area of the island and collection of manure for economically reasonable biogas generation is not reasonable and the quantity of urban waste that could be used for digestion is small.

In the late 2000s, the EU funded projects under REP-5,[15] which were aimed at reducing electricity demand by using alternative to fossil generated electricity. One project provided 240 solar water heaters at a discounted price, to offset the heating costs. However, since most homes did not use electrical water heaters for showers, this may have had a marginal effect on energy use on Niue. Another project provided gas ovens at a discounted price, aiming at displacing the use of electricity for cooking. Prior to this project, approximately half of households used LPG for cooking, with the remainder using electricity. A total of 380 stoves, including LPG cylinders and gas fittings, were installed in 2008. In addition to providing the stoves, REP-5 assisted Niue in securing a cheaper, safer, and more reliable supply of LPG by replicating a similar structure to the one used for the import of petrol and diesel.

Also under REP-5, Niue received grid–connected PV arrays for its hospital (30 kWp ground-mounted), for its high school (20 kWp roof-mounted), and for the NPC office (2 kWp roof-mounted). The combined 52 kWp of PV arrays are expected to generate 73 MWh per year, or roughly 2.4% of the current electricity consumption. Diesel fuel savings at the NPC are expected to be 18,000 l per year, which translates into a CO_2 emissions reduction of 53 tons. However recent figures show this currently accounts for 10.6% of the nation's peak load, 2% of the total electricity production, 2% reduction in fuel consumption and a reduction in greenhouse gas emissions by 48.6 metric tons per year.

Another initiative under REP-5 was an energy efficiency awareness campaign aimed at the general population has been running in parallel with the renewable energy activities to complement the reduction of electricity consumption through technological changes and to maximize the benefits of the introduction of solar PV systems to the island. REP 5 projects were expected to reduce the amount of diesel fuel used at the NPC by 188,000 L/year, and the CO_2 emissions by 437 metric tons/year.

Most recently the Niue Government, through a US$4 million grant from the Pacific Environment Community (PEC) Fund, intends to install a 200 kWp solar photovoltaic system (PV) directly to Niue's national electricity grid, as well as a battery bank to ensure an uninterrupted power supply that will stabilize the grid and allow for the installation of additional solar generators for the future. The project will complement ongoing efforts to increase renewable energy supply through a target of supplying 65% of the peak load, which will result in a 15.4% contribution to Niue's total electricity supply from solar power.

[15] http://www.rep5.eu.

B.3. Norfolk Island

Norfolk Island is the eroded remnant of a basalt volcano, formed from an elevated plateau surrounded by cliffs. The site of the original colonial settlement of Kingston is a low-lying area in the south of the Island. Government, community and recreational activities are predominantly located at Kingston, and commercial and retail activity is located in Burnt Pine in the centre of the Island. There are two smaller uninhabited Islands to the south of Norfolk Island, Phillip Island (190 ha) and Nepean Island (10 ha). The first European known to have sighted the island was Captain James Cook in 1774. The First European Settlement was established soon after with a party of convicts and free settlers. Due to the island's remoteness from the colony of New South Wales, the First Settlement was closed in 1813. The Second Settlement was established in 1825 and was solely a penal settlement and continued until 1855. The Third Settlement commenced in June 1856 with the arrival of the Pitcairn Islanders, resettled from Pitcairn Island that had become too small for the growing population. This settlement continues to this day.

Norfolk Island was included as part of the Commonwealth of Australia after the Federation of Australia in 1901. In 1979, Norfolk Island became a self-governing external Territory of Australia administered by the Norfolk Island Legislative Assembly, elected by the community. The Legislative Assembly has a range of federal, state and local governing powers. The Australian Commonwealth Government is represented on the Island by an Administrator.

Norfolk Island's internal revenue base is limited by its isolation. Since the 1960s, the Island's main industry has been tourism. Most fruit and vegetables are grown locally, since Norfolk Island prohibits the importation of fresh fruit and most vegetables. Beef is produced locally and imported. The primary exports from the Island are Kentia palm, native pine seed and seedlings. Government revenue is raised through a range of local taxes and duties and government business enterprises, such as telecommunications and electricity. There is no harbour on Norfolk Island and sea freight and cruise passengers are unloaded at jetties located at Kingston and Cascade Bay.

Since visitor numbers started decreasing in 2001, there has been a continual decline in the population due to a reduction in tourism income. In recent times, the island has undergone severe financial hardship due to the global economic crisis, triggering a further fall in tourist numbers. Unemployment is currently 2% compared to 5% for the rest of Australia (Deloitte Access Economics, 2011), however there are no unemployment benefits on Norfolk Island, and as a result, many people have left the Island and sought employment in the Australian mining sector. The decline in

