Regional Status Report on Efficient Lighting in Pacific Island countries and territories

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Regional Status Report on Efficient Lighting in Pacific Island Countries and Territories

Prepared for the Energy Programme, Economic Development Division of the Secretariat of the Pacific Community

Prepared by George Wilkenfeld and Associates Pty Ltd,

Energy Policy and Planning Consultants

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About the UNEP/GEF en.lighten initiative

The United Nations Environment Programme (UNEP)/Global Environment Facility (GEF) en.lighten initiative promotes and coordinates global efforts in the transition to energy efficient lighting. Its mandate is to accelerate the global commercialisation and market transformation of efficient lighting technologies by providing technical and policy support to countries. In doing so, it aims to strengthen capacities among governments, the private sector and civil society to lead successful lighting market transformation programmes around the world. The initiative has set a target for the phase-out of inefficient incandescent lamps globally by the end of 2016. For more information about the UNEP/GEF en.lighten initiative please visit: www.enlighten-initiative.org

About the SPC

The Pacific Community is an international organisation with 26 member countries and territories. Through its secretariat, the Pacific Community provides the Pacific Islands region with essential scientific and technical advice and services in sectors including sustainable development of fisheries and agriculture resources, food security, disaster risk reduction, energy, geoscience, transport, public health, education, human rights, gender, youth, culture, statistics, and water and sanitation. To achieve genuine and lasting improvement in people's lives, the focus of the Secretariat of the Pacific Community (SPC) is on delivering integrated services that address national and regional development challenges. Its goals are: the Pacific region and its people benefit from inclusive and sustainable economic growth; Pacific communities are empowered and resilient; and Pacific Island people reach their potential and live long and healthy lives.

In August 2010 at the 41st Pacific Islands Forum the Forum Leaders endorsed the Framework for Action on Energy Security (FAESP) 2010-2020 as the regional blueprint for the provision of technical assistance to the energy sectors of Pacific Island countries and territories (PICTs). FAESP encompasses the Leaders' vision for an energy-secure Pacific, where Pacific people at all times have access to sufficient sustainable sources of clean and affordable energy and services to enhance their social and economic well-being.

In April 2014, Ministers and officials responsible for energy and transportation ministries and departments from 10 PICTs, in a meeting in Fiji, noted that energy efficiency is a cost-effective way to address the increasing energy intensity of developing economies in the Pacific. They endorsed, among other initiatives, SPC-UNEP's efforts to develop a detailed regional strategy for the transition to efficient lighting in PICTs.[1]

1 http://www.spc.int/edd/en/document-download/finish/76-edd-reports/1377-energyministersresolutionenglish

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Acknowledgement

The Regional Status Report on Efficient Lighting in the Pacific Island Countries and Territories was prepared by George Wilkenfeld and Associates, Energy Policy and Planning consultants, Australia for the Pacific Efficient Lighting Strategy (PELS) Project managed by the Secretariat of the Pacific Community (SPC).

The report covers most of the SPC PICTs and benefitted from surveys and data collected by the Promoting Energy Efficiency in the Pacific – Phase 2 (PEEP 2) Project and the Pacific Appliance Labelling and Standards (PALS) Program. Their assistance is gratefully acknowledged.

The cooperation of the United Nations Environment Program (UNEP) en.lighten initiative in jointly working with SPC and contributing to the preparation of this report is also acknowledged.

SPC would like to thank Australian Aid for funding the preparation of this report.

Abbreviations

ADB	Asia Development Bank
AusAID	Australian Agency for International Development
BAU	Business as usual
CFL	Compact fluorescent lamp
FSM	Federated States of Micronesia
GDP	Gross domestic product
GEF	Global Environment Facility
GWA	George Wilkenfeld and Associates
HH	Household
HPS	High pressure sodium
IIEC	International Institute for Energy Conservation
IL	Incandescent lamp
LED	Light-emitting diode
LFL	Linear fluorescent lamp
LV	Low voltage
MEPS	Minimum energy performance standards
MV	Mains voltage
MVH	Mains voltage halogen
NA	Not available
NPV	Net present value
PALS	Pacific Appliance Labelling and Standards program
PELS	Pacific Efficient Lighting Strategy
PEEP 1	Promoting Energy Efficiency in the Pacific – Phase 1
PEEP 2	Promoting Energy Efficiency in the Pacific – Phase 2
PICT	Pacific island countries and territories
PNG	Papua New Guinea
PV	Photovoltaic
SPC	Secretariat of the Pacific Community
TV	Television
UNEP	United Nations Environment Program
USD	United States dollar
yr	Year

Executive summary

This report reviews the status of lighting energy use and programs to increase the energy-efficiency of lighting services in the Pacific Region. It was commissioned by the Secretariat of the Pacific Community (SPC) as part of a joint project with the United Nations Environment Program (UNEP) en.lighten initiative.

The aim of the report is to examine the:

* lighting technology and energy use in Pacific island countries and territories (PICTs);
* efficient lighting policies and regulations in place in the region; and
* efficient lighting programs and projects under way.

This will be followed by the development of a regional Pacific efficient lighting strategy (PELS) which will detail the priority policies and frameworks to be implemented, identify opportunities for regional or bilateral cooperation and indicate a sustainable financing plan including the potential for public-private partnerships.

This report covers the PICTs which are members of the SPC.[2] These vary widely in their populations, incomes, levels of electrification and consumption of energy services, including lighting. The total population covered is over 10 million people, of whom more than two thirds live in Papua New Guinea (PNG). About 35% live in households with access to mains voltage electricity, either from the grid or from local generators. However, the rates vary from near 100% in several PICTs to 12-13% in PNG and the Solomon Islands.

Modelling in this report indicates that lighting accounts for over 18% of household electricity use, 14% of non-household electricity use and nearly 15% of all electricity use in the Pacific region.

Although electrification rates, supply systems and generation fuel mixes vary between PICTs and within them, they nearly all have one attribute in common: the marginal electricity generation source is imported diesel fuel. This applies also to those PICTs which have significant hydro and other renewable energy resources. The economic and energy security value of increasing the energy efficiency of lighting and other end uses is therefore high.

The quality and quantity of data on energy use is relatively high by the standards of developing countries, due to the long term efforts of the PICTs, with the help of the development partners such as SPC. This report is also fortunate to draw on recent surveys and data collection by the Promoting Energy Efficiency in the Pacific – Phase 2 (PEEP 2) and the Pacific Appliance Labelling and Standards (PALS) programs.

Pacific regional households generally fall into the following typical lighting categories:

i. access to a grid that supplies electricity 24 hrs/day (or close to it). These households use mains voltage (MV) lights;
ii. access to generators that run for part of the night. These households have MV lights installed and use them while the generator is running. At other times, or for areas beyond the reach of the MV wiring, they may use portable lamps;
iii. access to fixed solar photovoltaic (PV) systems with battery backup. These households have low voltage (LV) lamps and possibly other low voltage appliances as well. When the storage is depleted, or for areas beyond the reach of the LV wiring, they may use portable lamps;
iv. households entirely dependent on portable lamps, of which there may be several in each household. These include lights with small solar cells on the body of the lamp and also non-electric lights such as kerosene lanterns.

2 With the exception of North Marianas, Guam, Pitcairn Island, Tokelau and American Samoa. These PICTs are not regular participants in the Pacific Appliance Labelling and Standards (PALS) program or other energy efficiency projects and are excluded from this report as there are no data available.

The number of fixed lamps in electrified households is relatively low. Detailed lighting surveys in the Cook Islands, PNG, Samoa, Tonga and Vanuatu suggest a regional average of about seven lamps per electrified household, and annual lighting consumption of 200-300 kWh (outside the French-speaking PICTs, which have much higher average income and electricity use than the others). This represents 16-26% of household electricity use, similar to the share used by refrigerators and freezers.

Lamp numbers vary significantly between households in the same PICT. This suggests there is considerable potential for growth in the consumption of lighting services in PICT households, through acquisition of more lamps and increasing the number of spaces lit per home, so it is important to ensure that this growth occurs in an energy-efficient way.

The dominant lamp type in household lighting is linear fluorescent lamps (LFL), about equally divided between 2 ft (610 mm) and 4 ft (1220 mm) tubes. In Vanuatu, the only PICT where data are available, T12 tubes – the least efficient type – predominate over T8 and T5. As most linear fluorescent lamps in use have ferro-magnetic rather than electronic ballasts, ballasts make up a surprisingly high 16-17% of total household lighting energy use.

In the four PICTs where detailed data are available, linear fluorescent lamps and their ballasts make up an estimated 70% of household lighting energy. While linear fluorescent lamp use predominates in all surveyed PICTs, the balance between incandescent lamps (ILs) and compact fluorescent lamps (CFLs) differs. On average about 18% of household lighting energy is used in incandescent lamps and 11% in CFLs. The use of light emitting diode (LED) tubes, LED lamps and mains voltage halogen (MVH) lamps in households appears to be negligible.

The data on street and outdoor lighting available from PEEP 2 indicate that the average potential for energy savings is about 280 kWh/year per lamp – about the same as the total lighting use of the average PICT household.

Lighting use in commercial and government buildings is the most difficult to estimate Even though lamp audits of particular buildings are expected to accumulate as PEEP 2 projects proceed, there will still be many uncertainties regarding the hours of operation of buildings and lamps, the total floor area of commercial buildings and how representative each building is of its own type, let alone other types (e.g. hotel lighting patterns are completely different from hospital and office lighting).

This report calculates the theoretical potential for electrical energy savings from increasing the efficiency of lighting in the Pacific region, compared with the current pattern of use, and given realistic rates at which savings could be realised. It is estimated that for the region as a whole:

- the savings in MWh delivered to end users over the period 2015-2030. This totals about 3.41 million MWh (3,410 GWh). The savings in electricity generated would be about 15% higher, due to transmission and distribution losses;
- the fuel costs avoided. This totals USD 1,019 million, of which nearly half is attributable to PNG;
- the other generation costs avoided (i.e. capital, operation and maintenance). This totals USD 153 million;
- the stream of savings, discounted at 7% (ie a saving next year is worth 7% less than a saving this year, a saving the year after is worth another 7% less and so on). On this basis the net present value (NPV) of total savings is USD 626 million, compared with the undiscounted value of USD 1,172 million;
- the savings in fuel imports amount to 1.35 million kilolitres (1.35 gigalitres); and
- the saving in greenhouse gas emissions associated with generation fuels amount to 3.72 million tonnes.

Consequently, there would be costs involved in achieving these savings. More efficient lamps, ballasts and luminaires cost slightly more to purchase than their less-efficient counterparts, although the cost differential is closing over time. It is not possible to estimate costs until the PELS is developed, because:

- it is possible to achieve energy savings either cheaply (e.g. by substituting a CFL for an incandescent lamp) or in a more costly way (by substituting an LED for a CFL);
- some technologies may not be adopted without policy intervention – e.g. mains voltage halogen lamps, which are 30% more efficient than incandescent lamps, would probably not gain significant market share in the Pacific region without mandatory lamp efficacy standards;
- the share of the potential energy benefit that is taken up as increased lighting services will depend on specific programs and policies; and
- efficient lighting programs may themselves involve both administrative and labour costs, and some additional economic cost, if working lighting is discarded prematurely rather than at the end of its natural service life.

However, the costing of lighting projects now under way indicate that Pacific region lamp substitution and replacement projects usually pay back within 12-18 months, so there is little doubt that a highly cost–effective regional efficient lighting strategy can be devised in due course.

1 Introduction

The en.lighten initiative

In the Pacific region, increased efficiency in the use of electricity is a fundamental component of achieving the region's "Sustainable Energy for All" objectives.[3] The market transition to efficient lighting in the region will, among others, result in making best use of available electricity and best available and appropriate technology to provide quality lighting service to consumers, as well as extending access to modern lighting services to more households, both on and off-grid.

Despite the limited contribution of Pacific countries to global climate change, the region suffers disproportionately from the adverse consequences. The lighting sector significantly contributes to the region's greenhouse gas emissions, as lighting represents a large share of total energy consumption and electricity generation is predominantly based on petroleum fossil fuels.

The global transition to advanced lighting requires coordinated efforts from governments, regional organisations, the private sector, development agencies and international financial institutions. It also requires the definition of strategies and the identification of actions needed to drive an accelerated switch to energy efficient lighting in all sectors at the global, regional and national levels.

In 2009 UNEP, together with the Global Environment Facility (GEF) and the private sector launched the en.lighten initiative. This public-private initiative aims to support countries to promote technologies with high performance and high energy efficiency, highlight best practices in developing and emerging countries, develop a comprehensive strategy to phase out inefficient and obsolete products to reduce emissions of greenhouse gases from the lighting industry, and replace traditional light sources with efficient alternatives, taking into account the environmentally sound management of products at the end of their life.

Several initiatives have been pursued in Pacific island countries and territories to promote the use of more efficient lighting technologies, including the coverage of lighting products in the Pacific Appliance Labelling and Standards (PALS) program, established in 2012. In early 2014, the Secretariat of the Pacific Community (SPC) agreed to collaborate with UNEP en.lighten to phase out inefficient incandescent lamps in the Pacific and ambitious policy changes through the development and implementation of a Pacific Efficient Lighting Strategy. This was endorsed by Pacific regional energy and transport ministers in April 2014.[4]

3 http://www.spc.int/fr/component/content/article/1608-pacific-launch-of-the-united-nations-decade-of-sustainable-energy-for-all.html
4 http://www.spc.int/en/component/content/article/216-about-spc-news/1660-energy-efficiency-discussions-elevated-at-regional-meeting-.html

Report scope

This regional status report is the first step in the development of PELS. It reviews the status of lighting energy consumption, technologies, markets and programs to increase lighting energy-efficiency in the Pacific Region.

The aim of the report is to examine the:

- lighting technology and energy in Pacific Island countries and territories (PICTs);
- efficient lighting policies and regulations in place in the region; and
- efficient lighting programs and projects under way.

The report covers most of the PICTs which are members of the SPC.[5] These vary widely in their populations, incomes, levels of electrification and consumption of energy services, including lighting. The total population covered is over 10 million people, of whom more than two thirds live in Papua New Guinea, where electrification rates are very low (see Table 1).The scope of the report includes residential, non-residential (commercial, accommodation and government) and outdoor/street lighting. The report will help PICTs identify priorities and will serve as a baseline for the future development of PELS.

Sources of information

The quality and quantity of data on energy use is relatively high by the standards of developing countries, due to the long term efforts of the PICTs, with the help of the SPC and aid donors. This report draws on a range of sources, some published as reports (indicated in the bibliography), some published on the Internet (generally footnoted) and others unpublished. The most important sources are:

- The documentation from the Asia Development Bank (ADB)-funded program Promoting Energy Efficiency in the Pacific (PEEP), phases 1 (PEEP 1) and 2 (PEEP 2). This documentation includes surveys on lighting technology and use undertaken in the Cook Islands, PNG, Samoa, Tonga and Vanuatu by the International Institute for Energy Conservation (IIEC). At present PEEP 2 has 33 technology deployment projects under way, 26 of which involve lighting.

- The documentation from the Pacific Appliance Labelling and Standards (PALS) program, funded by the Australian Agency for International Development (AusAID). This includes research on product trade flows carried out by the IIEC.

- The Cook Islands 2011 Census of population and dwellings, which includes a complete count of lamps in Cook Islands households.

- Information about PEEP 2 and other efficient lighting programs in the Pacific, provided by Peter Johnston, Director of Environmental and Energy Consultants Ltd, Suva

5 With the exception of North Marianas, Guam, Pitcairn Island, Tokelau and American Samoa. These PICTs are not regular participants in the Pacific Appliance Labelling and Standards (PALS) program or other energy efficiency projects and are excluded from this report as there are no data available.

2 Background

Pacific Island Countries

The island states of the Pacific region are generally grouped as follows:

- Melanesia, comprising Fiji, New Caledonia, PNG, Solomon Islands and Vanuatu;
- Polynesia, comprising Cook Islands, Niue, Samoa, Tonga, Tuvalu, French Polynesia and Wallis and Futuna;
- Micronesia, comprising Marshall Islands, Federated States of Micronesia (FSM), Palau, Kiribati and Nauru.[6]

For the purpose of analysing energy use in general, and lighting in particular, there are other factors overlaying these groupings:

- the north Pacific group: Marshall Islands, FSM and Palau have historical ties to the USA, and have mainly (but not exclusively) 110V, 60 Hz electricity supply systems;
- the Francophone group: French Polynesia, New Caledonia and Wallis and Futuna have ties to France, use European/Oceania electricity supply standards (230V, 50Hz), have a relatively high GDP per capita, near-complete electrification, and import a high share of their appliances and lighting products from Europe.
- the largest group, comprising both Polynesian and Melanesian PICTs in the south Pacific, uses 230V, 50Hz electricity supply, and has historically imported many of its appliances and lighting products from Australia and New Zealand.

All regional appliance markets have changed significantly over the past decade, with more products coming from China and other Asian countries.

Table 1 summarises the main population, electrification and economic parameters for the 17 PICTs covered in this report. The PICTs are arranged in energy/economic groups, with the three Francophone countries and the three 110 V Micronesian countries in the north Pacific grouped separately. The data are heavily skewed by PNG, which accounts for over two thirds of the regional population. Therefore total and average values are calculated with and without PNG. The Francophone countries also form a distinct group in terms of GDP and electrification rates, and removing them from the totals gives a more representative indication of the typical and average conditions in the other PICTs.

6 The PICTs listed are all members of the Secretariat of the Pacific Community (SPC). North Marianas, Guam, Pitcairn Island, Tokelau and American Samoa are also SPC members, but not regular participants in PALS or other energy efficiency projects. As there are no data on these PICTs they are not covered in this report.

Energy, electrification and electricity use

There are many different ways to measure rates of electrification. The most commonly used measure for the Pacific is the proportion of households that have access to mains voltage alternating current (AC) electricity from the grid or from a local generator, for sufficient hours per day (and night) to operate lights, a television and possibly a refrigerator and other small appliances. All PICTs have electricity grids serving their main islands and population centres, but electrification rates decline with remoteness. Many outlying villages have no generators at all.

The total population of the region is over 10 million people, of whom more than two thirds live in Papua New Guinea (PNG). About 33% live in households with access to mains voltage electricity, either from the grid or from local generators. However, the rates vary from near 100% in several PICTs to 12-13% in PNG and the Solomon Islands (Table 1).

With the evolution of PV and battery storage technology it is now possible to supply lighting, televisions, mobile phone recharging and highly energy-efficient refrigerator loads off the grid. Renewable energy generation is combined with fossil fuel generation in many PICTs, either by feeding hydro, PV or wind generation into the main grid or in remote systems which combine small diesel generators, PV and storage batteries. Several PICTs have significant hydro resources, many of which were developed decades ago, and which are used to the full extent that rainfall variability permits. More recently, there has been considerable investment in 'new' renewables such as PV, wind, biomass and bio-diesel. Renewable generation investments tend to be capital intensive and energy-constrained, in that the initial design determines the maximum energy output. In virtually all cases however, the *marginal* generation fuel is diesel. If an electrified household uses or saves a kWh at the margin, that kWh would almost certainly have to be generated by diesel, whether burned in a grid-connected power station or in a small local diesel generator. In that respect diesel generation is not energy-constrained in the short term, even though all of the fuel has to be imported.

For these reasons, the economic value of energy-efficiency programs in the PICTs that target electrified households or businesses is assessed against the cost of the diesel that would have been required to generate the energy saved (SPC 2011). The economic benefits of measures that target fully renewable off-grid forms of electricity supply and use (e.g. PV with or without batteries) are assessed in different ways.

Table 1 summarises the electricity consumption of the PICTs covered. PNG is by far the largest producer of electricity, with 96% for non-residential use – mainly for large mines and resource developments. Fiji and the Francophone countries also have large non-residential electricity loads. Excluding PNG, the household sector accounts for about 36% of total PICT electricity use.

Table 1 Main population, electrification and economic indicators for Pacific Island Countries and Territories

	Population	Households (HH)	Persons/ HH	Share of HH electrified	HH with electricity	HH without electricity	KWh/HH per year	Total Res GWh/year	Non-Res GWh/year	GDP M USD	GDP/Cap USD
Cook Islands	19,500	4.7	4,141	97%	4,020	121	2,342	9.4	15	337	17,300
Fiji	944,720	4.9	191,589	70%	134,112	57,477	1,770	237.3	542	4,440	4,700
Kiribati	112,850	7.5	15,087	51%	7,695	7,393	1,173	9.0	8	256	2,265
Nauru	10,084	3.5	2,885	99%	2,851	33	4,500	12.8	2	110	10,874
Niue	1,611	5.8	280	100%	280	-	4,158	1.2	2	22	13,875
Papua New Guinea	7,300,000	9.7	752,577	12%	92,000	660,577	1,430	131.6	2180	15,290	2,095
Samoa	219,998	8.7	25,150	96%	24,245	905	1,500	36.4	53	984	4,472
Solomon Islands	595,613	5.2	115,077	13%	14,960	100,117	1,016	15.2	56	1,348	2,264
Tonga	120,898	6.5	18,624	87%	16,203	2,421	1,206	19.5	25	546	4,518
Tuvalu	12,373	4.9	2,514	98%	2,475	39	1,197	3.0	2	48	3,861
Vanuatu	243,304	4.1	59,716	22%	13,138	46,578	1,582	20.8	38	1,046	4,300
Federated States of Micronesia	107,434	6.3	17,138	50%	8,516	8,622	3,882	33.1	20	348	3,235
Marshall Islands	64,522	3.4	18,818	70%	13,173	5,645	3,000	39.5	9	215	3,325
Palau	20,796	5.0	4,177	99%	4,132	45	5,575	23.0	54	246	11,810
French Polynesia	259,706	3.9	67,179	99%	66,451	728	2,880	191.4	380	6,567	25,285
New Caledonia	245,580	3.5	69,834	99%	69,077	757	4,000	276.3	438	8,951	36,448
Wallis & Futuna	14,944	5.0	2,975	99%	2,945	30	3,000	8.8	8.0	57	3,800
TOTAL	**10,293,933**	**7.5**	**1,367,762**	**35%**	**476,273**	**891,489**	**2,243**	**1068.3**	**3832.4**	**40,810**	**3,964**
Francophone PICTs	520,230	3.7	139,987	99%	138,473	1,514	3,441	477	826	15,574	29,937
Total excl PNG	2,993,933	4.9	615,184	62%	384,273	230,912	2,438	936.7	1652.0	25,520	8,524
Total excl Francophone	9,773,703	8.0	1,227,774	28%	337,800	889,975	1,752	591.8	3006.6	25,235	2,582
Total excl PNG and Francophone	2,473,703	5.2	475,197	52%	245,800	229,397	1,872	460.2	826.2	9,945	4,020
PICTs with lamp data (a)	603,700	5.6	107,632	54%	57,606	50,026	1,495	86.1	130.8	2,914	4,826

Source: World Bank, Asia Development Bank http://www.adb.org/key-indicators/2011/part-iii-regional-tables and SPC Prism database http://www.spc.int/prism/. Most data for 2012, but varies (a) See Table 2.

