Energy Efficiency (EE) on Refrigeration and Air Conditioning (RAC) Sector Regulations Development Options for Papua New Guinea

Deliverable 2 – Report on Market Assessment and Baseline for Air Conditioners (First Progress Report)

THE UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION (UNIDO)

D2. Baseline report

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ECONOLER

ABBREVIATIONS

CCDA	Climate Change Development and Authority
CCMA	Climate Change Management Act
CEPA	Conservation Environment and Protection Authority
CTCN	Climate Technology Centre and Network
DPCI	Provincial Delegations of Commerce and Industry
ECOWAS	Economic Community of West African States
EE	Energy Efficiency
EEC	Energy efficiency class
EU	European Union
GHG	Greenhouse gas
ILAC	International Laboratory Accreditation Cooperation
MEPS	Minimum energy performances standard
MVE	Monitoring, verification and enforcement (protocol)
NDE	National Designated Entity
PICT	Pacific Islands Countries and Territories
PPL	PNG Power Limited
RAC	Refrigerant and Air Condition
SGD	Single Goods Declaration
UNFCCC	United Nations Framework Convention on Climate Change

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EXECUTIVE SUMMARY

The power sector in Papua New Guinea faces a number of challenges including very low access to electricity services. Estimates suggest that about 55% of the country's 8,8 million inhabitants currently have access to electricity, an increase of more than 30% in the last decade[1]. The large majority of the population (88%) living in rural areas still lacks access to electricity, however.[2] This significantly impedes PNG's social and economic growth. In an effort to address the power sector challenges, the government has taken actions to improve the policy framework. In its 2010-2030 Development Strategic Plan, the Government set a target to reach 70% of electricity access by 2030. In order to help achieve this target a National Electrification Roll Out Plan is to be developed.

The National Designated Entity (NDE) of PNG has submitted a request for technical assistance (TA) to the Climate Technology Centre and Network (CTCN), which is the operational arm of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism and co-hosted by the United Nations Environment (UNEP) in collaboration with the United Nations Industrial Development Organization (UNIDO). The CTCN mandated Econoler to offer TA to the PNG Climate Change Development and Authority (CCDA) for the implementation of best policy and regulatory practices for both minimum energy performances standards (MEPS) and energy labelling in PNG for air conditioning (AC) appliances.

This CTCN project, which is funded by UNIDO, was timely and directly based on recent efforts carried out by the Pacific Appliance Labelling and Standards (PALS) Programme that is being led by the Secretariat of the Pacific Community (SPC), but also by the Renewable Energy and Energy Efficiency Partnership (REEEP). The main objective of the current CTCN project consists in designing an S&L program for ACs with a determined energy performance threshold and labelling categories as well as an appropriate monitoring, verification and enforcement (MVE) protocol

The project team has faced many challenges during the project. For instance, despite significant efforts from the local consultant team and an official intervention from the CCDA via an official letter, no appliance distributors and even the PNG Customs have provided data to the research team. Fortunately, although the justification for a proposed design of a S&L program can be affected by a lack of data, it is still possible that such a design be the 'right' one and that the implementation of such a program yields the expected energy savings and GHG emissions reduction.

The following tables show the proposed MEPS and labelling categories pursuant to a regional harmonization with the Australia/NZ S&L system.

Kind of product	Product class	Characteristics	Value of *R*			MEPS SEER value	MEPS EER value
Air-to-air unitary air conditioners	1	Wall mounted unitary double duct air conditioners		R	≤ 65kW	2.52	2.69

[1] World Bank (2019); https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=PG
[2] SEE4ALL 2019