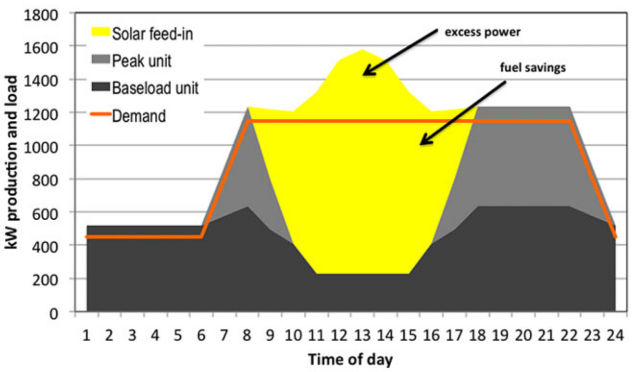

Figure B.1. Electricity production and load profile on Norfolk Island.
Source: Authors' own measurements during field work.

tourism activity has had a substantial negative impact on local incomes, and has resulted in a serious deterioration in the financial position of the Norfolk Island government. As a consequence, the Norfolk Island Government appealed to the Australian federal Government for assistance in 2010. It has been suggested that without Commonwealth government assistance the Norfolk Island Government would have run out of money to pay suppliers by June 2011 (Administration of Norfolk Island, 2011b). The Commonwealth and Norfolk Island Governments are working collaboratively to implement legislative and governance reforms to ensure Norfolk Island's future financial sustainability. The changes have commenced but are not completed, there is a programme of reforms to be undertaken up to July 2014; but the process is underway (Administration of Norfolk Island, 2011c).

B.3.1. Energy issues

In the long term, Norfolk Island's dependence on diesel fuel for electricity generation is viewed as environmentally, economically and socially unsustainable. Norfolk Island has been identified as a prime location for the use of three major renewable energy resources (solar, wind and wave power), however only solar–generated energy has been implemented to date.

The main challenge for the Norfolk Island Electricity Department in accepting small or large–scale alternative energy sources is to maintain the reliable functioning of the diesel engines for backup purposes. This is especially problematic as the alternative energy sources are intermittent, or affected by sporadic failure. At the time of writing the Norfolk Island grid experienced a mid-day 1.35 MW peak load fed in by solar generators scattered across the island, with the result of significant reduction in fuel use at the power plant, but on the other hand problems due to a mid-day excess solar generation of up to 0.4 MW, creating grid instability and overload (Figure B.1).

Further, the maintenance cost for the electricity system represents a fixed cost that does not decrease if power demand decreases. It would always be necessary to maintain diesel-generated power back up with associated fixed maintenance costs. This poses a barrier to introducing any intermittent alternative energy source, since the electricity price is likely to increase to cover the fixed maintenance costs of the diesel generated power system as well as the costs associated with the introduction and maintenance of an alternative source of power generation.

An ideal energy transition would be a reliable, base-load-type reduction of power demand. Norfolk Island Electricity recognizes the importance of symbiotic systems for small island sustainability. A major issue that has been identified at the Norfolk Island power house is that most of the fuel is in waste heat and although the power house demonstrates efficiency there is a large component of waste heat. It has been identified that the waste heat is an untapped resource and there are options for its use. For example, the waste heat from the power house could be used to provide energy to operate centralized cool stores. Refrigeration is by far the main end-use of electricity. There are other needs for heat, for example, for sterilization, cleaning, drying, laundry, etc.

B.4. Cocos (Keeling) Islands

The Cocos (Keeling) Islands consist of 27 coral islands, with two of the Islands inhabited, Home Island and West Island. North Keeling Island and the surrounding marine area around the Island form the Pulu Keeling National Park, established in 1995. It is an important example of an atoll in its natural state and supports an internationally significant seabird rookery. It is also home to land crabs, turtles, and a range of flora. Discovered by Captain Keeling in 1609, the Clunies-Ross family settled in the Cocos (Keeling) Islands in the 1820s and established a copra production industry. The labour force was drawn from Asia, particularly Malays, to work the plantations. Most of the settlement and copra production was based at Home Island. In 1857, the Islands were declared part of the British dominions and, in 1886, Queen Victoria granted the Islands to the Clunies-Ross family. The Islands became a Territory of Australia in 1955 as part of the Australian Indian Ocean Territories. The Australian Commonwealth has overall responsibility for the Islands including arrangements for the provision of state–type government services provided by Western Australian Government agencies. Local government functions and responsibilities are administered by the Cocos (Keeling) Islands Shire Council which was first elected in 1993 (Australian Government, 2010d).

The population on the two inhabited islands is generally split between European Australians on West Island and Cocos Malays at Home Island. The main language spoken is a Cocos dialect of Malay and English. About a quarter of the population speaks English at home (ABS, 1999). The

Cocos Malays descend from people brought to the Islands to work in the copra plantations in the 1800s. The European Australians at West Island are mainly employed in public service on short term postings for up to three years. In recent years, more people have settled on West Island to run small businesses. Economic activity on the Cocos (Keeling) Islands is limited, with the public sector providing the majority of employment in administration, education, health and local government services. The largest private sector activity is community services. Small businesses provide a range of goods and services including accommodation and tourism, which is a small but growing industry. Most food supplies and general necessities are shipped from Australia or elsewhere. Local food production is limited to domestic fruit and vegetable cultivation and fishing.