3 Existing lighting use

Residential

PICT households generally fall into the following typical lighting categories:

i. access to a grid that supplies electricity 24 hours/day (or close to it). These households use mains voltage (MV) lights;

ii. access to generators owned by a village, group of households or single household, that is run part of the time (and usually for part of the night). These households have MV lights installed and use them while the generator is running. At other times, or for areas beyond the reach of the MV wiring, they may use portable lamps;

iii. Access to fixed solar PV systems with battery backup, owned by a village, group of households or single household. These households have low voltage direct current (LVDC) lamps, and possibly other LV DC appliances as well. When the storage is depleted, or for areas beyond the reach of the LV wiring, they may use portable lamps;

iv. Households entirely dependent on portable lamps, of which there may be several in each household. The most common types are:
   a. Kerosene lanterns;
   b. 'Solar lanterns': these may have a small PV cell (and battery) on the body of the lamp/battery itself or a separate PV cell that the lantern/battery assembly can be plugged into for daytime recharging. The system may also be capable of recharging other small power devices, such as radios or mobile phones;
   c. Battery lanterns.

The amount of lighting services that households consume is constrained by the voltage, quality and quantity of electricity supply available, and the lighting technologies locally available as well as the income of the household and the price of energy.

Number of lamps

The number and type of fixed lamps per electrified dwelling is a reasonable first approximation of the access to lighting services in category 1 and 2 households.

Lamp count data are available from recent surveys in the Cook Islands, PNG, Samoa, Tonga and Vanuatu. In fact there are three separate surveys for Cook Islands – a pilot survey of 50 Rarotonga households by PEEP 1, the 2011 census of all households and 2013 survey by IIEC, all giving different results (Table 2).

Table 2 Average number of lamps in electrified households, selected PICs

	Vanuatu (IIEC)	Samoa (IIEC)	Tonga (IIEC)	PNG (IIEC)	Cook Is (PEEP 1)	Cook Is (census)	Cook Is (IIEC)	Weighted average	Lamp share
HH surveyed	1,438	1,000	500	756	50	4,372	162	406,239(a)	
CFL	2.1	1.6	1.6	0.1	4.3	5.0	11.0	1.9	29%
Linear Fluorescent	1.8	4.8	3.7	6.9	2.9	2.3	5.5	3.6	53%
Incandescent	0.5	0.5	2.1	0.1	4.0	2.7	3.0	1.1	16%
LED and other	0.1	0.1	0.0	0.1	0.3	0.5	0.2	0.1	2%
Total lamps	4.5	7.0	7.4	7.2	11.5	10.6	19.7	6.8	100%

(a) Electrified households in region (excluding Francophone PICTs and PNG) – see Table 1.

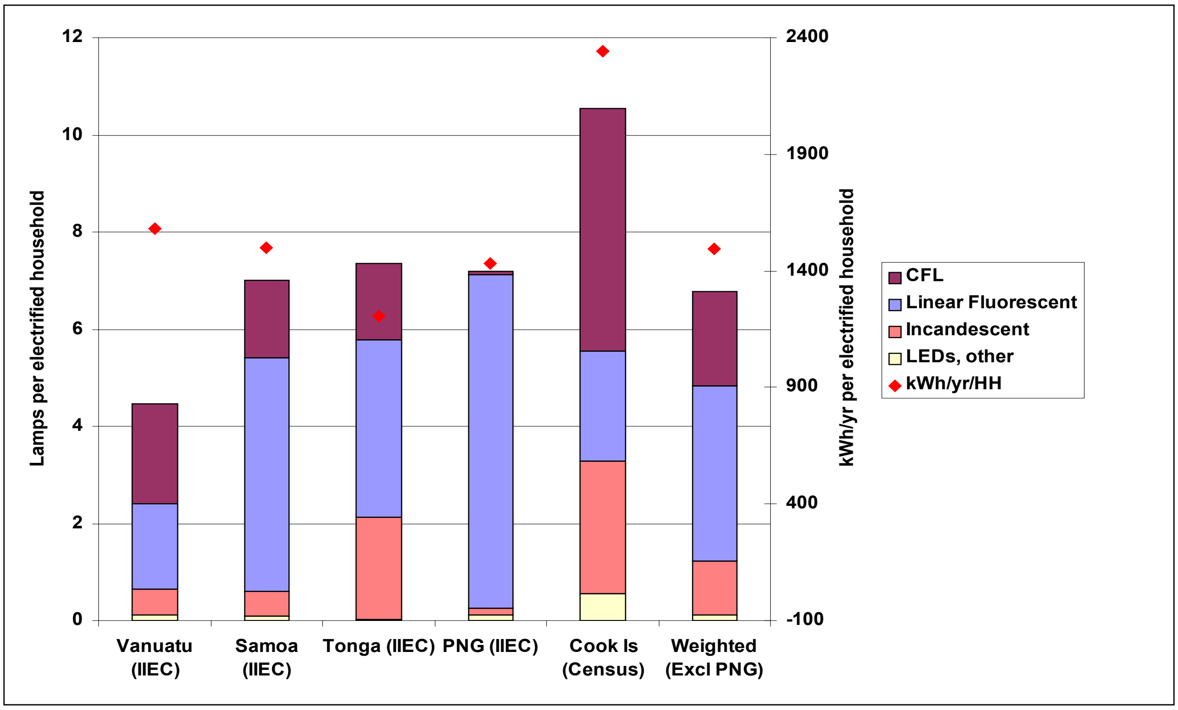

Figure 1: Average number of lamps in electrified households, selected PICs

The large discrepancy in the Cook Island lamp counts is somewhat puzzling. The IIEC surveys all used similar questionnaires, so the identification of lamp types should be reasonably consistent. However, the Cook Islands census also involved trained census-takers actually counting lamps in dwellings.

The Cook Islands have higher average household electricity use than the other PICTs (Figure 1) as well as higher GDP per capita (Table 1). This would be consistent with higher consumption of lighting services (more lamps and longer operation) as well as of other household energy services, but not necessarily by such a wide margin. The simplest explanation would be that IIEC's Cook Islands sample – the smallest sample in the surveys – was non-random and unrepresentative. This hypothesis is strengthened by the PEEP 1 pilot survey, which preceded the 2011 census but gave a much closer result to it (Table 2). Therefore it will be assumed that the census lamp count is correct.

PNG is an outlier in several ways. The household lighting sector is dominated by linear fluorescent lamps, and the use of single-cap lamps (incandescent, CFL or LED) is negligible. The average household electricity use is also far lower than the other PICTs.

The lamp count data in Table 2 are illustrated in Figure 1, along with the estimated electricity consumption per electrified household. It is assumed that the pattern of lighting use in Vanuatu, Tonga, Samoa and the Cook Islands is fairly representative of the region, but that PNG and the Francophone PICTs are outliers (at the lower and upper range of lighting energy use respectively). The average lamp count across these four PICTs weighted by the number of electrified households is indicated in Table 2 and Figure 1.

These data indicate that linear fluorescent lamps (LFLs) account for more than half the lamps installed in electrified households in the region and CFLs for about three in ten lamps. Incandescent lamps account for less than one in six lamps, and LEDs are virtually unknown.

Apart from the lamp counts, the IIEC surveys reveal some additional data (Table 3). The shorter 2 foot (610 mm) linear fluorescent lamps account for nearly half of all linear fluorescent lamps in Samoa and more than half in Tonga and Cook Islands, but only 26% in PNG. The rest are 4 foot (1220 mm) units. The share of LFLs with electronic ballasts, as distinct from ferro-magnetic or 'iron' ballasts, is barely 1% in Samoa but 20% on Tonga.

The data indicate that a high proportion of linear fluorescent lamps in Vanuatu are T12 (38mm diameter), which are being phased out in many lighting markets – they are no longer manufactured in the United States of America, for example.[7] The slimmer, more energy efficient T8 (26mm) and T5 (16mm) linear fluorescent lamps account for less than a third of installed linear fluorescent lamps. However, this may be an artefact of lamp life, and as old linear fluorescent lamps fail they may be replaced by T8s as a matter of course because T12s will become hard to obtain.

In Vanuatu, over a third of the CFLs in households use have separate ballasts, so when the tube fails it can only be replaced with another special tube having the same pin coupling. By contrast, only 1% of CFLs in Tonga are of this type. Nearly all CFLs have integrated ballasts, and either screw or pin connections that make them interchangeable with incandescent and LED lamps. Many CFLs were of low quality (PEEP 2 2014).

Table 3 Additional data from IIEC surveys

	Vanuatu	Samoa	Tonga	Cook Is	PNG
2ft LFL/Total LFL	NA	44%	63%	64%	26%
Electronic/total LFL ballasts	NA	1%	20%	NA	12%
Separate /total LFL ballasts	37%	NA	1%	NA	NA
LFL - T12	68%	NA	NA	NA	NA
LFL - T8	25%	NA	NA	NA	NA
LFL - T5	7%	NA	NA	NA	NA

NA = Not Available

7 http://www.p-2.com/helpful-information/blog/394-t12-phase-out-in-july-/NA

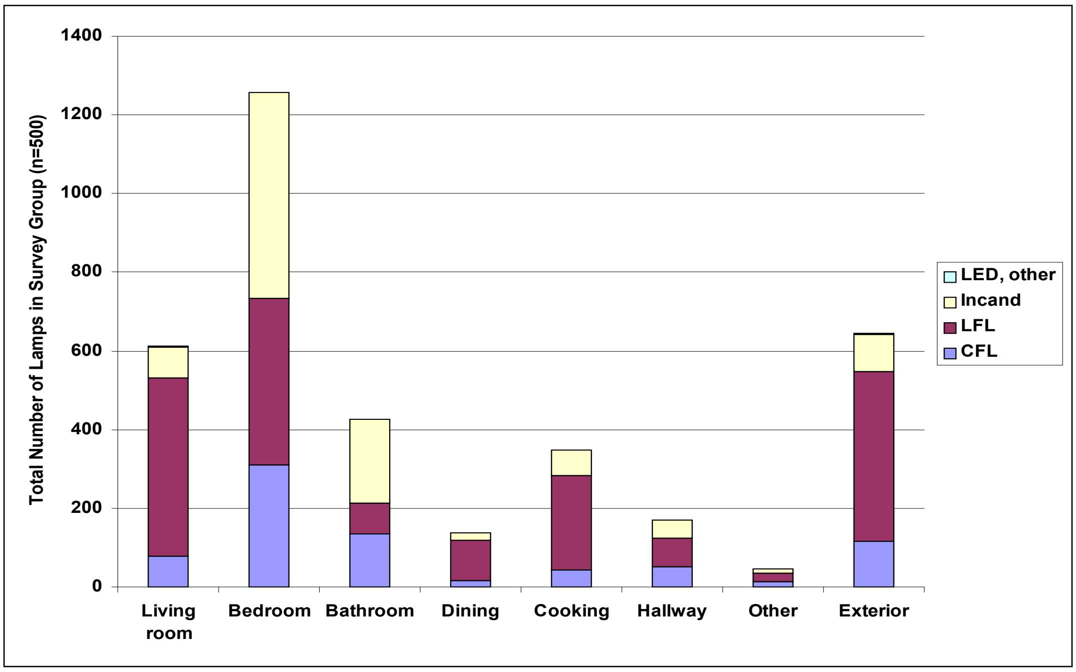

Figure 2: Distribution of lamps by room, Tonga Source: Tonga (2014)Usage

Usage

The energy used by each lamp depends on the length of time it is used, and this is often related to the space where the lamp is installed. Living areas tend to be occupied for longer than bedrooms and bathrooms, for example. Figure 2 and Figure 3 indicate the number and types of lamps in each space for Tonga.

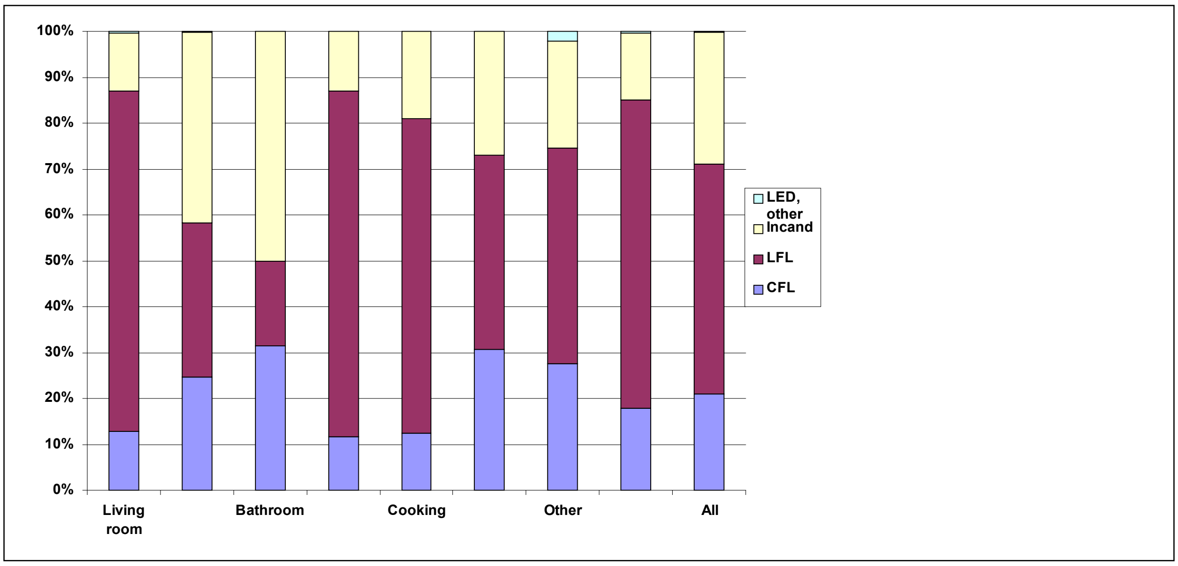

Figure 3: Lamp types by room, Tonga Source: Tonga (2014)

Some of the IIEC surveys also contain data on the wattage of lamps (presumably as recorded by the researchers) and the hours per day of lighting use reported by occupants. The data for Tonga are detailed enough to break down by room (Figure 2). The reported average wattage varies from about 28W in hallways to about 40W for exterior lights, and the average lamp usage from 2 hrs/day bathrooms to 6.4 hrs/day for external lighting, which would be consistent with overnight security use.

However, it should be noted that hours of use are notoriously difficult to recall accurately, as indicated by the wide range – from a reported average of 2.0 hrs. /day per lamp in Samoa to 5.7 hrs/day in Vanuatu (Table 4). There is greater consistency in the lamp wattages estimated (22W to 30W). The researchers would not have been able to observe the ballast wattages, so IIEC applied an inclusive wattage estimate to take external ballast load into account. As Table 4 indicates, external ballasts account for 14-17% of total household lighting energy use, because of the high share of linear fluorescent lamps (and in the case of Vanuatu, externally ballasted CFLs).

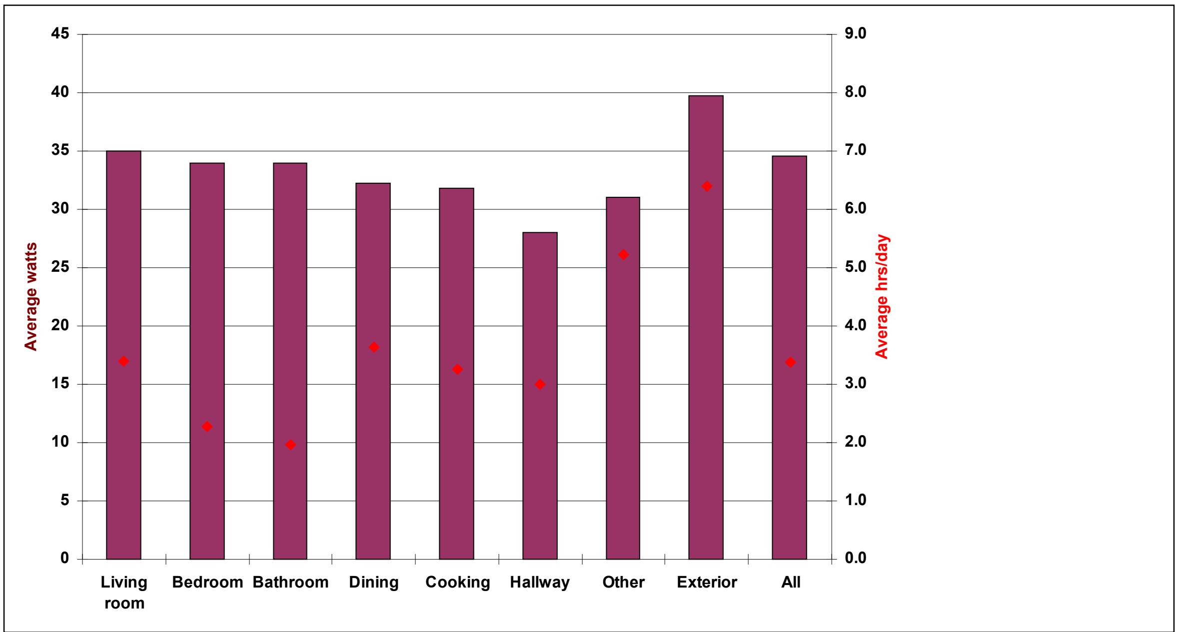

Figure 4: Average watts and hours of use by room, Tonga Source: Tonga (2014)

Table 4 Estimated average wattage and usage, all lamps

	Vanuatu	Samoa	Tonga
Lamps/Household	4.5	7.0	7.4
Average W/lamp (lamps only)	22.2	29.9	30.1
Average W/lamp (external ballasts)	4.5	5.9	5.0
Average W (combined)	26.7	35.9	35.0
Hours./day/lamp	5.7	2.0	3.4
Lighting kWh/year./HH calculated (a)	249	194(a)	319
Lighting kWh/year./HH reported	249	275	NA
Ballasts/Lighting energy	17%	17%	14%
Total kWh /yr./HH	1200 (1582)(b)	1500	1206
Lighting (calculated)/Total	21%/(16%)(b)	12%	26%
Lighting (reported)/Total	16%	18%	NA

(a) Calculated by GWA from data in IIEC reports. Lamp and ballast wattages for Tonga were standardised to reported Vanuatu values for same lamp types. (b) IIEC estimates lower total kWh/HH than the electricity utility, so apparent lighting share is higher.

Table 5 Household lighting energy by lamp types

	Vanuatu	kWh/year/HH	Samoa	kWh/year/HH	Tonga	kWh/year/HH	Weighted	kWh/year/HH
CFLs	21%	51	9%	25	8%	27	11%	32
LFLs	61%	152	84%	230	57%	184	70%	197
ILs	15%	39	7%	18	34%	109	18%	51
LEDs, other	3%	7	0%	1	0%	0	1%	2
	100%	249	100%	275	100%	319	100%	282

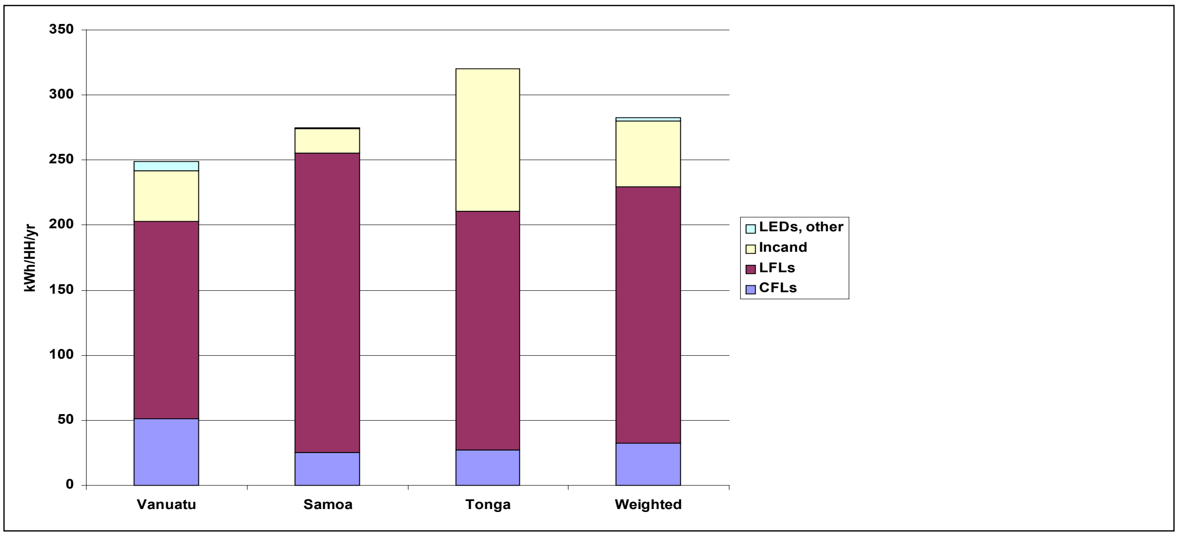

Figure 5: Household lighting energy by lamp types

The share of energy consumed by different lamp types is indicated in Table 5 and Figure 5 (note that detailed usage data are not available for the Cook Islands). On a weighted average basis, linear fluorescent lamps and their ballasts account for about 70% of household lighting energy, CFLs for about 11% and incandescent lamps for 18%, although the shares vary significantly between PICTs.