	2	Portable unitary double duct air conditioners		R	≤ 65kW	2.04	2.20
	3	Wall mounted unitary single duct air conditioners		R	≤ 65kW	2.52	2.69
	4	Portable unitary single duct air conditioners		R	≤ 65kW	2.04	2.20
	5	Ducted or non-ducted, excluding product classes 1 to 4		R	< 10kW	2.52	2.69
	6	Ducted or non-ducted, excluding product classes 1 to 4	10kW ≤	R	≤ 39kW	2.52	2.69
	7	Ducted or non-ducted, excluding product classes 1 to 4	39kW <	R	≤ 65kW	2.36	2.53
Air-to-air single-split systems	8	Non-ducted		R	< 4kW	2.96	3.14
	9	Non-ducted	4kW ≤	R	< 10kW	2.61	2.79
	10	Ducted		R	< 10kW	2.52	2.69
	11	Ducted or non-ducted	10kW ≤	R	≤ 39kW	2.52	2.69
	12	Ducted or non-ducted	39kW <	R	≤ 65kW	2.36	2.53
Air-to-air single-split outdoor units (not supplied or offered for supply as part of a single-split system)	13	Supplied or offered for supply to create a non-ducted system		R	< 4kW	2.96	3.14
	14	Supplied or offered for supply to create a non-ducted system	4kW ≤	R	< 10kW	2.61	2.79
	15	Supplied or offered for supply to create a ducted system		R	< 10kW	2.52	2.69
	16	Whether supplied or offered for supply to create a ducted or a non-ducted system	10kW ≤	R	≤ 39kW	2.52	2.69
	17	Whether supplied or offered for supply to create a ducted or a non-ducted system	39kW <	R	≤ 65kW	2.36	2.53
Air-to-air multi-split outdoor units (whether or not supplied or offered for supply as part	18			R	< 4kW	2.96	3.14
	19		4kW ≤	R	< 10kW	2.61	2.79
	20		10kW ≤	R	< 39kW	2.52	2.69
	21		39kW ≤	R	≤ 65kW	2.36	2.53

of a multi-split system)							
Water-to-air air conditioners	22			R	< 39kW	2.84	3.02
	23		39kW ≤	R	≤ 65kW	2.60	2.77

Proposed Labelling Categories for ACs in PNG

Australian's ACs Labelling Classification		PNG's ACs Labelling Classification (based on the Australia's one)		
SEER	**Stars**	**SEER**	**EER**	**Stars**
SEER< 1.8	0	N/A	N/A	N/A
1.8 ≤ SEER < 2.5	½	1.75 ≤ SEER < 2	1,90 ≤ EER < 2.16	½
2.5 ≤ SEER < 3	1	2 ≤ SEER < 2.5	2.16 ≤ EER < 2.68	1
3 ≤ SEER < 3.5	1½	2.5 ≤ SEER < 3	2.68 ≤ EER < 3.18	1½
3.5 ≤ SEER < 4	2	3 ≤ SEER < 3.5	3.18 ≤ EER < 3.68	2
4 ≤ SEER < 4.5	2½	3.5 ≤ SEER < 4	3.68 ≤ EER < 4.16	2½
4.5 ≤ SEER < 5	3	4 ≤ SEER < 4.5	4.16 ≤ EER < 4.64	3
5 ≤ SEER < 5.5	3½	4.5 ≤ SEER < 5	4.64 ≤ EER < 5.10	3½
5.5 ≤ SEER < 6	4	5 ≤ SEER < 5.5	5.10 ≤ EER < 5.56	4
6 ≤ SEER < 6.5	4½	5.5 ≤ SEER < 6	5.56 ≤ EER < 6.00	4½
6.5 ≤ SEER < 7	5	6 ≤ SEER < 6.5	6.00 ≤ EER < 6.44	5
7 ≤ SEER < 7.5	5½	6.5 ≤ SEER < 7	6.44 ≤ EER < 6.86	5½
7.5 ≤ SEER < 8	6	7 ≤ SEER < 7.5	6.86 ≤ EER < 7.28	6
8 ≤ SEER < 8.5	6½	7.5 ≤ SEER < 8	7.28 ≤ EER < 7.68	6½
8.5 ≤ SEER < 9	7	8 ≤ SEER < 8.5	7.68 ≤ EER < 8.08	7
9 ≤ SEER < 9.5	7½	8.5 ≤ SEER < 9	8.08 ≤ EER < 8.46	7½
9.5 ≤ SEER < 10	8	9 ≤ SEER < 9.5	8.46 ≤ EER < 8.84	8
10 ≤ SEER < 10.5	8½	9.5 ≤ SEER < 10	8.84 ≤ EER < 9.20	8½
10.5 ≤ SEER < 11	9	10 ≤ SEER < 10.5	9.20 ≤ EER < 9.56	9
11 ≤ SEER < 11.5	9½	10.5 ≤ SEER < 11	9.56 ≤ EER < 9.90	9½
11.5 ≤ SEER	10	11 ≤ SEER	9.90 ≤ EER	10

The simulations for the energy savings and the GHG emissions reductions were done with four different scenarios: with a MEPS threshold at 2.2 and 2.9 EER and a slow and a fast labelling implementation. The GHG emission factor is based upon the data provided by the Institute for Global

Environmental Strategies (IGES) and is established at 0.679 tCO_2/MWh. The following table shows these potential savings based on these assumptions.

Summary of the Energy Savings and GHG Emissions Reduction

MEPS	Labelling	Consumption	Savings (2021-2040)		
		(GWh)	GWh	M USD	ktCO2
Baseline		22,306	n/a	n/a	n/a
2.2	10.00%	19,507	510	62.2	346
2.2	15.00%	19,472	545	65.2	370
2.9	10.00%	19,163	855	102.0	580
2.9	15.00%	19,150	867	102.5	589

As shown in the table, the cumulative emission savings range from 346 ktCO2 to 589 $ktCO_2$, which is the equivalent of planting between 1,700,000 and 2,900,000 trees or taking between 75 000 and 125 000 cars off the PNG roads.[3]

PNG could thus greatly benefit from the implementation of a S&L program for ACs.

[3] https://www.epa.gov/energy

INTRODUCTION

The power sector in Papua New Guinea faces a number of challenges including very low access to electricity services. Estimates suggest that about 55% of the country's 8,8 million inhabitants currently have access to electricity, an increase of more than 30% in the last decade[4]. The large majority of the population (88%) living in rural areas still lacks access to electricity, however.[5] This significantly impedes PNG's social and economic growth. In an effort to address the power sector challenges, the government has taken actions to improve the policy framework. In its 2010-2030 Development Strategic Plan, the Government set a target to reach 70% of electricity access by 2030. In order to help achieve this target a National Electrification Roll Out Plan is to be developed.

However, PNG has seen significant increases in energy access and, hereby, in energy demand. In the PNG Development Strategic Plan, 2010–2030 (PNGDSP), the Government of Papua New Guinea estimates that the peak demand for electricity in 2021 will be about 700 MW and increase to over 1,400 MW by 2030[6]. Meeting this demand will require substantial new power generation resources, but it will not be enough. They will need to associate it with demand-side management measures to downgrade the country's energy intensity. Consequently, as with many developing countries throughout the world, it is essential for PNG to improve its energy efficiency (EE).

In fact, access to electricity in PNG has almost tripled in 7 years from 19.5 percent of the population in 2010 to 54.4% of the population in 2017[7]. The difference is even more significant for the rural population (11.8% in 2010 to 50.4% in 2017). This increasing demand has augmented not only the country's reliance on energy imports, but also the shortage of power and the country's energy bill. Improving EE is thus a potential measure to alleviate this situation. Since about half of the electricity produced in PNG comes from non-renewable sources, there could be significant benefits of adopting EE measures such as Standard & Labelling (S&L) Programs. The potential financial savings generated by the implementation of a S&L program in PNG are the following:

- Diesel imports reduction through lowering energy demand;
- Energy bills reduction for consumers;
- Infrastructure costs avoided–reduced capital and maintenance costs;
- Livelihood improvement through access to better quality products;
- Energy efficient products –Ensuring Pacific Islands Countries and Territories (PICTs) do not have to accept inefficient products banned from sale elsewhere;
- Emissions/Pollution reductions.