Conclusions

The most likely range of annual lighting usage in this group of PICTs is about 250 to 320 kWh/year per electrified household. The average total electricity use per household is in the range 1,200 to 1,600 kWh/year. This means that lighting accounts for roughly 16-26% of PICT household electricity use.

This analysis suggests a number of issues that need to be taken into account in developing a regional efficient lighting strategy for households:

- linear fluorescent lamps dominate household lighting energy, so energy efficiency program need to cover both tubes and ballasts;
- the distribution of lamp types varies considerably between PICTs, reflecting the history of each local lighting market. For example, Vanuatu appears to have a legacy of externally ballasted CFLs;
- there is a legacy of T12 LFLs with magnetic ballasts, which offer a significant opportunity for increasing energy efficiency of both tubes and ballasts. However, it would be advisable to plan programs which replace both at once (e.g. replace the entire fitting with a T8, T5 or tubular LED fitting with electronic ballasts);

- LEDs are still virtually unknown in the household lighting market;
- incandescent lamp use varies considerably – there is still potential for significant efficiency gains through incandescent replacements in some PICTs, such as Tonga and Cook Islands;
- there is considerable potential for growth in the consumption of lighting services in PICT households, through acquisition of more lamps and increasing the number of spaces lit per home, so it is important to ensure that this growth occurs in an energy-efficient way.

Business, government and public buildings

Lighting in offices, government and public buildings in PICTs is usually dominated by linear fluorescent lamps, often in multiple-tube luminaires. However, poor maintenance of diffusers and non-replacement of failed tubes means that the present level of illumination may be low, so the result of relamping with more efficient linear fluorescent lamps may be that some of the expected energy savings are taken as higher illumination.

Single-cap CFLs and incandescent lamps are also widely used, especially in the accommodation sector, where guest-room designs generally call for warmer and more localised lighting than that provided by linear fluorescent lamps.

The PEEP 2 program has published a table of the typical energy savings potential from upgrading one of the most common types of lighting installation in non-residential buildings: T8 linear fluorescent lamps with ferro-magnetic ballasts (see Table 6). The potential is even greater if the building is still using T12 lamps, but these seem to be uncommon outside the residential sector. Replacing ferro-magnetic with electronic ballasts reduces energy use by about 20%. Substituting T5 for T8 linear fluorescent lamps is more complicated because the tubes are slightly shorter, so either adaptors or new fittings are needed. As existing luminaires are often degraded, replacing an entire installation with new T5 luminaires offers the chance to improve lighting performance significantly. However, the potential energy savings may only be realised if the luminaires spacings are increased. The PEEP2 estimates in Table 6 suggest that option 4 uses 45% less energy than option 3, even though same linear fluorescent lamp and ballasts are used. It would require re-spacing of luminaires to achieve 45% fewer linear fluorescent lamps to achieve the theoretical savings – without re-spacing the substitution of the most efficient lighting options would increase light output rather than save energy.

In practice, there are many spaces with only one or two luminaires, so it is not possible to reduce their number. Even in large spaces with multiple luminaires the ceiling designs and the position of the wiring may limit the potential to change the layout. The final option to maximise energy savings would be to reconfigure the wiring and add daylight and movement sensors, to automatically switch off lamps in areas which are unoccupied and/or have adequate daylight. According to PEEP2 estimates such controls can reduce lamp operation by about 40% (compare options 4 and 5).

Table 6 Indicative energy saving available from non-residential lighting upgrades

Option		Lamp W(b)	Ballast W(b)	Total W(b)	W Saving (b)	% energy Saving(a)	% energy consumption	Usage factor(b)
1	T8 + Magnetic ballast	36	13	49	0		100%	0
2	T8 + Electronic ballast	36	3	39	10	20%	80%	0
3	T5 + Electronic ballast	28	3	31	18	37%	63%	0
4	Option 3 with luminaires replaced	15	2	17	32	65%	35%	0.55
5	Option 4 with control systems added	9	1	10	39	79%	21%	0.60

(a) From PEEP 2 (2014). (b) Interpolated and estimated by GWA to match PEEP estimates.

Street, outdoors and high bay lighting

Street and outdoors lighting is widely used in towns throughout the Pacific. High bay lighting is typically used in industrial buildings and warehouses, which are less common in the region, given the limited industrial base. The lamps used in these applications are similar, although street and outdoor lighting luminaires must be designed for higher levels of durability and weather resistance.

The number and type of street lamps in each PICT is generally known, because they are the responsibility of either the utility or of the government. As they are almost universally un-metered, the energy consumption is estimated from the lamp types. For example, the PEEP1 project (PEEP 1 2011) found that there were 3,208 street lights in Tonga in 2010 (0.027 lights per capita). They were mainly high pressure sodium (HPS) lamps, linear fluorescent lamps and mercury vapour lamps. An estimated 60% were in operating condition, with the rest in various stages of disrepair (McGill 2014). This has significantly changed since 2010 due to projects by PEEP 2 and Tonga Power and Light, which substituted LED street lights. As a result, the average efficacy of street lighting in Tonga is now 100 lumens/W compared with 60-65W in PNG, Samoa and Vanuatu.[8]

According to PEEP 2 there are only 246 light points for street and outdoor lighting in the Cook Islands, or 0.013 lights per capita). About 85% of these use relatively energy efficient lighting technologies such as LED and induction lamps.[9] This gives a relatively high average efficacy of 93 lumens/W (Table 20 in the Annex).

In 2011 PEEP 1 reported the following observations about street lighting in the five PEEP countries (Cook Islands, PNG, Samoa, Tonga and Vanuatu):

"Most of the existing assessed street lighting fixtures in the five countries present one or more of the following deficiencies:

- old fixtures in bad condition;
- rusted due to salt in the air;
- lack of internal reflectors;
- opaque lenses;
- lack of metering points;
- very low lighting levels;
- poor light quality;
- poor light colour rendering; and
- high maintenance costs from the need to regularly replace lamps and fixtures".

Light-Emitting Diode (LED) technology was selected as offering the best overall solution to address these problems. The key advantages of high quality LED street lights include:

- improved night time visibility due to higher colour rendering, higher colour temperature and increased luminance uniformity;
- significantly longer lifespan between lamp replacements;
- lower energy consumption once lumen depreciation (the fall off in light output over time) is taken into account;
- reduced maintenance costs;
- instant-on with no run-up or re-strike delays;
- no mercury, lead or other known lamp disposal hazards;
- lower environmental footprint;
- an opportunity to implement programmable controls (e.g. bi-level lighting)" (ADB 2011)

8 http://www.ee-pacific.net/index.php/database
9 Induction lamps are gas discharge lamps in which the energy required to generate light is transferred from outside the lamp envelope to the gas inside via an electric or magnetic field. This avoids limitations on lamp life and other problems associated with internal electrodes .

The energy savings available from replacing HPS street lights with LEDs are typically about 50-60%. Over its service life, a 100W LED has a similar light output to a 250W HPS: although the luminance of the HPSs when new is slightly higher, they degrade more than LEDs (McGill, 2014). LEDs can also operate at part load, so the addition of light and motion sensors can reduce energy use even more.

Solar and portable lighting

Solar lanterns

Some PICTs have low rates of access to electricity: in Vanuatu, PNG and Solomon Islands the electrification rates are in the range 11-22% (Table 1). Even in the more electrified PICTs, there are many outlying villages and islands without mains access or generators. In these areas the only choice for household lighting is portable lanterns. The traditional fuel for these is kerosene, but solar lanterns have become widely available in recent years.

The completion report on an AusAID project which distributed over 24,000 solar lanterns in Vanuatu from May 2010 to mid-2012 observed that:

> "…increased use of solar lanterns has occurred concurrently with a massive reduction in the use of kerosene for lighting over the 2009 to 2013 period. In 2006, 83% of rural households used kerosene for lighting. By 2010 about 50% of rural households used kerosene for lighting. By 2013…less than 10% of households were still using kerosene…The reduction in kerosene use in rural areas is relatively uniform across the country, showing little significant regional variation. Solar lighting, on the other hand, rose from about 4% in 2009 to over 25% in 2010 and has continued to rise ever since." (DFAT 2014)

Solar lamp ownership is not limited to non-electrified households. Table 7 indicates that about 15% of solar lanterns are owned by households either connected to the grid or with access to a generator.

Solar lanterns have several advantages over kerosene lamps:

- Safety – no risk of fire and no combustion products;
- Convenience – cannot run out of fuel;
- No energy costs;
- Greater durability; and
- Brighter light.

The main technical disadvantage is the limitation of the battery. However, DFAT (2014) reports that "The duration of the light is - surprisingly - not as important an issue as it might be considered in theory. Provided a light exceeds three to four hours on a single charge, then it is considered functional for most purposes."

The other barrier is cost. The large numbers of lanterns distributed free or at a subsidised price in Vanuatu created a market in which costs came down considerably. As the savings in kerosene are high, the payback periods are very short, of the order of one or two months (DFAT 2014).

Table 7 Electrification status of households owning solar lamps, Vanuatu 2013

HH without electricity	Access to solar (a)	Access to generator	Access to grid	Total households	HH with Access to MV electricity
800	390	122	94	1406	216
56.9%	27.7%	8.7%	6.7%	100.0%	15%

Source: DFAT 2014. All households surveyed owned solar lamps, including those reporting 'no electricity'. (a) Not clear from responses whether this was interpreted as ownership of a solar lantern only, or ownership of a larger PV system.

Small solar systems

Small solar systems supply not only lighting but also other high-value services such as communications (television, radios and phone charging). All this can be supplied by a 'pico-solar' PV array of 24-32W (IEA 2013).

'Pico-solar' PV systems have experienced significant development in the last few years, combining the use of very efficient lights (mostly LEDs) with sophisticated charge controllers and efficient batteries. With a small PV panel of only a few watts, essential services can be provided, such as lighting, phone charging and powering a radio. Expandable pico-solar systems have entered the market. Households can start by buying a small kit, later adding an extra kit, allowing extra lights and services to be connected.

Although these systems go well beyond lighting, the demand for light is often the main driver. The IEA notes that the possession of such a system should not be taken as indicating that a household is electrified, since high-power devices (even small ones, such as irons) cannot be operated (IEA 2013).

Lighting product markets

Imports

Some data on the value and source of appliances and lighting products imported to PICTs was collected by the Renewable Energy and Energy Efficiency Partnership (REEEP 2012). The lighting data relied on customs classifications, which were not always uniform. In most PICTs imports were reported for incandescent, linear fluorescent lamp and 'other' categories. As the value of the 'other' category was much higher (see Figure 6) it probably covered other lamp types such as LEDs and CFLs as well as fittings, fixtures and luminaires.

Export data were not analysed, so trans-shipments were not consistently accounted for. It is known, for example, that some products for Wallis and Futuna, Vanuatu and elsewhere are trans-shipped through New Caledonia and products for the southern PICTs are sometimes trans-shipped through Fiji. Table 8 summarises the available customs data for all lighting categories. There were no data at all for Cook Islands or Marshall Islands. The value of imported lighting products averaged about USD 1.2 per person per year. In the south Pacific the range was USD 0.4 – 1.9 per person per year. The Solomon Islands is a gross outlier, suggesting that the customs data for that country are far from complete.

Table 8: Estimated value of lamp imports, based on customs data

	2007	2008	2009	2010	2011	Avg 2007-11	USD/ cap
Cook Islands							NA
Fiji	148,957	318,537	295,664	560,825		330,996	0.4
Kiribati		84,473	99,360	46,450		76,761	0.7
Nauru				5,607		5,607	0.6
Niue			5,142	704	777	2,208	1.4
Papua New Guinea		3,779,613		7,833,513	7,419,278	6,344,135	0.9
Samoa		515,542	513,341	148,148	430,890	401,980	1.8
Solomon Islands	1,920	2,295	3,698	4,625	6,690	3,846	0.01
Tonga	124,495	231,567	199,389	192,695	422,601	234,149	1.9
Tuvalu				12,854	28,660	20,757	1.7
Vanuatu	406,852	781,585	289,079	353,319	267,666	419,700	1.7
FSM	87,510	27,647	39,755	54,650	39,837	49,880	0.5
Marshall Islands							NA
Palau		103,625	51,976	73,481	72,797	75,470	3.6
French Poly	4,223,282	4,513,309	3,714,764	5,200,312	4,868,339	4,504,001	17.3
New Caledonia	2,002,154	2,268,187	2,302,598	2,540,699	2,556,383	2,334,004	9.5
Wallis & Futuna	-	-	-	-	-		NA
Total (a)	**6,995,170**	**12,626,378**	**7,514,766**	**17,027,882**	**16,113,917**	**12,055,623**	**1.2**

All values USD (Exchange rates at mid-2014)

Most PICTs were reasonably close to this average, except for the high-income Francophone PICTs, which accounted for over half the value of reported lighting imports. This may be due partly to the relatively high quality and completeness of their data compared with the rest of the Pacific. For the other PICTs however, some of the years where no imports are recorded may not be missing data – as product demand is relatively low in many PICTs, it is possible that no containers of lighting products were imported in some years.

Sources of lamp imports

The data on sources of lamp imports are incomplete and inconclusive. The origin recorded by customs is often the last port of trans-shipment rather than the country of origin (REEEP 2012). For example, the southern PICTs record nearly two thirds of their lighting imports by value coming from Australia and New Zealand (Figure 7), both of which stopped manufacturing lamps years ago – although they still manufacture fittings, luminaires and ballasts. China is the next largest source of lighting product imports.

The source of imports in the Francophone countries is quite different, with about half coming from France and other European countries (Figure 8). Most of the balance comes from China, which is now the main site of global CFL manufacture, accounting for about 80% of global production in 2010 (CLASP 2011). It also produces most of the world's incandescent lamps, although the number started falling in 2008 and fewer are produced than CFLs. Indonesia also has a significant regional lamp manufacturing industry, making both linear fluorescent and single-cap lamps. The production of ILs has declined considerably in the past years, and the production of LEDs is increasing.[10]

10 http://m.bisnis.com/en/read/20140325/95/26390/sales-of-led-lamp-may-reach-40-million-units

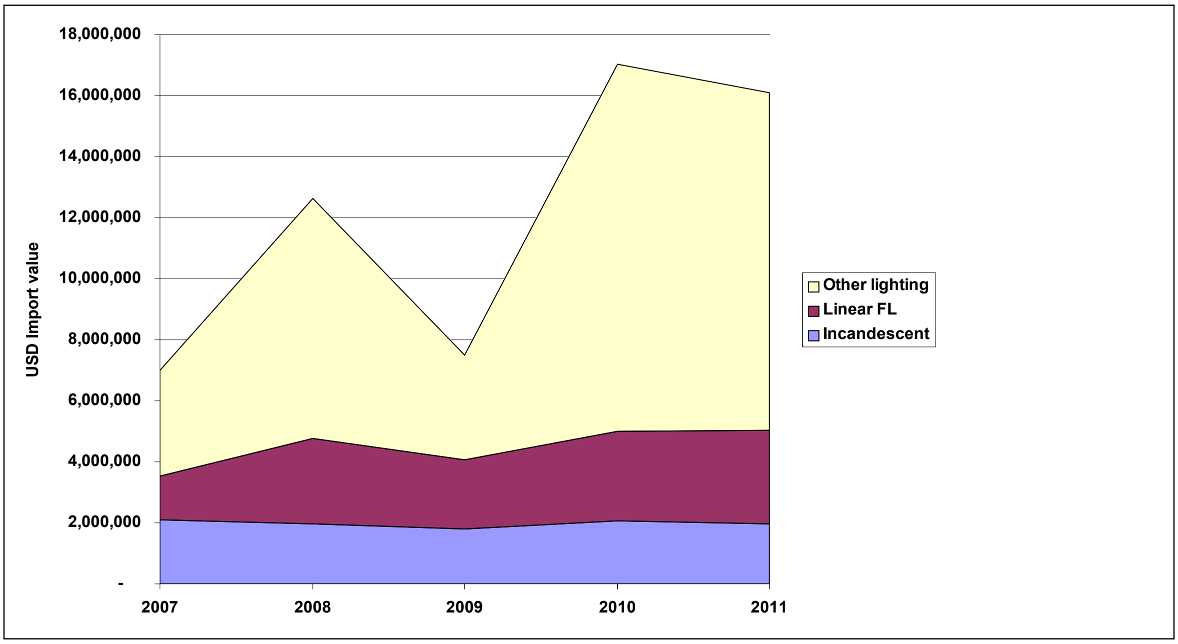

Figure 6: Estimated value of lamp imports by customs category, all PICTs
Source: REEEP (2012)

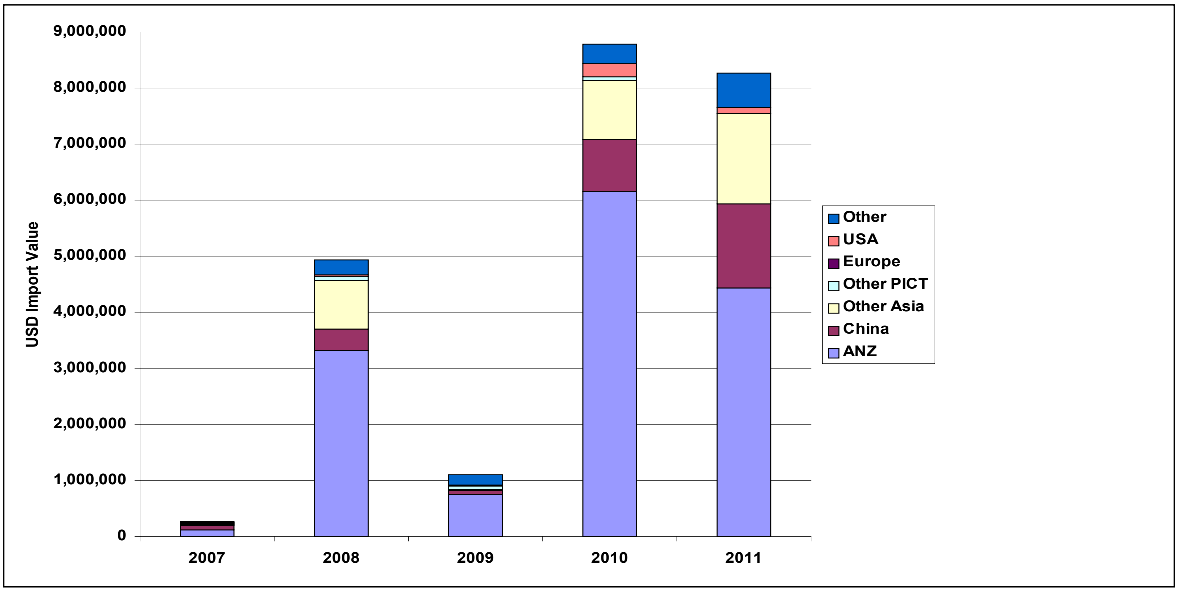

Figure 7: Sources of lighting products Fiji, Kiribati, Samoa, Tonga and Vanuatu

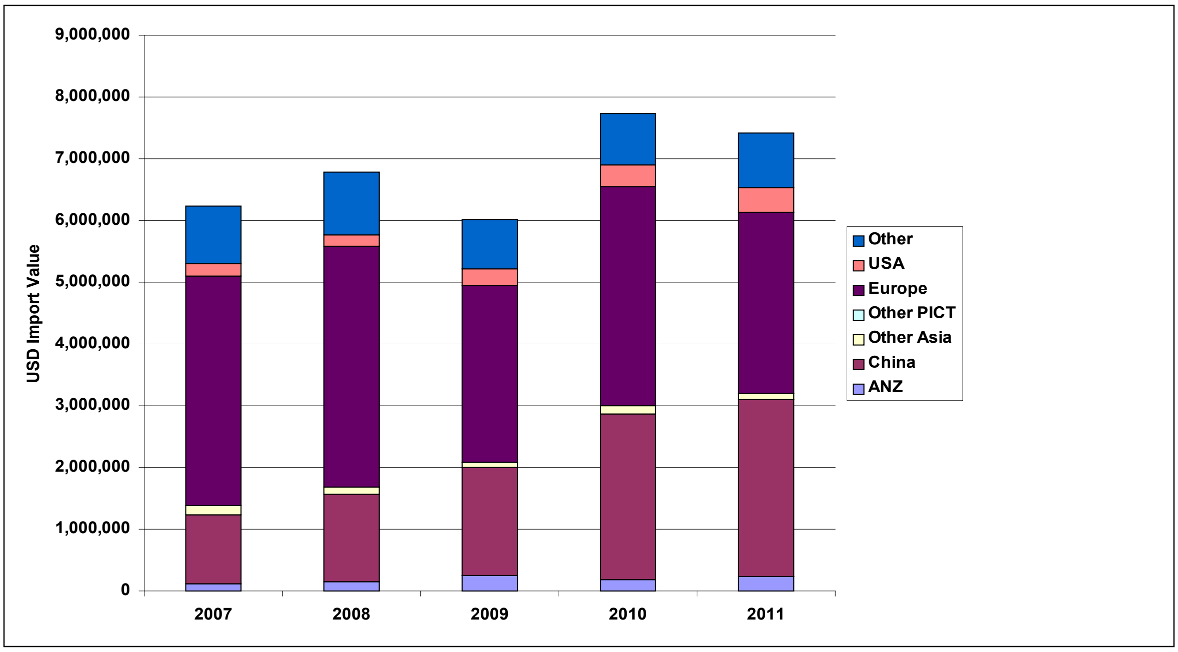

Figure 8: Sources of lighting product imports New Caledonia and French Polynesia

Lamp distribution

Lamps and lighting products are distributed through a wide range of supply channels in the Pacific. For the households and general markets, ILs, CFLs and linear fluorescent lamps are widely available from supermarkets, hardware stores and general stores. These are often generically branded (e.g. marked 'CFL' on the package without brand names or traceable manufacturer details).