The National Designated Entity (NDE) of PNG has submitted a request for technical assistance (TA) to the Climate Technology Centre and Network (CTCN), which is the operational arm of the United Nations Framework Convention on Climate Change (UNFCCC) Technology Mechanism and co-

[4] World Bank (2019); https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=PG
[5] SEE4ALL 2019
[6] Government of Papua New Guinea, Department of National Planning and Monitoring. 2010. Papua New Guinea Development Strategic Plan, 2010–2030 . Port Moresby.
[7] The World Bank, Access to electricity (% of population) – Papua New Guinea, https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=PG. Consulted on December 17th 2019.

hosted by the United Nations Environment (UNEP) in collaboration with the United Nations Industrial Development Organization (UNIDO). The CTCN mandated Econoler to offer TA to the PNG Climate Change Development and Authority (CCDA) for the implementation of best policy and regulatory practices for both minimum energy performances standards (MEPS) and energy labelling in PNG for air conditioning (AC) appliances.

This CTCN project, which is funded by UNIDO, was timely and directly based on recent efforts carried out by the Pacific Appliance Labelling and Standards (PALS) Programme that is being led by the Secretariat of the Pacific Community (SPC), but also by the Renewable Energy and Energy Efficiency Partnership (REEEP).

The objectives of the current CTCN project are as follows:

› Establish a rationale for selecting AC priority types of equipment and a regulatory approach;
› Assist CCDA in drafting the necessary legislative text framework for the implementation of MEPS for target equipment and the regulations on performance test standards;
› Design an appropriate monitoring, verification and enforcement (MVE) protocol;
› Organise two half-day workshops aimed at raising awareness among market actors about the importance of MEPS and energy labels and collect their comments;
› Develop three trainings for the main PNG stakeholders.