LEDs are available from specialist electrical and lighting contractors in the larger towns, and are also sold on-line.[11] Specialist lighting stores tend to carry higher-quality name-branded lamps and also lighting fixtures. They generally target the non-residential market, and are also the main importers of street lamps and other specialist lighting.

Other important sources of energy-efficient lamps (and advice) are aid-funded projects. These arrange the selection and import of lights, and generally try to ensure their quality. The lamps are often distributed by local contractors to the project, which may include the electricity utilities.

Product quality

Product quality is a constant issue. Although there is no lack of poor quality lamps, it is difficult to identify and obtain good quality lamps. Aid projects sometimes find that the quality of samples submitted as part of tenders is not matched by the actual lamps delivered. There are relatively few companies in the Pacific region willing to secure, import and guarantee high quality lamps. The lead times for obtaining supplies may be in the order of months.

There is a history of poor quality CFLs in the Pacific. Power voltage and frequency fluctuations are common, and this shortens the service life of CFLs and hastens lumen degradation. Apparently CFLs made to tolerate such conditions are marketed in India, but are not available in the Pacific region.[12] The impact on power quality of poor quality lamps with low power factor and harmonic distortion is also an issue.

11 See for example http://www.ateamelectricalfiji.net/lightinglamps.htm www.sigatokaelectric.com.fj and http://www.yellowpages.com.fj/listings/2526/referer/4271/

12 Peter Johnston, personal communication

Outdoor lighting lamps and luminaires also have special difficulties, due to power quality, the corrosive marine environment and the exposure to sun and wind. Contractors do not always appreciate the need for all components to be weatherised, and to keep to tender design specifications.

Under-use of lighting

The demand for lighting in the Pacific is often under-served, even in electrified households and public buildings. This means that the benefits of greater efficacy are often taken as increased light rather than less energy. While this is just as valuable in health, social and economic terms, it means that the projected reductions in energy use may not be realised.

4 Efficient Lighting Initiatives

Energy efficiency policies and institutional capacity

Most PICTs have adopted formal national energy policies although the institutional arrangements, capacity and resources for implementing them vary widely (see Table 9). Most of the policies include recognition of the potential to increase the efficiency of energy use in all sectors, including lighting. There are also regional and collective energy initiatives, coordinated by the SPC.

In September 2014, leaders of the Pacific attending the UN Conference on Small Island Developing States (SIDS) in Samoa) signed the SIDS Dock Statute.[13] The ultimate goal is to increase energy efficiency by 25% (from a 2005 baseline), to generate a minimum of 50% of electric power from renewable sources, and to decrease use of conventional transportation fuel by 20–30% by 2033. By signing the statute, the leaders have endorsed the establishment of the first ever international organisation to focus only on SIDS sustainable energy challenges.

In New Caledonia and French Polynesia, which are administratively linked to France, the agencies responsible for energy policies and programs are the local offices of ADEME (Agence De l'Environnement et de la Maitrise de l'Energie), each with three to four staff.[14] The information leaflets on lighting (and other end uses) produced by ADEME for France are all accessible in those PICTs. There are some local ADEME initiatives, including rebates for solar water heaters, but it is not currently known whether local lighting initiatives have taken place.

In other PICTs there have been promotions of energy-efficient lamps, especially CFLs, from time to time. Some of these have involved free lamp giveaways funded by aid programs.

PEEP projects

Most of the efficient lighting activity in the Pacific region to date has taken place in the five countries covered by the PEEP program – Cook Islands, PNG, Samoa, Tonga and Vanuatu. The PEEP ADB Regional Technical Assistance (RETA), approved in September 2008, was financed on a grant basis by the Clean Energy Fund under the Clean Energy Financing Partnership Facility. The RETA arose from a consultation process conducted in 2007 on behalf of the Global Environment Facility (GEF) Pacific Alliance for Sustainability.

The Phase 1 technical assistance consultant's report (PEEP 1 2011) reported the following pilot projects related to efficient lighting:

- Cooks Islands: replacement of incandescent lamps with CFLs in the capital, Rarotonga, and in the outer islands. This included an awareness campaign, the procurement by tender of 12,000 CFLs (meeting quality specifications) and free distribution (by voucher) of CFLs by retailers. This amounted to roughly 4 CFLs per household;
- Tonga: replacement of 109 high pressure sodium (HPS) street lamps with LEDs; and
- Vanuatu: trial energy efficiency retrofits in a hotel, including replacement of incandescent lamps with CFLs.

13 http://sidsdock.org/a-stunning-development-in-samoa-leaders-take-responsibility-for-re-ee-development-in-sids
14 http://www.gouv.nc/portal/page/portal/gouv/institutions/guide_institutions/Guide%20Institution%202014%20ok_2014.pdf
http://www.polynesie-francaise.ademe.fr/polynesie-francaise/notre-carte-didentite

PEEP 1 assessed the design, performance and impact of the pilot projects. The findings were used to develop the measures in PEEP 2. Table 10 summarises the PEEP 2 lighting projects currently under way, and the share of savings expected from residential, non-residential and outdoor lighting respectively. Each project involves working with local authorities, businesses and utilities to source high-efficiency lamps of good quality and to substitute them for existing lamps which they own or control or, for the residential programs, to distribute lamps free to households.

The total projected annual savings (2,967 MWh/yr) are equivalent to about 1% of the total estimated lighting energy of the 5 PICTs involved (see Modelling Approach). This indicates the vast scope for further project of this type.

The projects are further broken down by sector in Table 11, Table 12 and Table 13. The savings are valued at about USD 0.49 to 0.55 per kWh. These are somewhat higher than the estimated marginal electricity supply cost of USD 0.34 per kWh used in the present study (Table 15), but it is likely that the PEEP 2 costs are from the perspective of electricity consumers, and so include other utility costs such as retail margins and taxes.

Table 9 Energy agencies, resources and policies, selected PICTs

PICT	Agency responsible for energy planning , coordination, leadership and governance	Number of staff in energy planning office/department	Year national energy policy endorsed	Implementation plans or roadmaps
Cook Islands (a)	Energy Division established under Energy Act 1998. Act was amended in 2012 to establish the Energy Commission responsible for the regulating the energy sector	2	2003	Cook Islands Renewable Enertgy Charts endorsed in 2011
Fiji (a)	Energy Department established in 1981 during energy/oil crisis.	Est. 50 (more project staff recruited in 2012)	2006	National Energy Implementation Plan endorsed in 2006
Federated States of Micronesia	Energy Division is at the Department of Resources and Development. National Government. Established the National Energy Working Group during the 2008 energy crisis.	1 staff at the National Energy Division	2010	FSM National & States Energy Action Plans (2010)
Kiribati(a)	Energy Planning Unit under the Ministry of Works and Public Utili-ties	4	2009	No implementation plan
Nauru(a)	Energy policy development mandated by Ministry of Commerce Industry and Environment. Nauru Utilities Corporation implements all national, regional and international donor projects.	No Energy unit.	2009	No implementation plan. Energy Roadmap is being developed in 2012 by SPC/ GIZ and IRENA
Niue(a)		0	2005	Strategic Action Plan 2005
Palau(a)	Energy Office, Ministry of Infrastruc-ture, Industry and Commerce	2 (1 is temporary)	2010	Strategic Action Plan 2005
Papua New Guinea	Energy Division of the Department of Petroleum and Energy	14 (estimated)	2006 draft not yet endorsed by Parlt.	Draft Energy Plan 2006
Republic of Marshall Islands	Energy Planning Division of the Ministry of Resources and Develop-ment	2 local staff, 1 SPC staff & counterpart and 1 EE adviser, 1 Petroleum Adviser	2009	Energy Action Plan endorsed in 2009
Samoa(a)	Energy Division under the Ministry of Finance and Economics	3	2007	Samoa Energy Sector Plan - SESP endorsed in 2012

Solomon islands	Energy Division under the Ministry of Mines, Energy and Rural Electrification. The Energy Unit established in 1984 within the Geology Department.	16 (6 are technicians)	2007	Was being revised in 2012
Tonga	TERM C is coordinating the implementation of the Energy Roadmap that was developed in 2012.	7 - for energy planning and coordination, 2 technicians for each island	Draft May 2002	Tonga Energy Road Map (TERM) 2009
Tuvalu(a)	Energy Office under the Ministry of Public Works and Energy	2	2009	Renewable Energy and Energy Efficiency Master Plan 2020. No implementation Plan.
Vanuatu	Department of Energy task with managing and reforming the energy sector	3	2009	Vanuatu National Energy Roadmap (2013 - 2020) focus on Renewables and Electricity

Source: SPC. Personal communication (a) Signatory to SIDS statute, September 2014

Table 10 Summary of projected impacts of PEEP2 lighting projects

	Number	kWh/yr saving	%	USD/yr saved	CO_2 t/yr saving	USD/kWh	kg CO_2-/kWh
Street lighting projects	11	334058	11%	185343	286	0.55	0.857
Residential lighting projects	6	1317635	44%	614787	1139	0.47	0.864
Commercial & public sector	9	1315945	44%	603631	972	0.46	0.739
	26	2967638	100%	1403761	2397	0.47	2.460

Source: PEEP 2 http://www.ee-pacific.net/

Table 11 PEEP2 lighting projects - residential

		kWh/yr saving	USD/yr saving	CO_2 t/yr saving	USD/kWh	kg CO_2/kWh
Cook Is		158819	95329	127.0	0.60	0.800
Samoa		127166	57225	123.6	0.45	0.972
Tonga	Outer Islands	233533	70717	213.0	0.30	0.912
Tonga	Tongatapu	149466	75560	136.0	0.51	0.910
Vanuatu	Pt Vila	455024	252791	378.0	0.56	0.831
Vanuatu	Luganville	193627	63165	161.0	0.33	0.831
		1317635	614787	1138.6	0.47	0.864

Table 12 PEEP2 lighting projects – commercial and public buildings

		kWh/yr saving	USD/yr saving	CO_2 t/yr saving	USD/kWh	kg CO_2/kWh
PNG	PNG Power head office	221035	93858	136.0	0.42	0.615
PNG	Pt Moresby general hospital	101347	42910	62.0	0.42	0.612
PNG	Science Faculty UPNG	83357	44060	51.0	0.53	0.612
Samoa	Govt bldgs - lighting	333997	150299	219.0	0.45	0.656
Samoa	Govt bldgs - luminaires	49094	22092	47.7	0.45	0.972
Samoa	Commercial sector	97344	43805	74.6	0.45	0.766
Tonga	Public sector buildings	158706	48058	144.7	0.30	0.912
Vanuatu	Public sector buildings	121599	82989	101.1	0.68	0.831
Vanuatu	Local public sector & schools	149466	75560	136.0	0.51	0.910
		1315945	603631	972.1	0.46	0.739

Table 13 PEEP2 lighting projects - street and outdoors

PICT	Location	Lamp type	Units	kWh/yr saving	kWh/ lamp	USD/yr saving	USD/ kWh	CO2 t/yr saving	kg CO_2/ kWh
Cook Is	Rarotonga airport	Solar LED	8	8150	1019	4900	0.60	6.7	0.822
Cook Is	Punanga Rui Market	Solar LED	21	8030	382	4830	0.60	6.6	0.822
Cook Is	Marina & Wharf	Solar LED	20	8634	432	9360	1.08	6.9	0.799
Cook Is	Outer Islands	EE Street	45	867	19	541	0.62	1.0	1.153
PNG	Resid area Pt Moresby	EE Street	160	41370	259	39256	0.95	29.9	0.723
PNG	Resid area Alotau	EE Street	178	46025	259	17262	0.38	44.9	0.976
Samoa	Apia	EE Street	152	37227	245	16752	0.45	24.4	0.655
Tonga	Outer Islands	EE Street	161	45189	281	26328	0.58	41.0	0.907
Tonga	Tongatapu	EE Street	135	52030	385	30314	0.58	47.0	0.903
Vanuatu	Luganville	EE Street	160	40520	253	15758	0.39	34.0	0.839
Vanuatu	Pt Vila	EE Street	160	46016	288	20042	0.44	44.0	0.956
Total			**1200**	**334058**	**278**	**185343**	**0.55**	**286.4**	**0.857**

Other programs

In the Cook Islands the 12,000 CFLs distributed free during PEEP 1 were left to the householders to install for themselves. Another 10,000 CFLs have been given away since, this time installed by auditors. The 22,000 CFLs distributed so far represent 5.5 per electrified household, by far the highest number of any PICT surveyed (see Table 2). This will limit the scope for further substitution of CFLs in the Cook Islands.

Tonga Power has undertaken lighting programs in association with the Government of Tonga and PEEP. This involved retrofitting over 880 street lights with LED lamps, saving about 130 kWh/lamp/year (McGill 2014). Tonga Power also retrofitted its own power station buildings with LED fittings connected to motion detectors. The Government of Tonga has also tried to promote CFL and LED lamps to the public, but has been hampered by poor product quality.

The Republic of the Marshall Islands has undertaken a street lamp replacement program, partly, funded by the International Union for Conservation of Nature (IUCN). The project aimed to make the street lights on Majuro and Ebeye more energy efficient by replacing the mercury vapour and sodium vapour lights with LED lights. The project was completed in 2011 with a total of 689 replacements carried out at an investment of USD 570,000. Work on the ground was completed through a collaborative effort with the Marshall Islands Energy Company.[15]

The Government of Palau is in the process of procuring 20,000 CFLs to distribute – roughly three per household, to be given out on surrender of incandescent bulbs. It also has a lighting upgrade program for government buildings.

Implications for Pacific efficient lighting strategy

PELS is following the en.lighten "integrated policy approach" for lighting products:

1. Minimum Energy Performance Standards;
2. Supporting Policies and Mechanisms;
3. Monitoring, Verification and Enforcement; and
4. Environmentally Sound Management.

The following sections relate existing capabilities and programs to the PELS strategy.

15 https://www.iucn.org/about/union/secretariat/offices/oceania/priorities/priority_greeneconomy/energy/work/energyprojects.cfm?12828/Street-lights-that-cost-less-to-operate

Minimum energy performance standards

At present the only PICT that has regulations in place that are capable of preventing the import of any category of appliance or lamp on the basis of energy efficiency is Fiji, which in 2012 mandated the Australian and New Zealand minimum energy performance standards (MEPS) and energy labels for household refrigerators and freezers.

The implementation of MEPS for lighting products will rely heavily on the Pacific Appliance Labelling and Standards (PALS) program. PALS is an AusAID-funded program established in 2012 to assist PICTs to implement MEPS and mandatory energy labelling. PALS is managed by the SPC, working in co-ordination with the PICTs which have agreed to join the PALS program. PALS funds research, stakeholder workshops, drafting of regulations where required and the establishment of administrative frameworks and public information campaigns.

Table 14 lists the PICTs which are most advanced, and the product categories which each has covered or proposes to cover in its regulations. PNG, Solomon Islands and Tuvalu also participate in PALS. In all cases to date, the draft regulations reference Australian and New Zealand standards for product energy testing, labelling and MEPS. North Pacific countries (FSM, RMI and Palau) also participate in PALS activities. They use different product standards from the south Pacific due to their different voltage requirements and product sources, and have not committed to regulatory approaches.

Table 14 Current scope and status of PALS program

PICT	Status of regulations	Refrigerators and freezers	Air conditioners	Lighting	Other
Fiji	Enacted	Covered	UC	UC	UC Commercial refrigeration, clothes washers, dishwashers, televisions
Samoa	Draft	Covered (a)	Covered (a)	Covered (a)	
Tonga	Draft	Covered (a)	Covered (a)	Covered (a)	
Cook Islands	Draft	Covered (a)	Covered (a)		Clothes washers
Kiribati	Draft	Covered (a)	Covered (a)	Covered (a)	Commercial refrigeration
Vanuatu	Draft	Covered (a)	Covered (a)	Covered (a)	

(a) Included in current draft regulations for MEPS and energy labelling. UC = Under consideration

The draft regulations refer to the ANZ standards for lighting, in particular:

* Single-cap lamp efficacy standards which would preclude the import and sale of tungsten filament incandescent lamps. Mains voltage halogen lamps (which are 30% more efficient) would be the least efficient lamp types permitted. The relevant standards are AS/NZS 4934.1(Int):2008 *Incandescent lamps for general lighting service Part 1: Test methods – Energy performance* and AS 4934.2-2011 *Incandescent lamps for general lighting services Part 2: Minimum Energy Performance Standards (MEPS) requirements*;

* Linear fluorescent lamp efficacy standards which would preclude T12 mono-phosphor tubes (which are disappearing from the market anyway). Tri-phosphor T8 would be the least efficient permitted. The relevant standards are AS/NZS 4782.1:2004 *Double-capped fluorescent lamps – Performance specifications Part 1: General (IEC 60081:2000 MOD)* and AS/NZS 4782.2:2004 *Double-capped fluorescent lamps – Performance specifications Part 2: Minimum Energy Performance Standards (MEPS)* and AS/NZS 4782.3(Int):2006 *Double-capped fluorescent lamps – Performance specifications Part 3: Procedure for quantitative analysis of mercury present in fluorescent lamps* (which covers CFLs as well as linear fluorescent lamps);

* Ballast energy efficiency standards which would preclude the least efficient ferro-magnetic ballasts (which are largely disappearing from the market anyway, in favour of electronic ballasts). The relevant standards are AS/NZS 4783.1:2001: *Performance of electrical lighting equipment—Ballasts for fluorescent lamps—Method*

of measurement to determine energy consumption and performance of ballasts lamp circuits and AS/NZS 4783.2:2002: *Performance of electrical lighting equipment—Ballasts for fluorescent lamps—Energy labelling and minimum energy performance standards requirements*;

- CFL standards which prescribe minimum levels of performance and durability, and maximum levels of mercury content. The relevant standards are AS/NZS 4847.1:2010 *Self-ballasted lamps for general lighting services Part 1: Test Methods – Energy performance,* AS/NZS 4847.2:2010 *Self ballasted lamps for general lighting services Part 2: Minimum Energy Performance Standards (MEPS) requirements* and AS/NZS 4782.3(Int):2006 *Double-capped fluorescent lamps – Performance specifications Part 3: Procedure for quantitative analysis of mercury present in fluorescent lamps* (which covers LFLs as well as CFLs).

The adoption of these standards throughout the region, by means of the regulations being developed under the PALS program, would achieve the en.lighten objective of "phasing out inefficient incandescent lamps in the Pacific" and would also set MEPS for CFLs, linear fluorescent lamps and ballasts. The PALS regulations will also provide a framework for adoption of future lighting MEPS, such as those that may be developed for LEDs and off-grid lighting products.

Supporting policies and mechanisms

There are several initiatives which could act as supporting policies and mechanisms for PELS. One of these is PEEP 2, which will provide a large amount of pre- and post-implementation data on its efficient lighting projects. Apart from enabling MEPS, PALS can also support PELS by including information about efficient lighting selection in its public information programs.

Consumer awareness

Consumers, whether household or business, need to be aware of the efficient lighting options at key decision points – when planning a new building, changing fixtures and luminaires or simply replacing a lamp. Information can come from many sources – product manufacturers, contractors, suppliers, utilities, government agencies and the labelling of the product itself. Lighting is a highly technical area, with many possibilities for confusing and misleading information.

Concepts such as efficacy and lumens are difficult for the general consumer to grasp, which is why single–cap lamp performance is usually expressed in terms of the wattage of an incandescent lamp with a similar lumen output.

Although several PICTs have initiated information programs on energy-efficient lighting (generally with the support of aid funding), there is scope for co-ordinating the form and content of such communications so there is regional consistency.

Support with capital costs

The average incomes in PICTs are low. Although many households have difficulty in meeting their energy bills, and so would benefit greatly from more efficient lighting, they also have difficulty in paying more for efficient lamps. This barrier is sometimes addressed by aid programs which subsidise the cost of such lamps, so that they can be given away free or sold at a lower price. Free give-away programs need to be designed so that the new lamps are actually substituted, not hoarded or sold. This may involve auditors actually doing the installation, or requiring that working ILs be surrendered for CFLs.

RMI has a Renewable Energy and Energy Efficiency Equipments Exemption Act, which states that "no import duty shall be levied on Energy Efficient Equipment (initially air conditioning units, refrigerators and freezers, fluorescent and LED lightings) which have an Energy Star label or equivalent". The extent to which this provision has been used is not known.

Other supporting policies

Fiji is developing a new building code, which will for the first time have a section on energy efficient lighting. The proposed provisions are:

- requiring maximum use of day lighting;
- maximum design power loads for lighting;
- bi-level switching of lamps adjacent to windows;
- lighting MEPS similar to Australian and New Zealand standards; and
- a requirement for electronic ballasts.

The Government of Palau Housing Authority is also proposing a code on energy efficient lighting.

While building codes are very valuable for ensuring that lighting in new buildings is energy-efficient, they cannot of course increase the lighting efficiency in existing buildings.

Monitoring, verification and enforcement

PELS will rely heavily on PALS for monitoring, verification and enforcement. PALS is helping train customs agencies in participating PICTs in recognising appliances and lighting products that are subject to regulation, whether for MEPS or energy labelling. The proposed regulations empower authorised officers to enter premises of product suppliers and retailers to inspect items and collect samples or other evidence. The regulations also contain penalties for proven breaches, from fines to the seizure of products, so there will be strong incentives for compliance.

Product testing

A major impediment to the adoption of energy-efficient lighting in the Pacific is the poor and variable quality of locally available product such as CFLs and LEDs. Consumers may be persuaded by the case for preferring more efficient lighting technologies, but find that they do not perform as expected. This not only undermines the cost-effectiveness case, but can damage the reputation of that technology in the long term so that consumers remain wary of it even if product quality improves.

The maintenance of product quality and monitoring of toxic materials content relies on the ability of regulators and other stakeholders to randomly select samples and have them tested quickly. In the Pacific, lamp importers may come and go, so if it takes months for a government agency in a PICT to get a sample tested, the importer may already have left the market by the time the results come back.

The Government of Tonga, for example, has sent lamps to the Global Efficient Lighting Centre in China, but experienced a number of delays and problems, including getting customs clearance for samples of products that are no longer legal for sale in China, and the backlog of testing of samples from Africa and North Asia.

There may be a case for setting up a lamp testing facility in and for the Pacific, possibly based at a tertiary institution such as the University of the South Pacific.

Environmentally sound management

Because CFLs contain mercury, an approach that follows the principle of pollution prevention and environmentally sound management is required. This approach included minimizing toxicity at the design and manufacturing stages, while instituting the treatment of spent lamps.

The standards for CFLs and linear fluorescent lamps that are proposed for adoption in the PALS countries specify maximum mercury levels. These need to be monitored through occasional check testing of samples.

Lamps also need to be disposed of safely at the end of their service lives. Currently, no PICT has adopted legislation on the collection and recycling of lamp waste. PEEP 2 has obtained a ‘bulb-eaters’ for each of the five PICTs where it is operating.[16] These crush bulbs and retain any mercury in an activated carbon filter. The filters can then be safely disposed of in landfill sites, while the clean crushed glass can also be landfilled in steel barrels. Each machine costs about USD 10,000 so to make best use of it, a collection system that reaches to remote parts of each PICT is necessary.

16 http://www.ee-pacific.net/index.php/news1

5 Estimated impacts on energy use

Modelling approach

A simplified modelling approach has been used to project the energy savings and cost savings available from increasing the energy-efficiency of lighting in PICTs. The same sub-model is used for each PICT, individually calibrated to be consistent with the known data. The following section uses the Cook Islands as the example to illustrate the operation of the model. Note that the results are preliminary, and can be adjusted for any new information received.

Household lighting

The basis of each calculation is the lamp characteristics input sheet (see example, Table 18). This includes:

- The average number of each type of lamp per household. For the PICTs with data available (Cook Islands, PNG, Samoa, Tonga and Vanuatu) this is set to match the actual data. For the other PICTs, the weighted average default values in Table 2 are used, except for the PICTs where household energy use averages 3,000 kWh/yr or more (see Table 1). For these PICTs the higher Cook Islands lamp count (Table 2) has been used.
- Estimated average watts per lamp type, including any external ballasts;
- Estimated average hours per day usage (applied equally to all lamps).

These estimate generate a 'business as usual' (BAU) annual lighting energy consumption per household – in Table 18, for example, this is 382 kWh/yr. The lamps are then manually reassigned to more efficient types using the following rules:

- The number of linear fluorescent lamps and single-cap lamps (bulbs) per household remains the same;
- The number of incandescent lamps is set close to zero, as there will always be some residual use of them throughout the projection period to 2030 (eg from old lamp stocks, even if their import is prevented);
- Mains voltage halogen (MVH) lamps account for small share of incandescent lamp replacements, but most replacements are either CFLs or LEDs; and
- Linear fluorescent lamps mainly transition from T12 to T8 and from ferro-magnetic (M) to electronic (E) ballasts. There is also a small increase in the use of T5 linear fluorescent lamps in households.

These estimates generate a revised annual lighting energy consumption per household – in Table 18, for example, this is 278 kWh/yr (27% below BAU). This is a theoretical maximum saving which cannot be achieved instantly – it can only be realised as lamps are renewed, fixtures and fittings are changed and new houses are built. The estimated rate of realisation is indicated by the top-most curve in Figure 13. This assumes that efficient lighting programs are introduced in 2015. The initial rapid realisation rate is due to lamp substitution (either accelerated replacements or at the time of failure), but this slows as further savings depend on fixture replacement, which occurs over a longer time span. When the Pacific regional lighting strategy is finalised, it may be possible to model more specific realisation curves depending on the mix of measures adopted in each PICT.

Furthermore, some of the projected savings may be realised over time without specific program measures due to changes in the lighting market (in this respect what is called "BAU" here is actually a frozen efficiency case). For example, T12 linear fluorescent lamps are now increasingly rare, so when existing T12 tubes reach the end of their life then T8 would be the most likely replacement option in any case.

Lighting energy use in the Pacific is so low that there is clearly a demand for further lighting services even in household which are already electrified. Average annual household lighting consumption per electrified household is projected to increase as further lamps are acquired, at a rate of 2% per year in the PICTs where lighting usage is low and 1% per year where it is already higher. These are the author's assumptions, and the model can be re-run with other assumptions.

The number of households has been projected based on expected population growth and a gradual reduction in the number of people per household (i.e. the number of dwellings increases faster than population growth). The share of households with access to mains voltage electricity (grid or generated) is also projected to increase gradually in the PICTs where it is not already near 100% – from about 27% in 2012 to 34% in 2030.

Regional household without electricity (the vast majority of which are in PNG) also have a need for off-grid PV and portable lighting, as discussed earlier in this report, but changes in those markets will not impact on electricity generation and fuel costs, so they are not included in this modelling.

The assumptions used for diesel generation costs are indicated in Figure 13. These are based on a constant real price of oil at USD 100 per barrel, in 2014 USD over the projection period (i.e. ignoring inflation). The same assumptions are used for all PICTs for the time being, although it is recognised that different PICT grids vary considerably. The average also includes both grid-scale generators and smaller generators, which have lower efficiency (although as they are located near the loads the distribution losses may well be lower than average.

Again, it is recognised that many PICT electricity systems include significant shares of renewable energy. However, if we assume that renewable generation is always fully utilised to the extent of its availability, then if one extra kWh of energy is needed (e.g. if a household purchases an IL instead of a CFL) it will almost always be generated by diesel, and conversely the fuel saved at the margin will also be diesel.

Street and public lighting

The street light counts available for the Cook Islands indicate 0.013 lights per capita and for Tonga, 0.027. Lights for off-street areas such as car parks or wharfs would be additional. Therefore the number of outside public lights per capita has been set at between 0.03 for the less electrified PICTs to 0.06 for the most electrified.

It has been assumed that each lamp averages 80W and operates for 6 hours per night for the less electrified PICTs and 8 hours for the most electrified. The most efficient options (LEDs) are assumed to average 30W per lamp. Therefore the efficiency potential is calculated simply as a saving of 50W per lamp (except in the Cook Islands, where LED street lights are now the norm. In this case the average reduction potential has been set at 20W per lamp).

Table 15 Electricity fuel, generation and distribution cost assumptions

	Units	Values
Crude oil	USD/barrel	100
Refining margin		10%
Transport margin		10%
Refining on-cost	USD/ barrel	10
Transport on-cost	USD/ barrel	10
Total fuel cost	USD/ barrel	120
Litres fuel/ barrel	litres/ barrel	159
Total fuel cost - delivered	USD/litre	0.75
Thermal content of fuel	MJ/litre	39.6
Generation efficiency (a)		27%
Electricity generated	MJ elec/litre	10.7
Electricity generated	kWh/litre	2.97
T&D losses (a)		15%
Delivered	kWh/litre	2.52
Marginal fuel cost	USD/kWh	0.30
Marginal capital cost(a)	USD/kWh	0.04
Marginal maintenance cost(a)	USD/kWh	0.005
Marginal total cost	USD/kWh	0.344
CO_2-e per kWh delivered (a)	kg/kWh	1.09

(a) From SPC (2011)

Commercial and government lighting

This sector is the most difficult to estimate. Even though lamp audits of particular buildings are expected to accumulate as PEEP 2 projects proceed, there will still be many uncertainties, for example:

- The hours of operation of buildings and lamps;
- The total floor area of commercial buildings; and
- How representative each building is of its own type, let alone other types (e.g., hotel lighting patterns are completely different from hospital and office lighting).

It is assumed that the amount of built space and economic activity is roughly proportional to population. Therefore this sector of lighting has been modelled by assuming a per capita kWh/year allowance, ranging from a low of 70 kWh/year/person in the least electrified PICTs to 150 in the most electrified. In each case the total non-household lighting energy has been checked against total non-household electricity consumption (see Table 1), and if the lighting estimate exceeds 50% it is adjusted downward.

The potential for efficient lighting to reduce electricity consumption in non-residential buildings has been set at 40%, based on the options illustrated in Table 6. As some of these options would be taken up in the normal course of business, the efficiency potential is assumed to fall linearly to 25% by 2030. Again, the realisation rate is held to the curve in Figure 13, because it takes time for lamps and fittings to be changed.

Lighting share of electricity use

In aggregate, these assumptions and calculations indicate that lighting accounts for over 16% of household electricity use, 12% of non-household electricity use and over 13% of all electricity use in the Pacific region (Table 16).

Table 16 Estimated lighting share of electricity use, Pacific region

	GWh/yr
Household lighting	175
Total household electricity	1,068
Lighting/Total household electricity	16.4%
Non-household lighting	465
Total non-household electricity	3,832
Lighting/Total non-household electricity	12.1%
Total lighting	640
Total electricity	4,901
Lighting/Total Electricity	13.1%

Potential benefits and costs

Energy, cost and emissions savings

The theoretical potential for electrical energy savings from more efficient lighting in the Pacific region is summarised in Table 17. These are 'instantaneous' savings in that they would require complete and immediate substitution of lamps, fixtures and fittings, which is clearly impossible. Figure 11, Figure 12, Figure 13 and Figure 14 illustrate the rate at which the savings could probably be realised.

Table 17 'Instantaneous' potential for energy savings through efficient lighting, Pacific region, current consumption

	BAU GWh/yr	Reduced GWh/yr	Saving GWh/yr	Savings %
Household	175	140	35	20%
Street and Public	33	13	20	61%
Commercial and Government	432	259	173	40%
Total	**640**	**412**	**228**	**36%**

Table 19 indicates, for each PICT and for the region as a whole:

* The savings in MWh delivered to end users over the period 2015-2030. This totals about 3.41 million MWh (3,410 GWh). The savings in electricity generated would be about 15% higher, due to transmission and distribution losses;
* The fuel costs avoided. This totals USD 1,019 million, of which nearly half is attributable to PNG;
* The other generation costs avoided (i.e. capital, operation and maintenance). This totals USD 153 million;
* The stream of savings, discounted at 7% (ie a saving next year is worth 7% less than a saving this year, a saving the year after is worth another 7% less and so on). On this basis the net present value (NPV) of total savings is USD 626 million, compared with the undiscounted value of USD 1,723 million;
* The savings in fuel imports amount to 1.35 million kilolitres (1.35 gigalitres); and
* The saving in greenhouse gas emissions associated with generation fuels amount to 3.72 million tonnes.

Associated costs

Of course, there would be costs involved in achieving the potential savings identified. More efficient lamps, ballasts and luminaires cost slightly more to purchase than their less-efficient counterparts, although the cost differential is closing over time as technologies mature and their production volumes increase. It is not possible to estimate costs until the programs in the Pacific regional strategy are developed, because:

* It is possible to achieve the same energy savings either cheaply (e.g. by substituting a CFL for an incandescent lamp) or in a more costly way (by substituting an LED lamp). The LED may have other advantages – longer life, dimmability, better colour rendition and less environmental risk on disposal – but these benefits are very difficult to cost (other than lamp life);
* Some technologies may not be adopted without policy intervention – e.g. mains voltage halogen lamps, which are 30% more efficient than incandescents, would probably not gain significant market share in the Pacific region without mandatory lamp efficacy standards;
* The share of the potential energy benefit that is taken up as increased lighting services will depend on specific programs and policies;
* Efficient lighting programs may themselves involve both administrative and labour costs, and some additional economic cost, if working lighting is discarded prematurely rather at the time of natural replacement.

However, the costings of lighting projects now under way indicate that Pacific region lamp substitution and replacement projects usually pay back within 12-18 months (PEEP 2 2014) so there is little doubt that a highly cost–effective regional lighting strategy can be devised in due course.

Table 18 Lamp characteristics input sheet (Cook Islands)

Lamp type	Sub-type	Avg W lamp	Avg W ballast	Avg W total	Number Of lamps	Hrs per day	kWh/yr	Revised Number	Change in number	Revised kWh/yr	Change in kWh/yr	Change in kWh/yr
Incandescent		50		50	2.50	3.5	159.7	0.20	-2.30	12.8	-146.9	-92%
Mains voltage halogen		35		35	0.50	3.5	22.4	1.00	0.50	44.7	22.4	100%
CFL		14		14	5.00	3.5	89.4	6.00	1.00	107.3	17.9	20%
LED		14		14	0.20	3.5	3.6	1.00	0.80	17.9	14.3	400%
LFL	4 ft T12 M	40	11.5	51.5	0.10	3.5	6.6	0.00	-0.10	0.0	-6.6	-100%
	2 ft T12 M	20	9.5	29.5	0.10	3.5	3.8	0.00	-0.10	0.0	-3.8	-100%
	4 ft T8 M	36	11.5	47.5	0.90	3.5	54.6	0.50	-0.40	30.3	-24.3	-44%
	2 ft T8 M	18	9.5	27.5	0.90	3.5	31.6	0.50	-0.40	17.6	-14.1	-44%
	4 ft T8 E	36	3	39	0.10	3.5	5.0	0.55	0.45	27.4	22.4	450%
	2 ft T8 E	18	2	20	0.10	3.5	2.6	0.55	0.45	14.1	11.5	450%
	4 ft T5 E	28	3	31	0.05	3.5	2.0	0.10	0.05	4.0	2.0	100%
	2 ft T5 E	14	2	16	0.05	3.5	1.0	0.10	0.05	2.0	1.0	100%
					Number	Target	Calc kWh/yr					
	% of LFLs 2 ft		50%	Tot bulbs	8.20	8.30	275	8.200	0.00	183	-92	-34%
	% With electronic ballast		13%	Tot LFL	2.30	2.26	107	2.30	0.00	95	-12	-11%
					10.50	10.55	382	10.50	0.00	278	-104	-27%

Table 19 Summary of energy saving potential from more efficient lighting, all PICTs

	MWh	Fuel savings	Other savings	Total savings	Fuel savings	Other savings	Total savings	Kl fuel	t CO2-e
	Saved 2015-30	$M USD	$M USD	$M USD	$M NPV(a)	$M NPV(a)	$M NPV(a)	saving	saving
Cook Islands	25103	$ 7.5	$ 1.1	$ 8.6	$4.0	$0.6	$4.6	9944	27367
Fiji	797239	$ 238.4	$ 35.9	$ 274.3	$127.8	$19.2	$147.0	315801	869147
Kiribati	60548	$ 18.1	$ 2.7	$ 20.8	$9.3	$1.4	$10.7	23984	66010
Nauru	8664	$ 2.6	$ 0.4	$ 3.0	$1.4	$0.2	$1.6	3432	9445
Niue	1625	$ 0.5	$ 0.1	$ 0.6	$0.3	$0.0	$0.3	644	1772
PNG	1230776	$ 368.0	$ 55.4	$ 423.4	$194.1	$29.2	$223.3	487533	1341787
Samoa	131382	$ 39.3	$ 5.9	$ 45.2	$21.3	$3.2	$24.5	52043	143232
Solomon Is	160478	$ 48.0	$ 7.2	$ 55.2	$25.1	$3.8	$28.9	63568	174953
Tonga	79870	$ 23.9	$ 3.6	$ 27.5	$12.7	$1.9	$14.6	31638	87074
Tuvalu	9260	$ 2.8	$ 0.4	$ 3.2	$1.5	$0.2	$1.7	3668	10095
Vanuatu	93664	$ 28.0	$ 4.2	$ 32.2	$15.1	$2.3	$17.3	37102	102112
FSM	52423	$ 15.7	$ 2.4	$ 18.0	$8.4	$1.3	$9.7	20766	57152
Marshall Islands	47820	$ 14.3	$ 2.2	$ 16.5	$7.5	$1.1	$8.6	18942	52133
Palau	27370	$ 8.2	$ 1.2	$ 9.4	$4.4	$0.7	$5.1	10842	29838
French Polynesia	341068	$ 102.0	$ 15.3	$ 117.3	$55.5	$8.4	$63.8	135103	371831
New Caledonia	323147	$ 96.6	$ 14.5	$ 111.2	$52.7	$7.9	$60.6	128004	352294
Wallis and Futuna	17405	$ 5.2	$ 0.8	$ 6.0	$2.8	$0.4	$3.2	6894	18975
Pacific Region Total	**3407842**	**$ 1,019**	**$ 153.4**	**$ 1,172**	**$543.9**	**$81.9**	**$625.8**	**1349908**	**3715217**

(a) Net present value at 7% discount rate

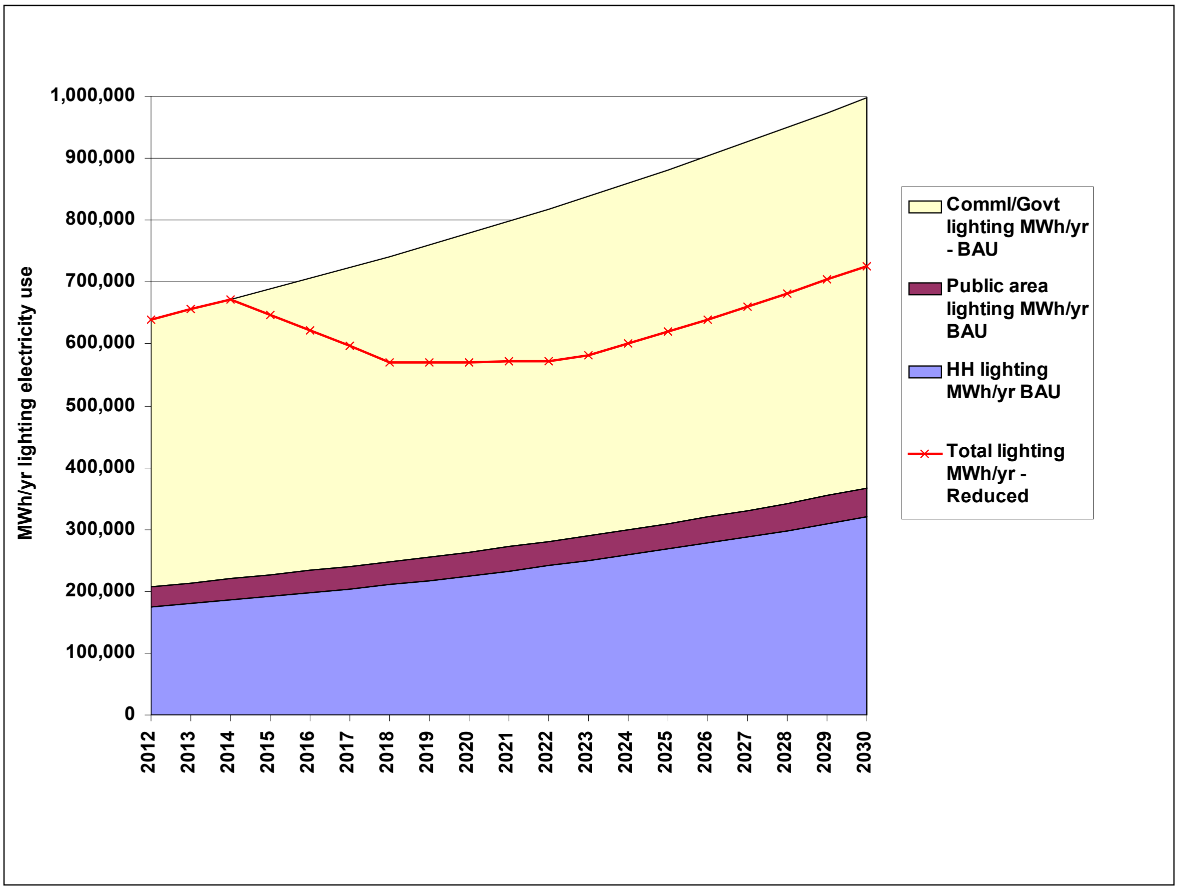

Figure 9: Projected BAU lighting electricity and savings potential, Pacific Region