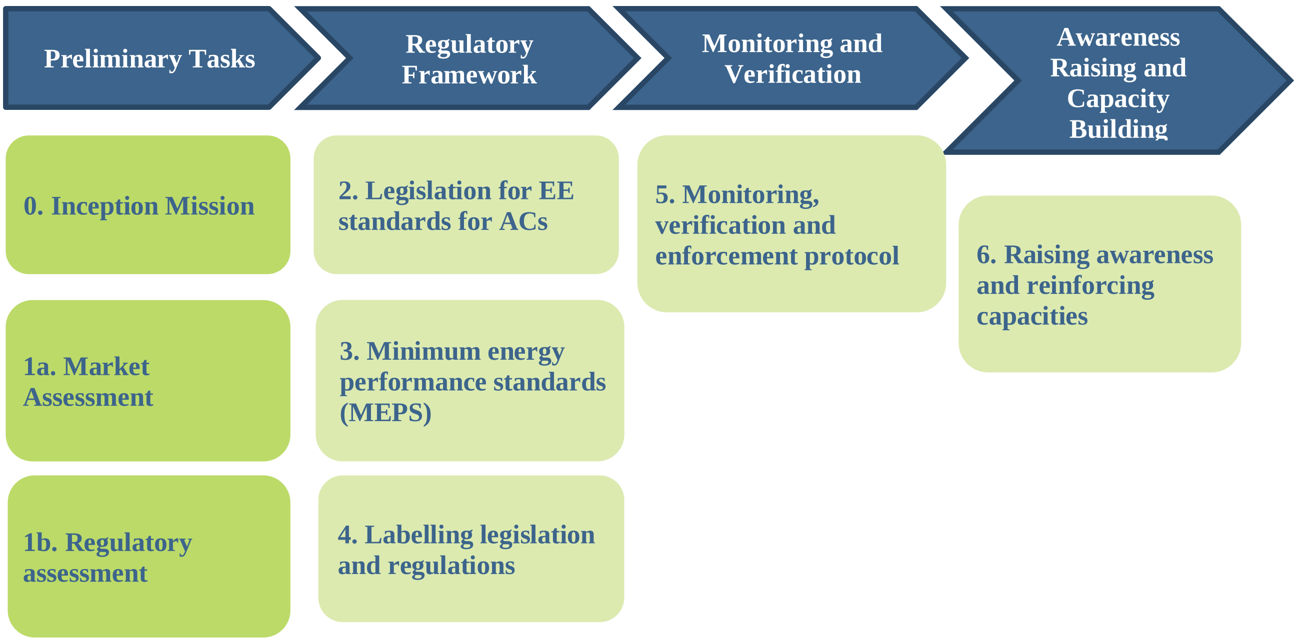

Figure 1: Overview of Project Activities

During the Inception Meeting in November 2018, a discussion took place between the Econoler team and the CCDA to discuss the main project objectives and ensure that the project is properly understood, accepted, and implemented by all stakeholders. Unfortunately, despite several attempts from the project team, it has not been possible for Econoler's Project Manager to talk directly with the CCDA since.

This report presents the results of the market assessment (despite a serious lack of collaboration from the stakeholders). It also shows the results of the benchmarking on best practices in S&L programs, including those in the same region, or countries manufacturing and exporting ACs to PNG. Finally, the recommendations of the labelling classification and the MEPS for different types of ACs are presented. An economic analysis and emissions reduction estimates were also carried out, and the results show that a concerted S&L effort for PNG will have the potential to reduce overall electricity demand significantly, temper peak electricity demands, and will reduce pollution both nationally and regionally.

1 MARKET ASSESSMENT

In order to establish the most effective and impactful market-transformation or S&L programs, governments can benefit from a thorough understanding of the markets they aim to influence. Market baselines provide the necessary level of detail about a given market at a specific point in time and can be invaluable for developing MEPS, energy labelling or other EE policy measures. The benchmarked level for the baseline is based on the availability and quality of data. If the efficiency parameters and sales data for all the models in a market are known, then the baseline thresholds can be less stringent than the case where only the model data is available.

According to the "Methodological tool" of the UN's Framework Convention on Climate Change, Appendix 2:

> The baseline thresholds shall be set at least the 80th percentile of units sold in the reference period where the units are sorted from the highest to the lowest baseline energy intensity factor ($EC$90/80,p;$SEC$90/80,q; $EEI$90/80,r) under the condition that the data of refrigerator or air conditioner models available is complete including the sales data.
>
> Otherwise, where requirements in paragraph 2 cannot be complied with (e.g. sales data is not available), the baseline threshold shall be set at minimum 90th percentile of models available in the reference period where the units are sorted from the lowest to the highest energy efficiency or at the level specified by the mandatory minimum efficiency performance standard (MEPS), whichever is higher.

In the case of PNG, it was not possible to obtain market data directly. Despite the significant efforts made by the local consultant team and an official intervention from the CCDA, no appliance distributor or even the PNG Customs authority has provided data to the research team. Indeed, the market assessment team has struggled to win PNG stakeholders' collaboration in data-sharing. In addition, no answer from the 10 stakeholders has been received, even after many attempts to follow up. An official letter from the CCDA office was sent to the stakeholders to no avail.

For this market assessment, the sales data in PNG was collected with difficulty by looking for and verifying different sources of information. Thus, the recommended strategy (i.e., the baseline threshold set at minimum 85th percentile of the models available) should be implemented. In fact, the strategy of the last resort would have been to set the baseline threshold at minimum 90th percentile of the models available if no sales data were available at all.

1.1 Producers and Suppliers

List of Importers

According to OEC[8],air-conditioning products are mostly imported from China and Australia (39% and 35% respectively), followed by Malaysia (9.6%), the Czech Republic (4.0%), Japan (3.4%), Singapore (3.0%) and Germany (2.4%) and the Netherlands (0.6%). The remaining 3% is distributed

[8] The Observatory of Economic Complexity (OEC), Papua New Guinea (2017), https://oec.world/en/profile/country/png/. Consulted on November 29, 2019.

among New Zealand, Fiji, the Philippines, Turkey, Canada, Indonesia, Italy, Israel, South Korea and the USA.