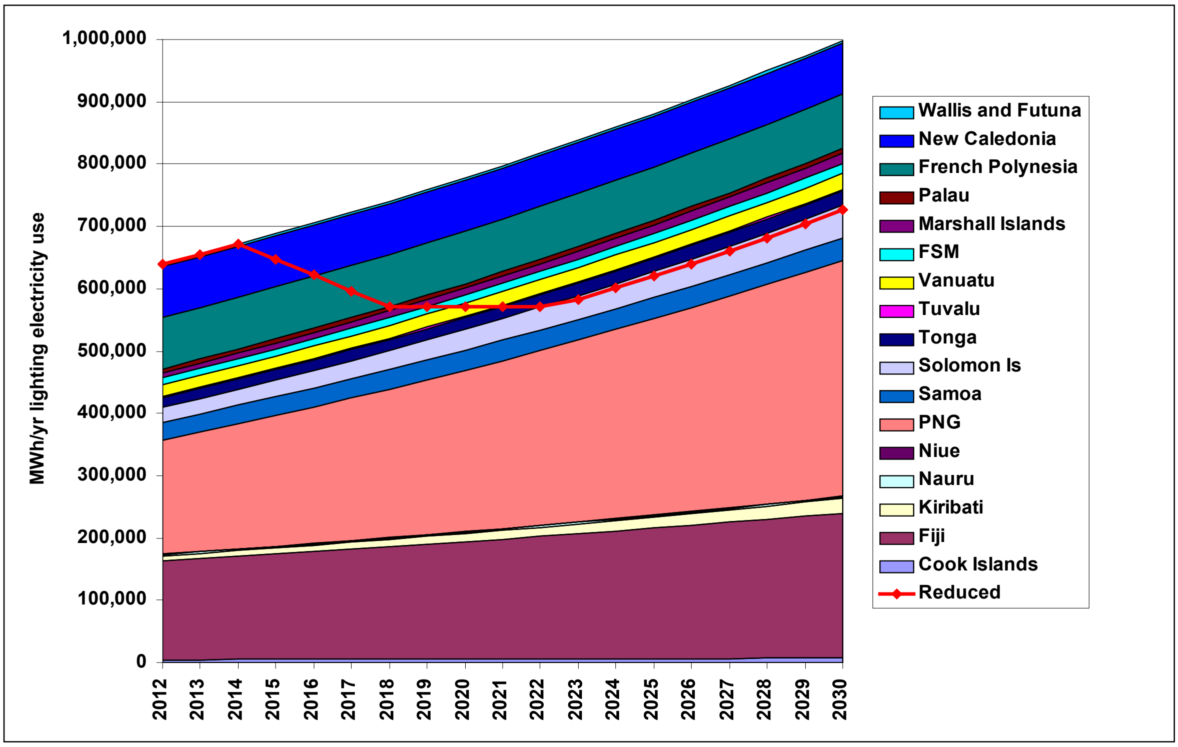

Figure 10: Projected BAU lighting electricity and savings potential, by PICT

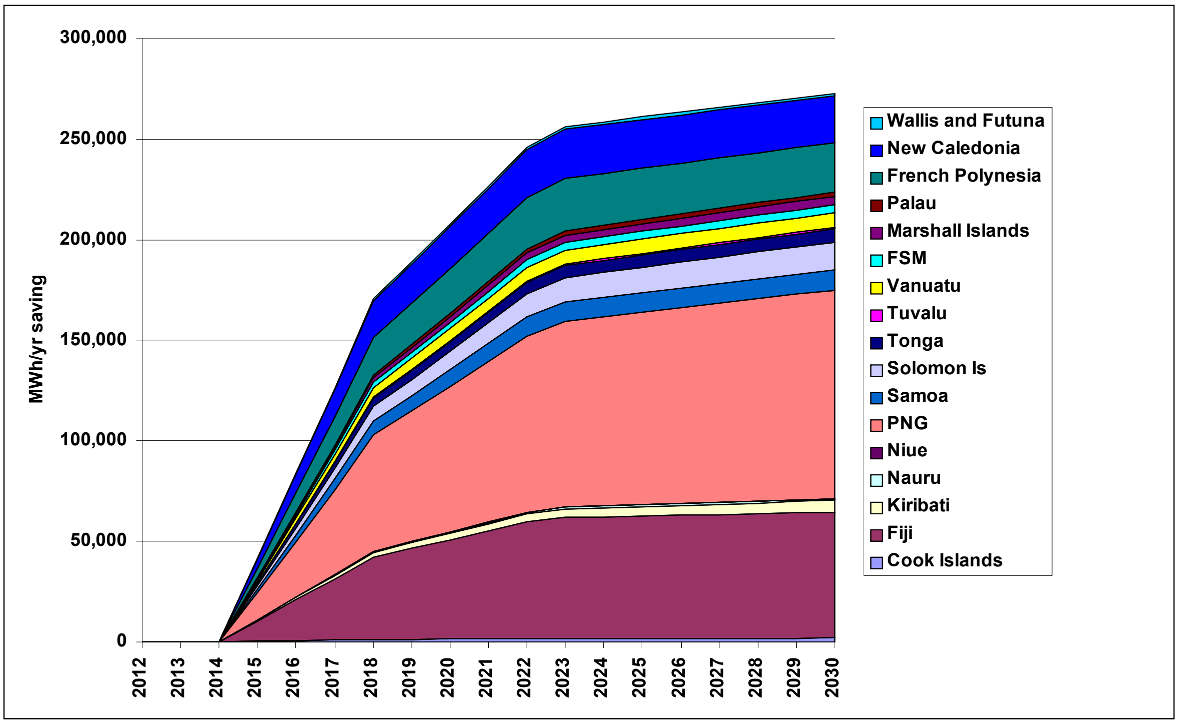

Figure 11: Projected lighting energy savings by PICT

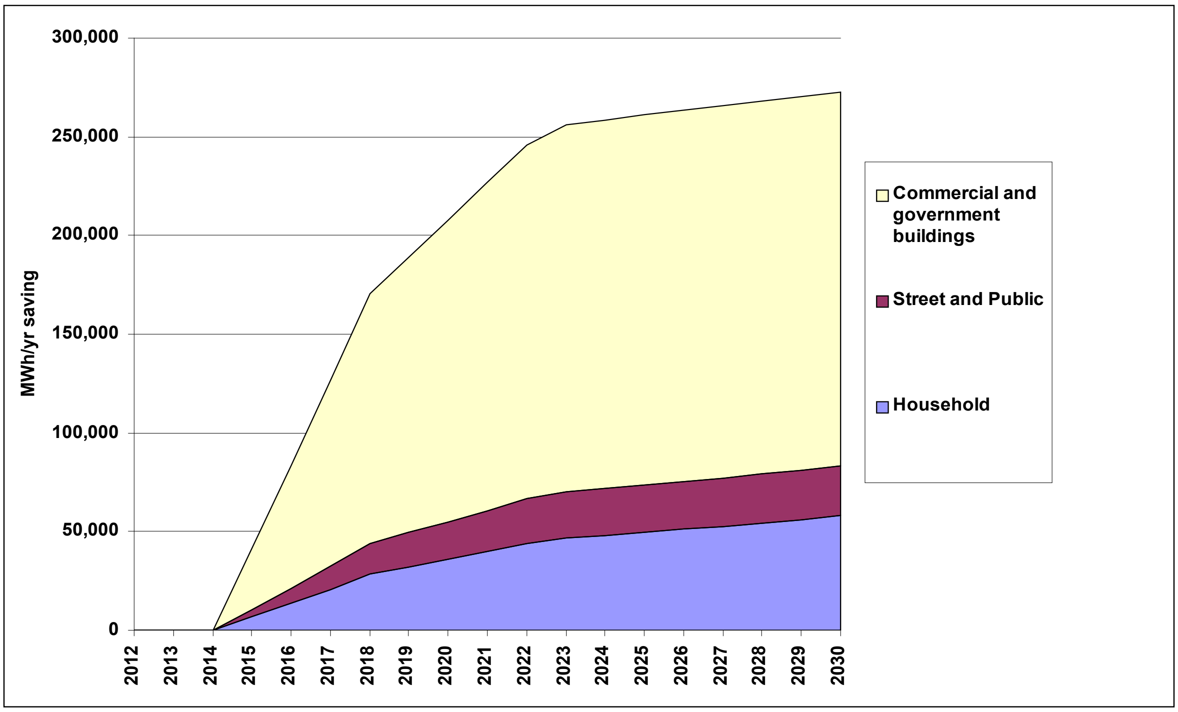

Figure 12: Projected lighting energy savings by sector

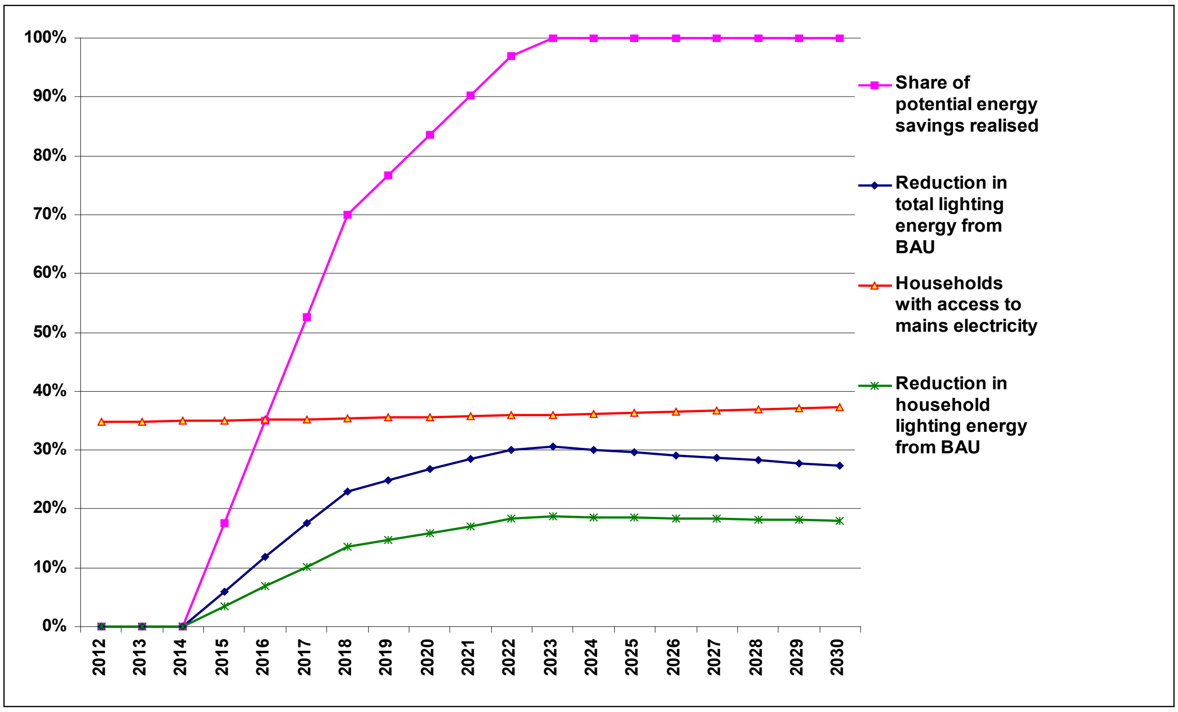

Figure 13: Projected percentage savings in lighting energy

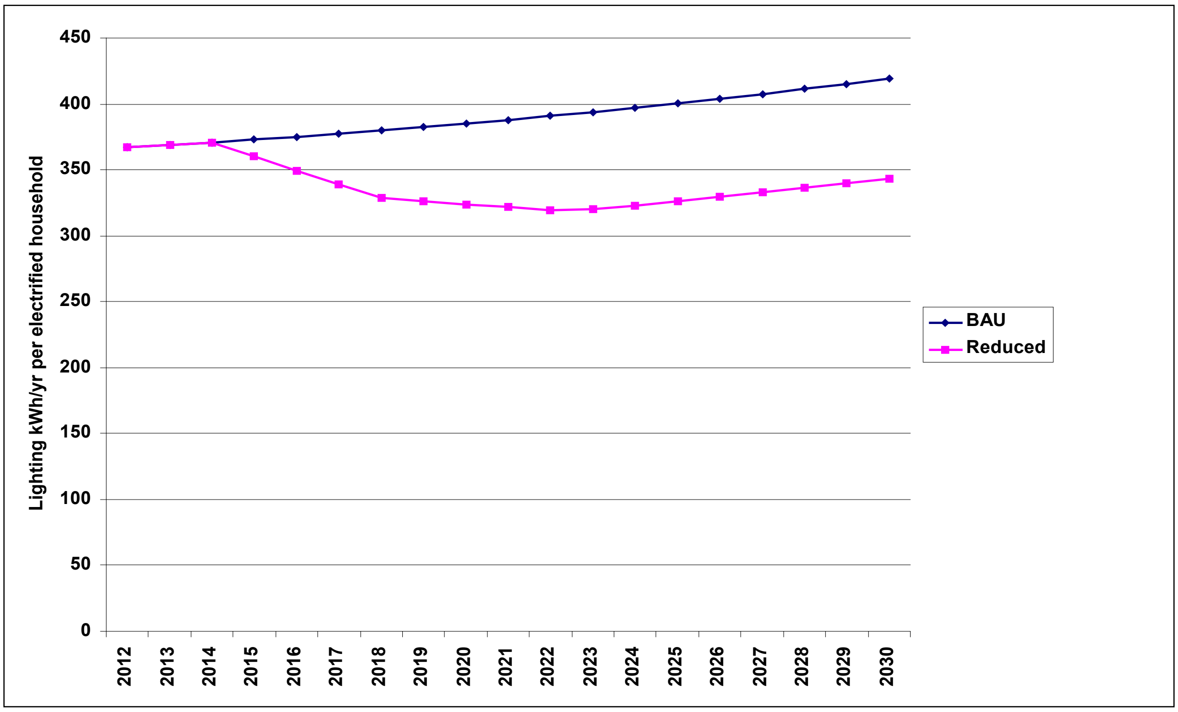

Figure 14: Projected average lighting energy use per electrified household

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PICT Annexes

Cook Islands

Available data

According to PEEP 2 there are only 246 light points for street and outdoor lighting in the Cook Islands, about 85% of which are based on relatively energy efficient lighting technologies such as LED and induction lamps, as summarised in Table 20. The weighted average lamp efficacy for all street and outdoor lighting is 93 lumen per watt.

Table 20 Number of street and outdoor lights - Cook Islands

Technology	Typical wattage	Number (2012)
Induction lamp	195	195
LED	13	13
High pressure sodium	37	37
High pressure sodium	150	1

Source: PEEP 2 http://www.ee-pacific.net/index.php/database/country-information/cook-islands#01

Table 21: Non-residential Buildings energy use data – Cook Islands

Building type	Number surveyed	kWh/m2/yr
Offices	32	11 – 431
Hospitals	5	5 – 176

Source: PEEP 2 http://www.ee-pacific.net/index.php/database/database1/building-sector

Lighting programs under way

Table 22: PEEP 2 Projects impacting on lighting energy use – Cook Islands

Project	Target Location or Sector
Outdoor lighting – replace with Solar LED	Rarotonga airport
Street lighting – replace with Solar LED	Punanga Rui Market
Street lighting – replace with Solar LED	Marin & Wharf
Street lighting – replace with EE lamps	Outer Islands
Commercial Buildings EE measures including lighting	Edgewater Resort & Spa
Commercial Buildings EE measures including lighting	Public sector
Residential EE lighting program	Residential sector

Source: PEEP 2 http://www.ee-pacific.net/index.php/projects

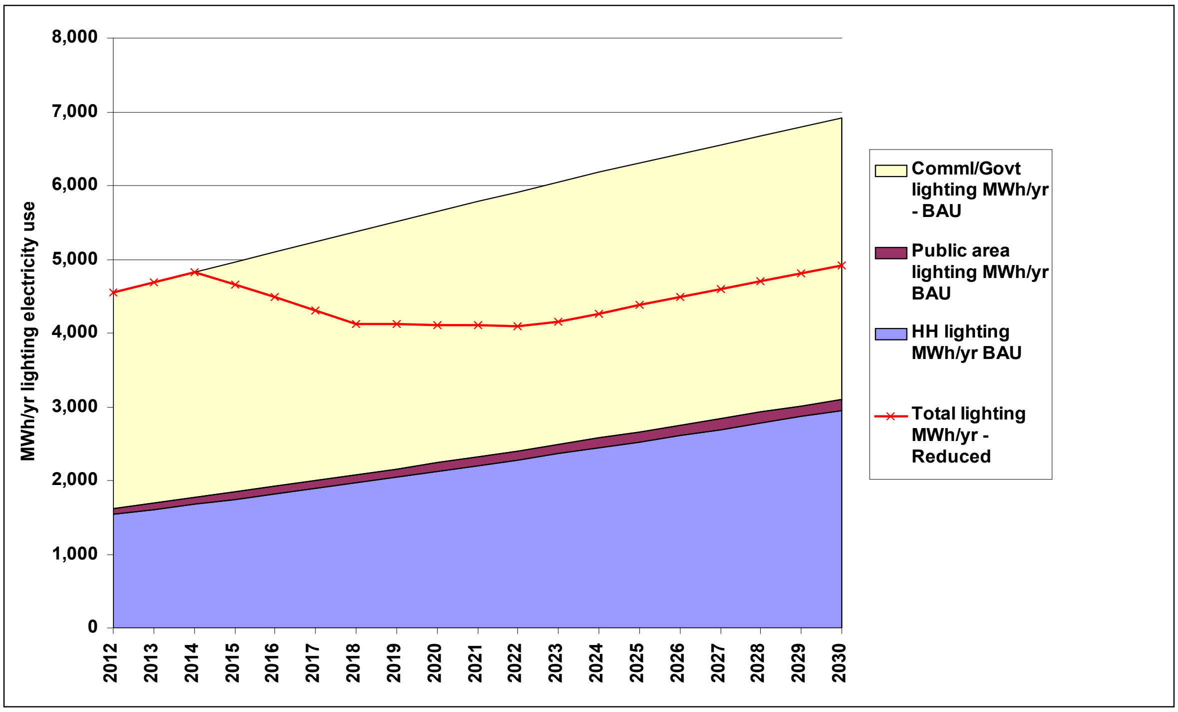
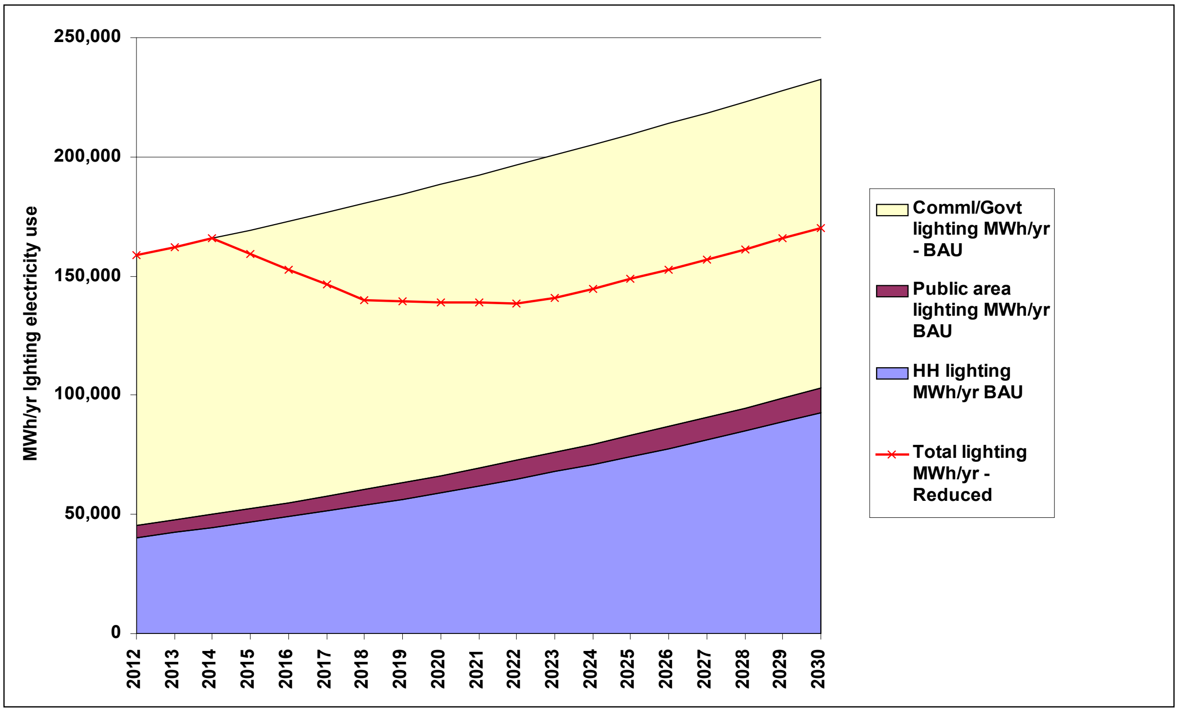
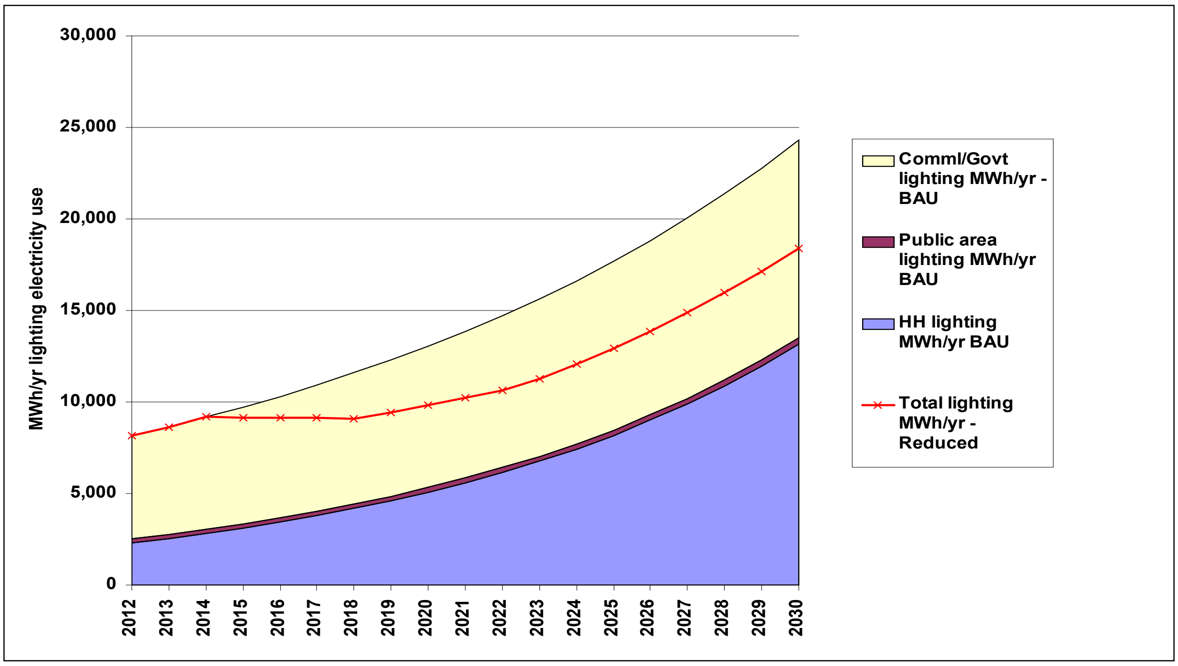


Table 23: Cook Islands estimated energy saving potential - lighting



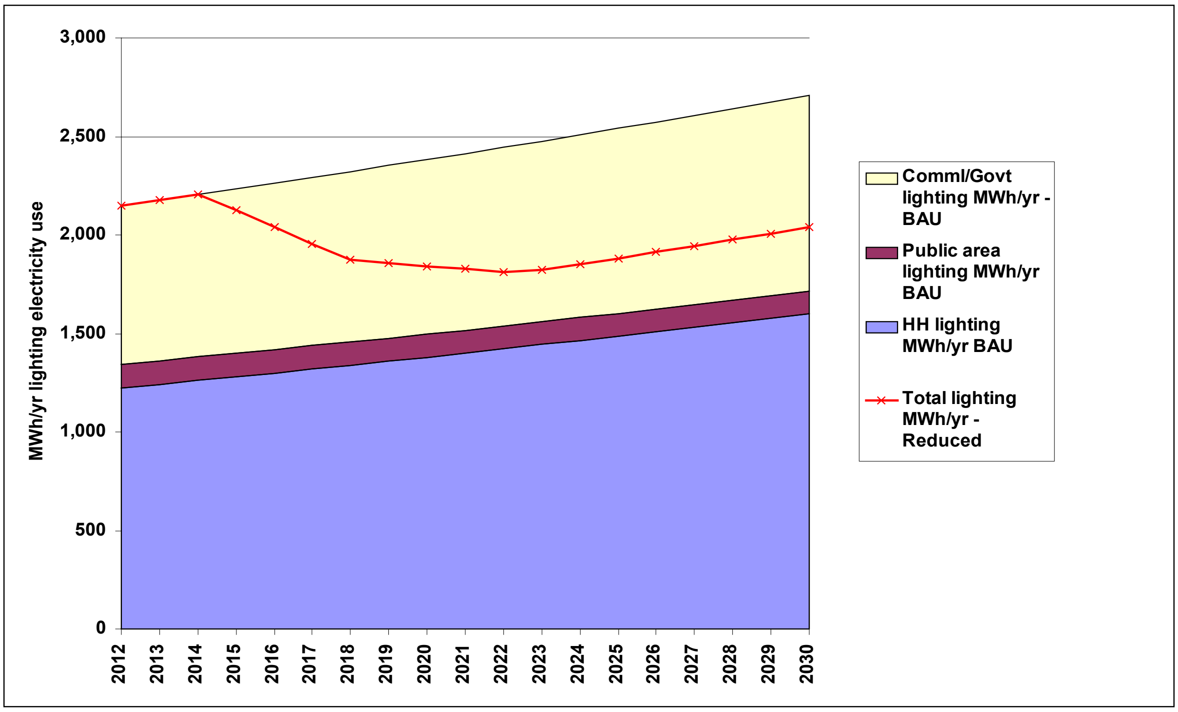
Fiji

Table 24: Fiji estimated energy saving potential - lighting



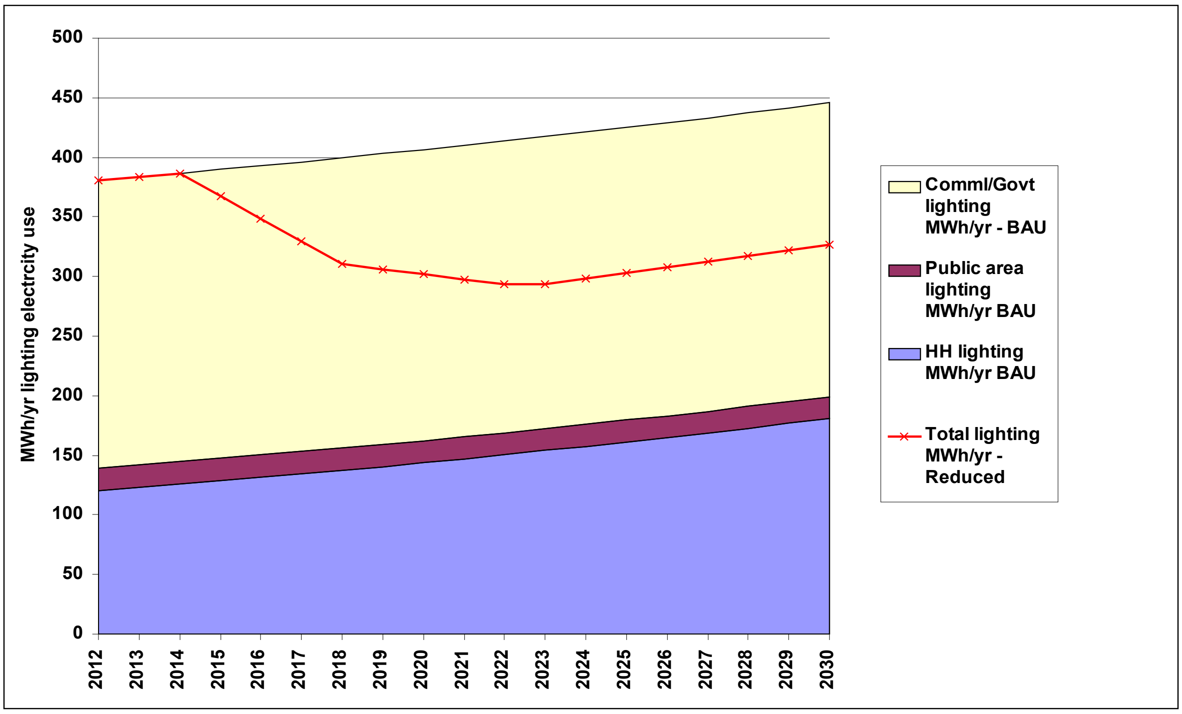
Kiribati

Table 25: Kiribati Estimated Energy Saving Potential - Lighting



Nauru

Table 26: Nauru estimated energy saving potential - lighting



Niue

Table 27 Niue estimated energy saving potential - lighting

Papua New Guinea

PNG has a weighted average street lighting lamp efficacy of about 65 lumens per watt, as 90% of lamps are Mercury Vapour and the remaining 10% are High Pressure Sodium (HPS) and fluorescent lamps.

Table 28: Non-residential buildings energy use data – PNG

Building type	Number surveyed	kWh/m2/yr
Offices	2	10 – 74
Hotels & Resorts	5	12 – 2,635

Source: PEEP 2 http://www.ee-pacific.net/index.php/database/database1/building-sector

Lighting programs under way

Table 29: PEEP 2 Projects impacting on lighting energy use – PNG

Project	Target Location or Sector
Street lighting – replace with EE lamps	Residential area Pt Moresby
Street lighting – replace with EE lamps	Residential area Alotau
Commercial Buildings EE lighting	Papua New Guinea Power Limited (PPL) Head Office
Commercial Buildings EE lighting	Pt Moresby General Hospital
Commercial Buildings EE measures including lighting	Science Faculty Building, University of PNG

Source: PEEP 2 http://www.ee-pacific.net/index.php/projects

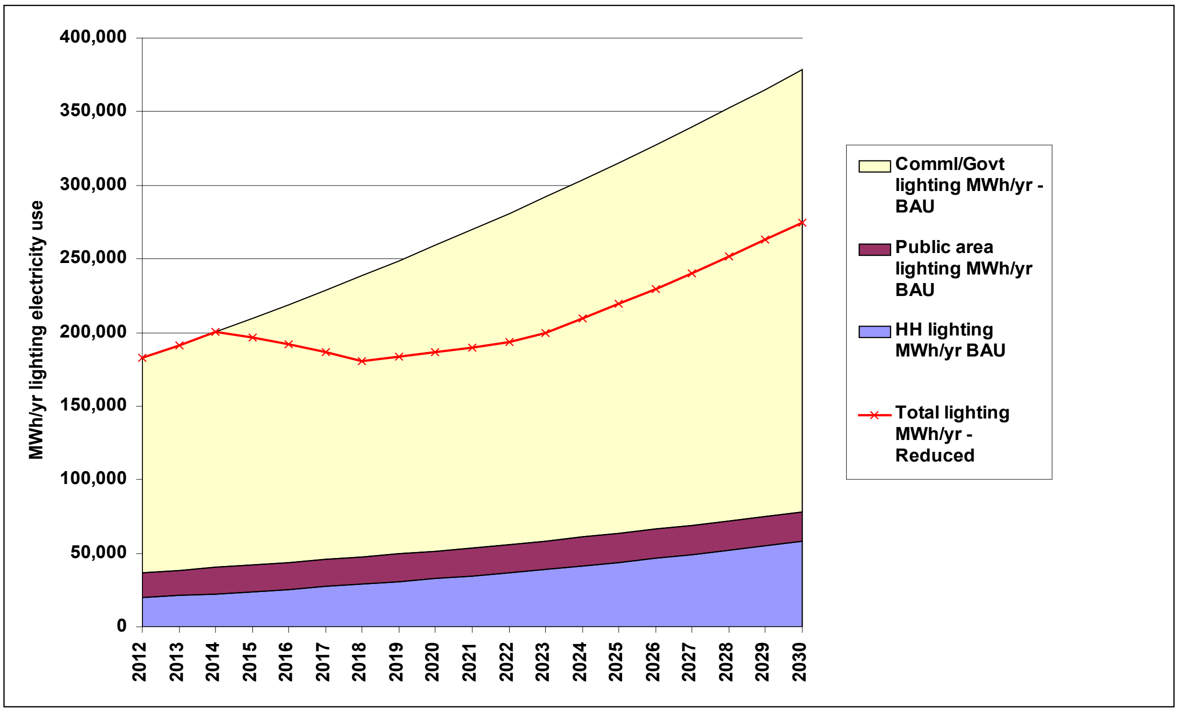


Table 30: PNG estimated energy saving potential - lighting

Samoa

Available data

For Samoa the weighted average lamp efficacies are below 60 lumens per watt, as over 95% of street lighting is still based on mercury vapour and fluorescent lighting technologies.

Table 31: Non-residential Buildings energy use data – Samoa

Building type	Number surveyed	kWh/m2/yr
Offices	24	8 – 379
Hotels & Resorts	9	11 – 270
Commercial buildings & retailers	17	4 – 226

Source: PEEP 2 http://www.ee-pacific.net/index.php/database/database1/building-sector

Lighting programs under way

Table 32: PEEP 2 Projects impacting on lighting energy use – Samoa

Project	Target Location or Sector
Street lighting – replace with EE lamps	Apia
Commercial Buildings EE lighting	Government Buildings
Commercial Buildings EE luminaires	Government Buildings
Residential EE lighting program	Residential sector
Commercial Buildings EE lighting	Commercial buildings

Source: PEEP 2 http://www.ee-pacific.net/index.php/projects

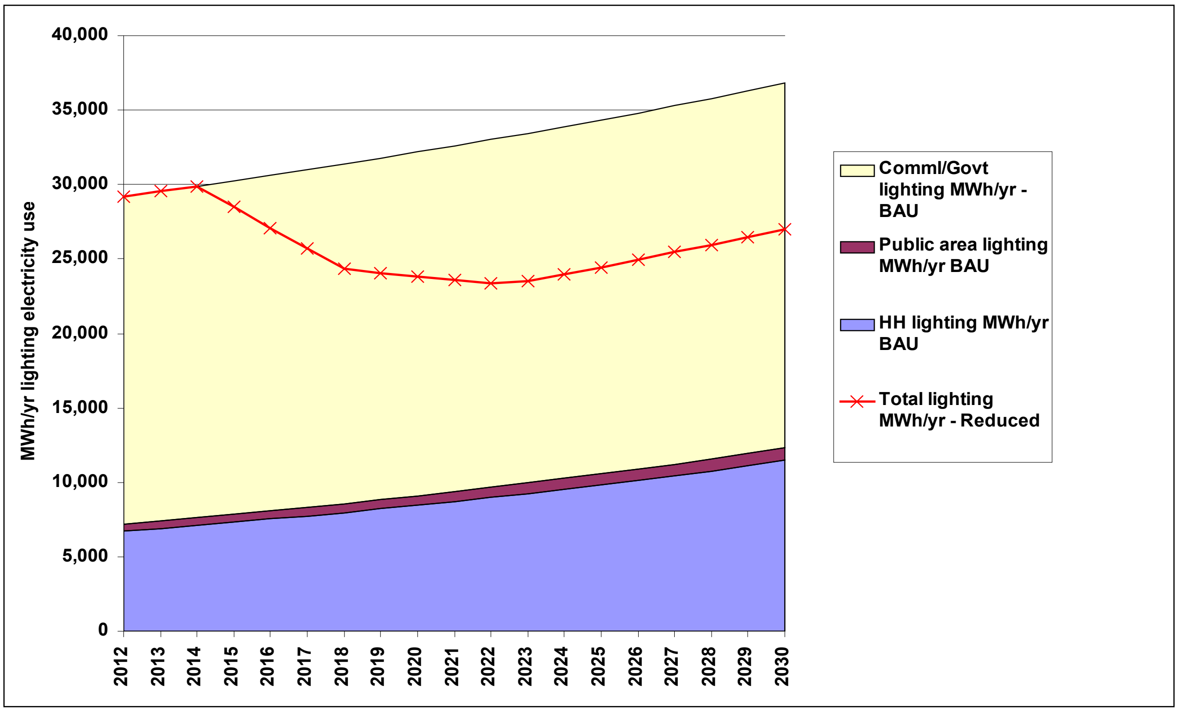
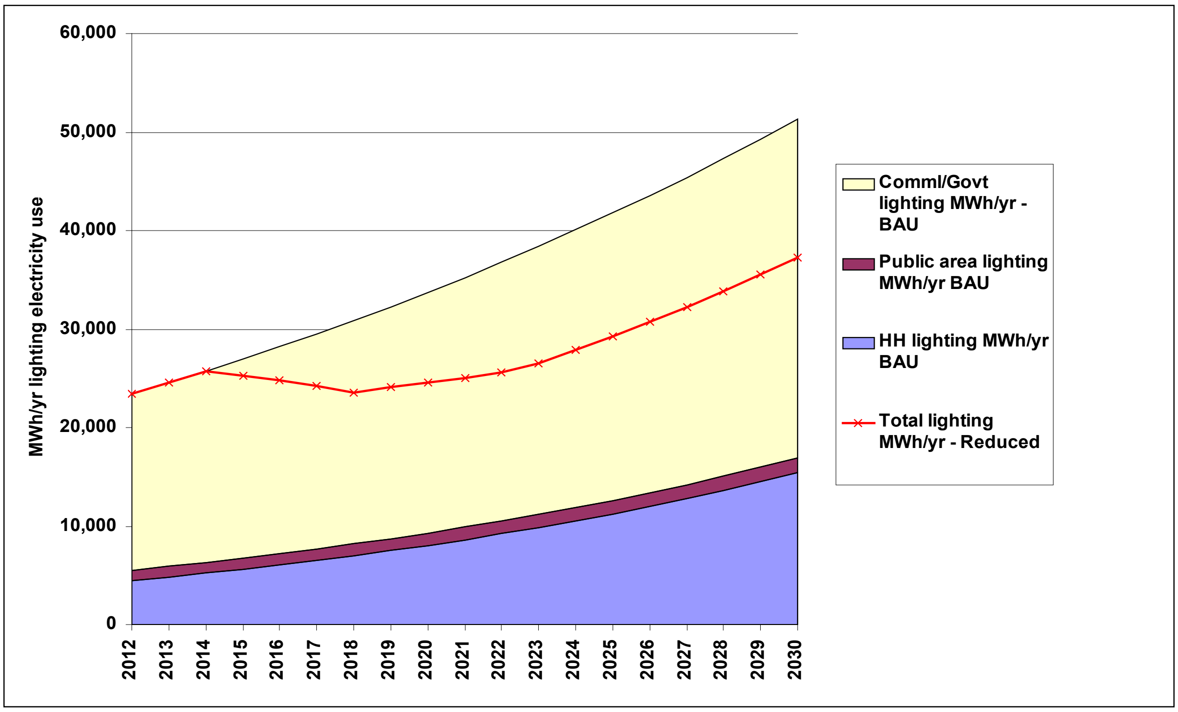


Table 33: Samoa estimated energy saving potential - lighting



Solomon Islands

Table 34: Solomon Islands Estimated Energy Saving Potential - Lighting

Tonga

According to PEEP 2 the weighted average lamp efficacy for all street lighting is a relatively high 100 lumen per watt as a result of utilisation of high pressure sodium (HPS) lamps and LED luminaires (partially supported by ADB during the PEEP1 project).

Table 35: Non-residential Buildings energy use data – Tonga

Building type	Number surveyed	kWh/m2/yr
Offices	5	9 – 698

Source: PEEP 2 http://www.ee-pacific.net/index.php/database/database1/building-sector

Lighting programs under way

Table 36: PEEP 2 Projects impacting on lighting energy use – Tonga

Project	Target Location or Sector
Street lighting – replace with EE lamps	Outer Islands
Street lighting – replace with EE lamps	Tongatapu
Commercial Buildings EE lighting	Government Buildings
Residential EE lighting program	Outer islands
Residential EE lighting program	Tongatapu

Source: PEEP 2 http://www.ee-pacific.net/index.php/projects

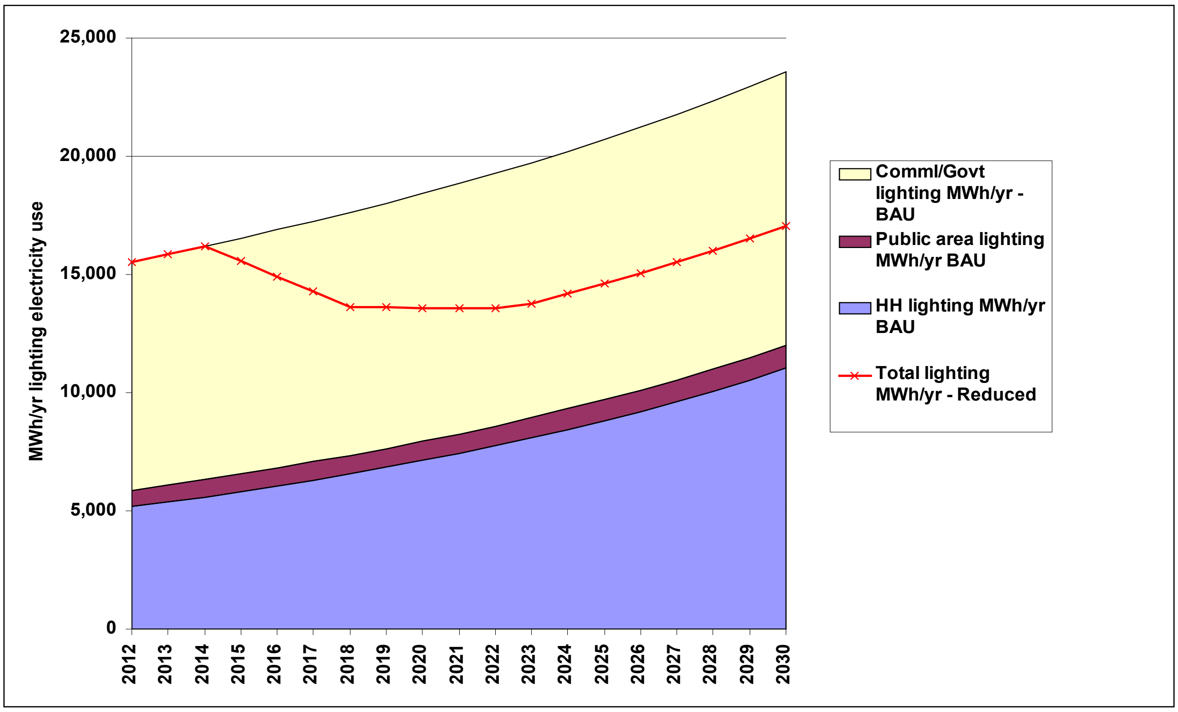
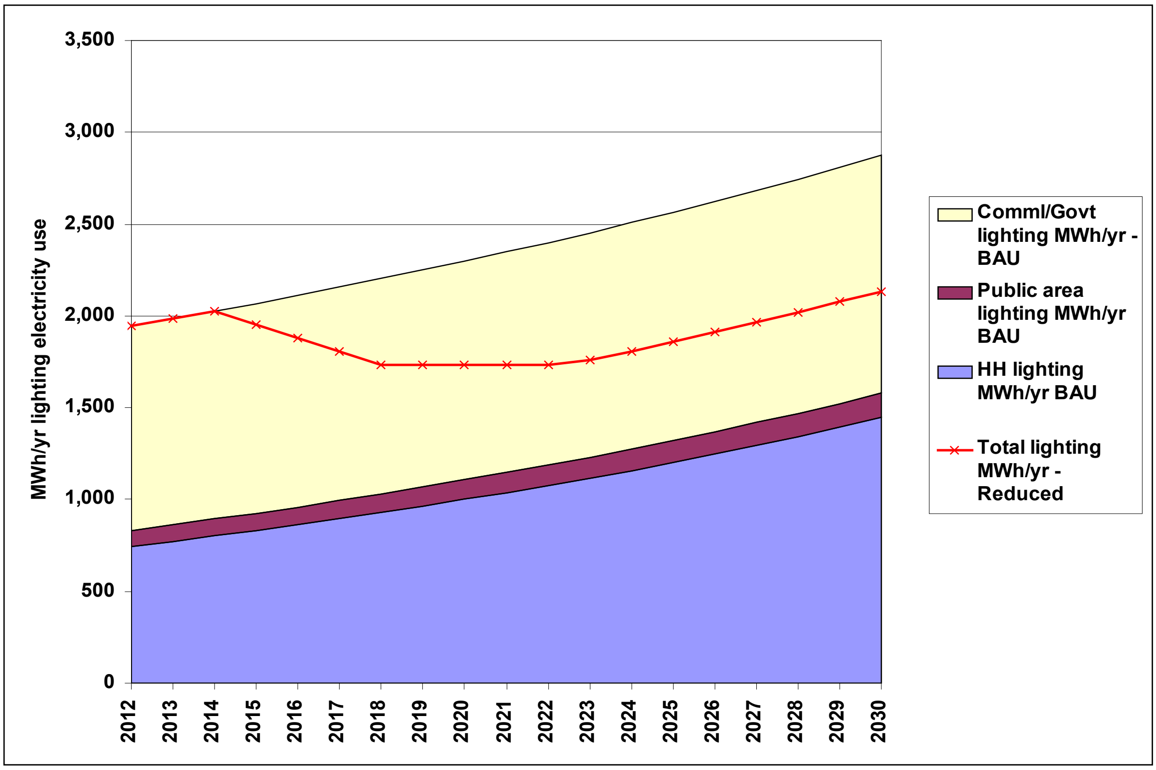


Table 37: Tonga estimated energy saving potential - lighting



Tuvalu

Table 38: Tuvalu estimated energy saving potential - lighting

Vanuatu

For Vanuatu the weighted average lamp efficacies are below 60 lumens per watt, as over 95% of street lighting is still based on mercury vapour fluorescent lighting technologies.