Manufacturing Countries

Room air-conditioners (ACs) are not domestically manufactured or assembled in PNG. So, all the models are imported. The data regarding the brands and countries of the manufacturers of the most common electrical appliances in PNG has been compiled based on an electric-appliance survey of three major retailers and wholesalers in Port Moresby conducted by the International Institute for Energy Conservation (IIEC) in June 2012.[9] The data gathered included information about the appliance brands and the manufacturing countries. In 2012, the countries manufacturing ACs (of various sizes) with their products in PNG were mostly China, Australia, New Zealand, Thailand, Japan and South Korea.

Producers and Suppliers

China exported the highest dollar-value worth of air-conditioners over the last few years (which represents 34.4% of the overall exported air-conditioner units) and the top 4 Chinese air-conditioner producers are:

- Midea;
- Haier;
- Gree;
- Chigo.

Among them, only Gree and Chigo are air-conditioner companies and Haier and Midea have wider product offerings. Founded in 1991 in Zhuhai, Gree is now the world's biggest air-conditioner producer.

1.2 Sales Volume

The data on imports available from the customs authorities and NSO was not shared with the research team.[10] Therefore, our team looked for alternative sources of information to find the data about the imports. Two main sources were found: the online platform created by the Observatory of Economic Complexity (OEC)[11] and the 2012 REEEP country report for PNG.

REEEP published a report in November 2012, providing the number of the AC units of various sizes imported into PNG from 2008 to 2010.[12] Over that period, the annual numbers remained similar, growing from 21,161 units in both 2008 and 2009 to 21,297 in 2010, representing an increase of less than 1%. However, the monetary value of the import value changed significantly over that same

[9] The Observatory of Economic Complexity (OEC), Papua New Guinea (2017), https://oec.world/en/profile/country/png/. Consulted on November 29th 2019.
[10] These organizations required a MOU for this data sharing with CCDA, which was not willing to comply to that request.
[11] The Observatory of Economic Complexity (OEC), Papua New Guinea (2017), https://oec.world/en/profile/country/png/. Consulted on November 29, 2019.
[12] International Institute for Energy Conservation – Asia (IIEC Asia), *Country Report for Papua New Guinea - Technical Analysis of Appliance Markets to Support the Pacific Appliance Labelling and Standards (PALS) Programme*". November 2012. https://www.reeep.org/sites/default/files/IIEC%20Country%20Report_PNG_8November2012.pdf. Consulted on December 3, 2019.

period. As indicated in the report, the large differences among the annual import values might indicate bulk purchase of appliances by wholesalers, retailers or private companies, based on the assumption that there was no change in the customs authorities' interpretation of the harmonized system codes. In order to get the most reliable import value, Econoler decided to use an average value of the air-conditioners imported over the three years of 2008, 2009 and 2010 as the import value in 2010. The result is an import value of PGK 19,358,099 (**USD 5.68 million**) in 2010 for, as mentioned, **21,297 units**.

The OEC[13] created an online platform releasing international trade data for all the countries in the world. It includes visual narratives about the countries and the products that each country imports and exports. OEC collected data dating from 1962 from the following sources, cleaned all this data and made it compatible with its platform:

- The Centre for International Data from Robert Feenstra[14] used for compiling the data from 1962 to 2000;
- UN COMTRADE[15] used for compiling the data from 2001 to 2017.

Based on the OEC's data, the ACs imported by PNG had a total import value of **USD 7.46 million in 2017**, excluding the sales volume of the AC parts that are without any refrigeration unit. Based on the assumption that there was a linear increase over the 2010-2017 period, we can estimate the quantity of ACs sold in PNG in 2017 at **29,733 units**. Table 1 below shows the breakdown of the import value by air-conditioner type in PNG in 2017.

Table 1: Breakdown of the Import Value by type of air-conditioner in PNG in 2017

Type	Import Value (USD)	Share of the Air-conditioners imported
Air-conditioners Window/Wall Types, Self-Contained	4.68 million	59.0%
Air-conditioners with Reverse Cycle Refrigeration	1.42 million	17.9%
Air-conditioners with Refrigeration Unit	1.36 million	17.5%
Air-conditioners without Refrigeration Unit (not considered in our analysis)	450,000	5.7%
Total	**7.93 million**	**100%**

Source: The OEC, Papua New Guinea (2017).