Table 39: Non-residential buildings energy use data – Vanuatu

Building type	Number surveyed	kWh/m2/yr
Offices	2	3 – 18

Source: PEEP 2 http://www.ee-pacific.net/index.php/database/database1/building-sector

Lighting programs under way

Table 40 PEEP 2 Projects impacting on lighting energy use – Vanuatu

Project	Target Location or Sector
Street lighting – replace with EE lamps	Luganville
Street lighting – replace with EE lamps	Pt Vila
Commercial Buildings EE lighting	Public Sector Buildings
Commercial Buildings EE lighting	Provincial, Local Public Sector and School Buildings
Residential EE lighting program	Luganville
Residential EE lighting program	Pt Vila

Source: PEEP 2 http://www.ee-pacific.net/index.php/projects

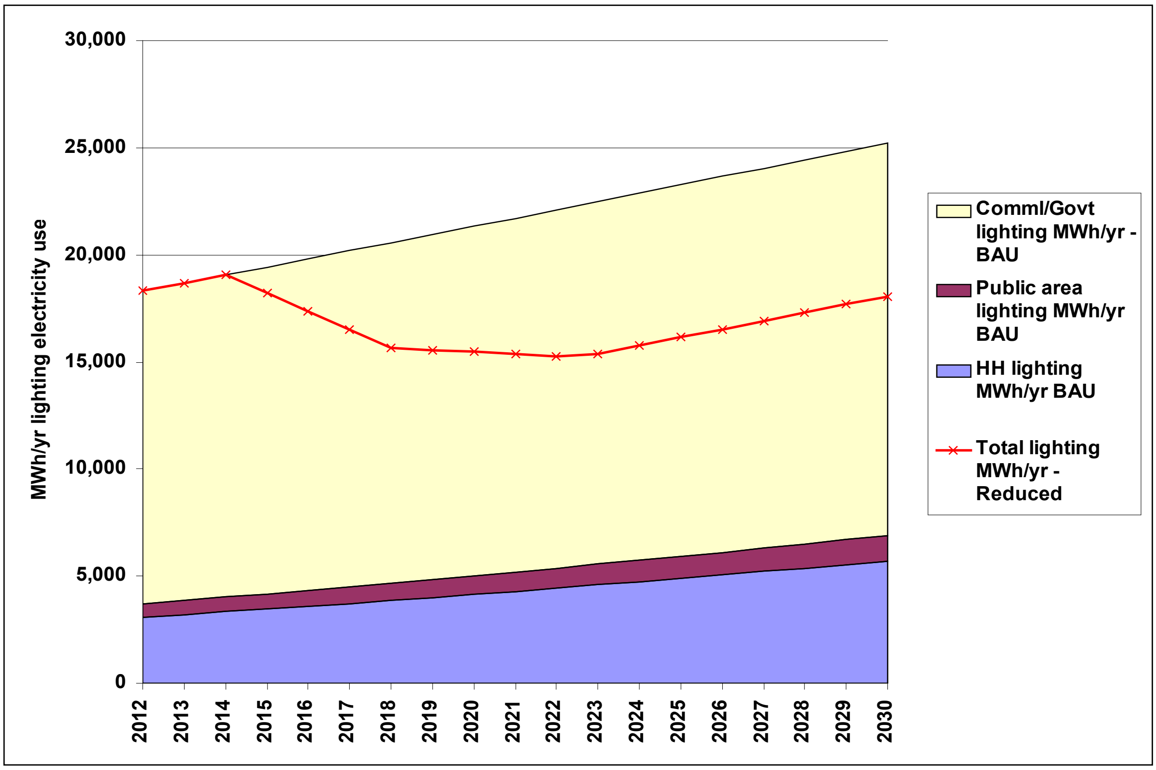
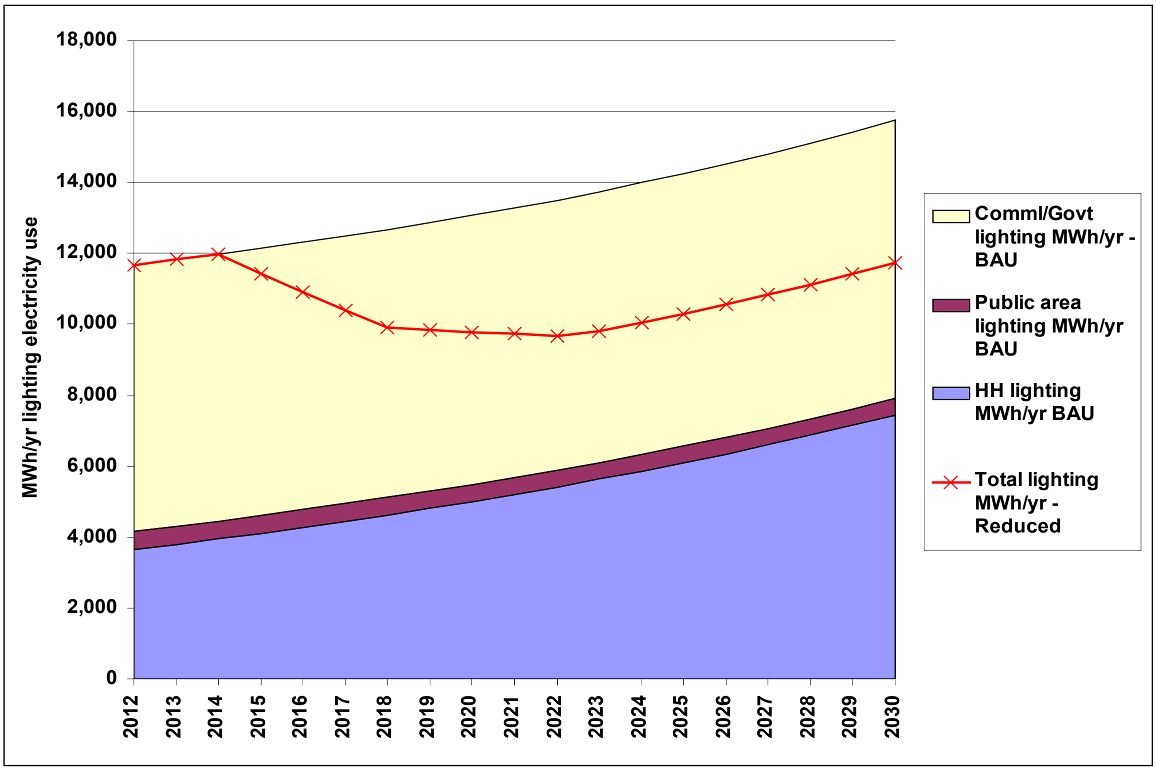
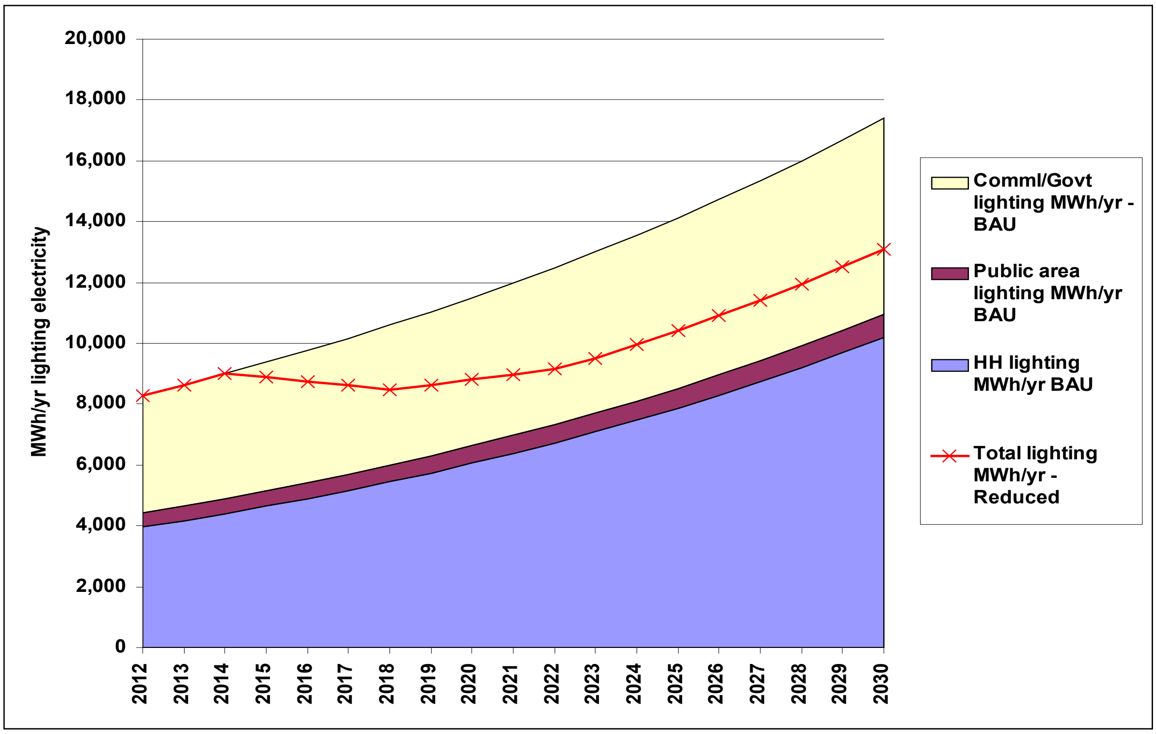


Table 41: Vanuatu estimated energy saving potential - lighting



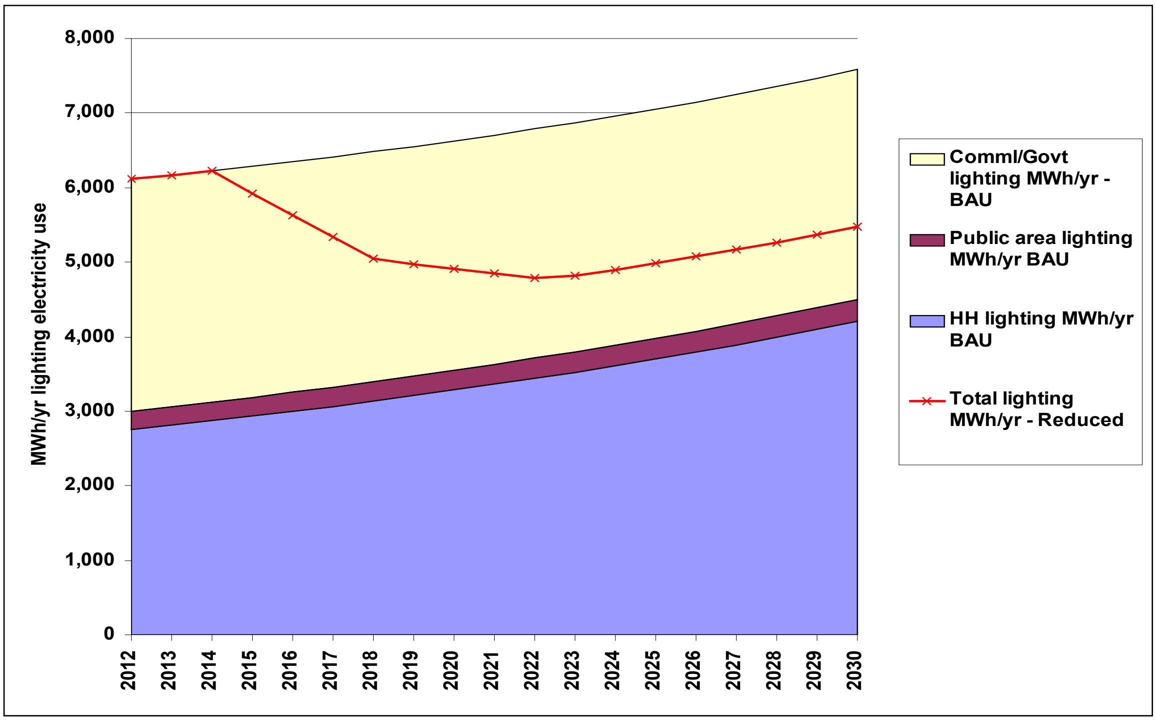
Federated States of Micronesia

Table 42: FSM Estimated Energy Saving Potential - Lighting



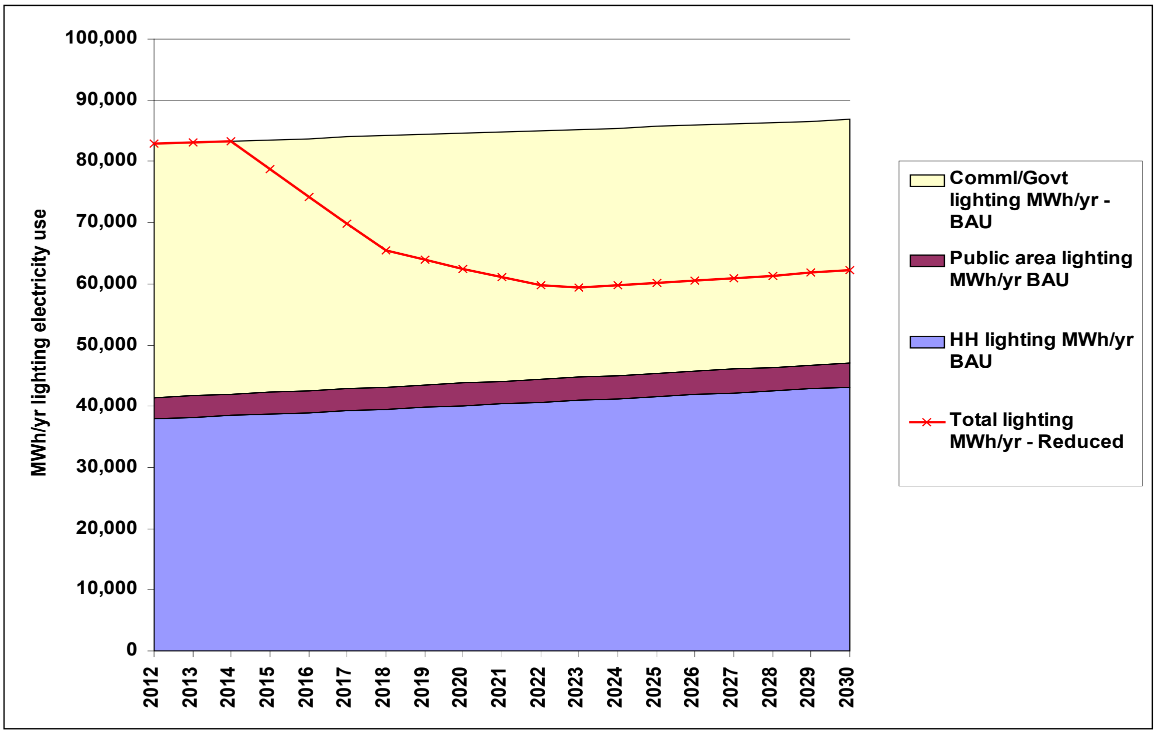
Republic of the Marshall Islands

Table 43: RMI Estimated Energy Saving Potential – Lighting



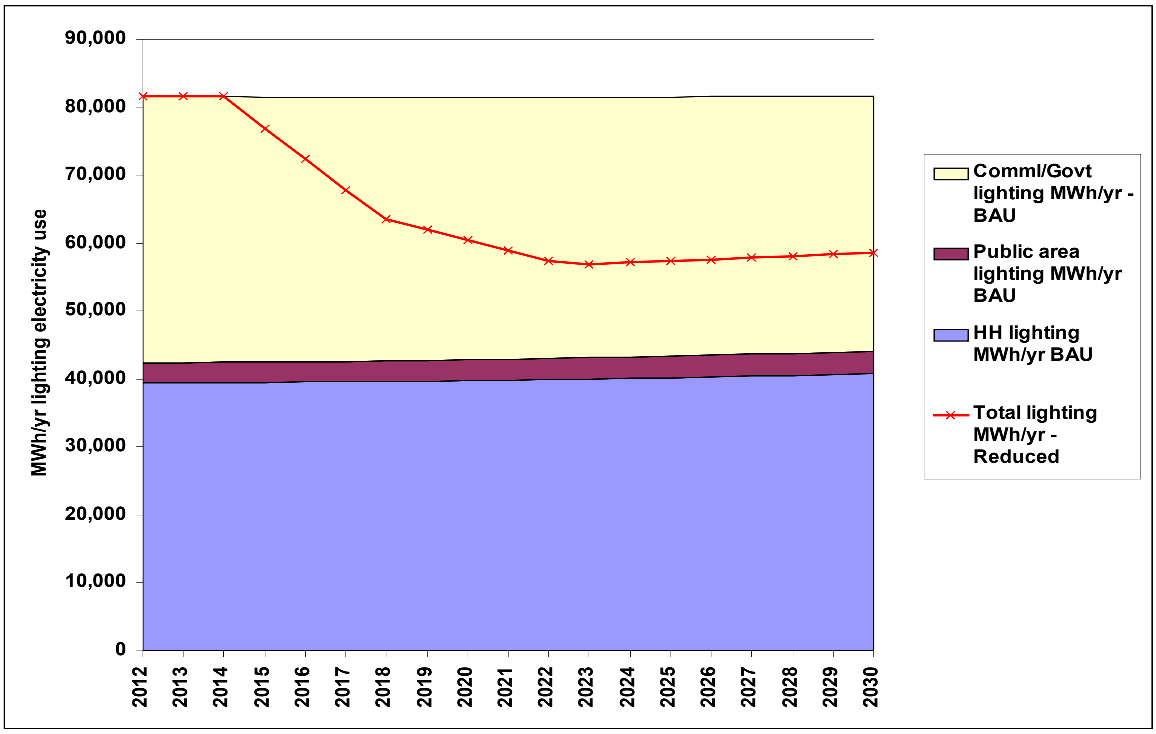
Palau

Table 44: Palau Estimated Energy Saving Potential – Lighting



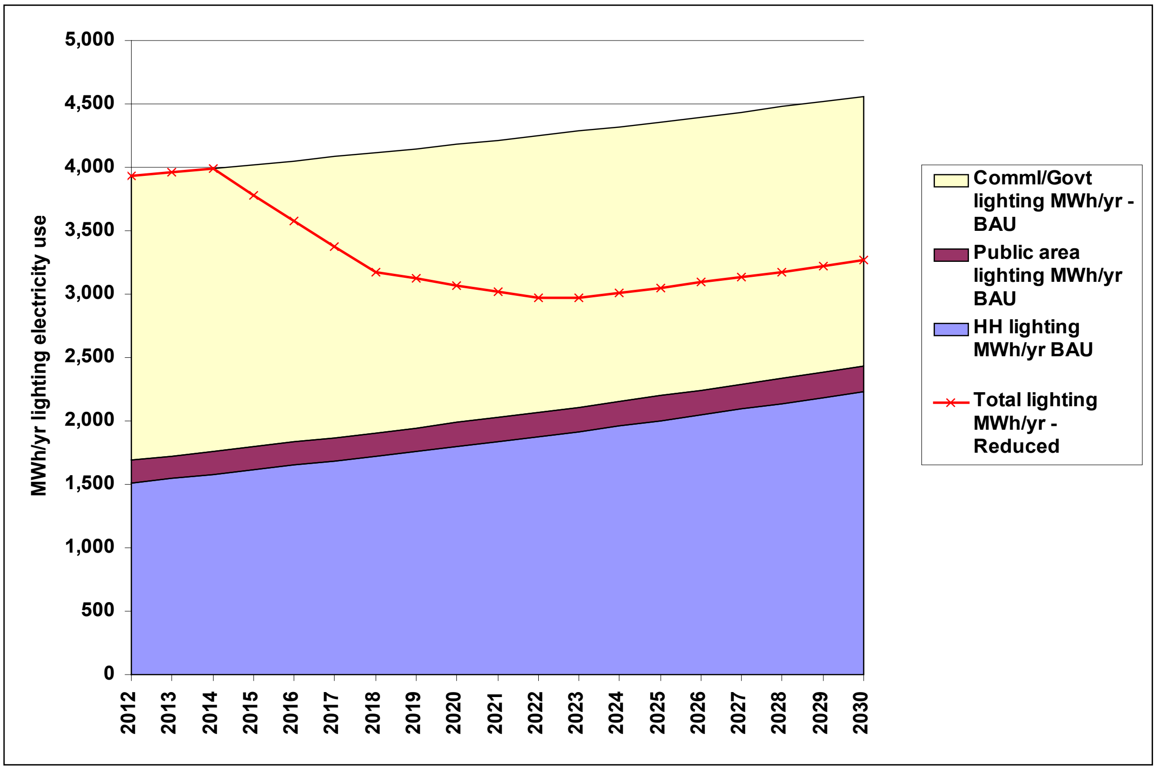
French Polynesia

Table 45 French Polynesia Estimated Energy Saving Potential – Lighting



New Caledonia

Table 46 New Caledonia Estimated Energy Saving Potential – Lighting



Wallis and Futuna

Table 47: Wallis and Futuna Estimated Energy Saving Potential – Lighting

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