Of course, the import values do not necessarily correspond to the sales values. However, given the lack of data, this assumption seems reasonable. Also, the long period considered for this assessment (20 years) evens the potential errors out.

[13] The Observatory of Economic Complexity, Papua New Guinea (2017), https://oec.world/en/profile/country/png/. Consulted on November 29, 2019.
[14] The Centre for International Data from Robert Feenstra, https://cid.econ.ucdavis.edu/. Consulted on December 3, 2019.
[15] UN Comtrade Database, https://comtrade.un.org/. Consulted on December 3, 2019.

Figure 2 shows the unit sales projection based on a linear extrapolation with the data presented above. This projection is used to determine the potential energy savings and GHG emissions reduction (see Section 4).

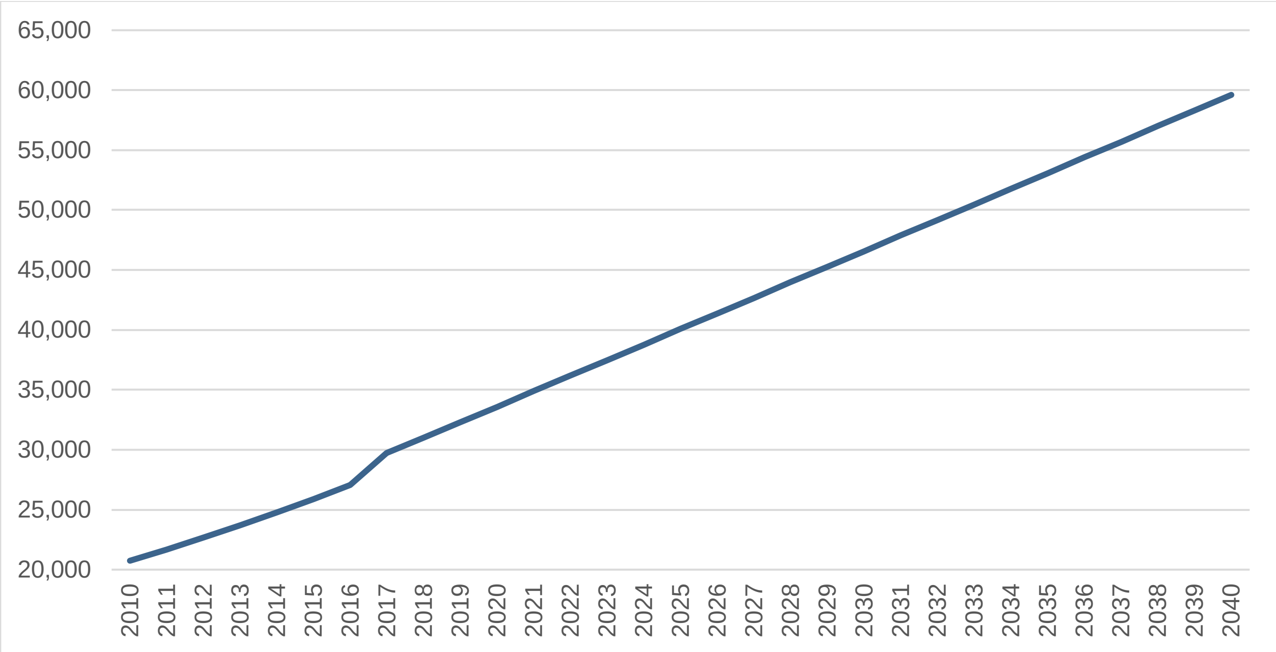

Figure 2: AC Unit Sales Projection in PNG by 2040

1.3 Sales by Type

Unfortunately, the breakdown of the total number of air-conditioners sold by type is unavailable. Only the breakdown of the import values by type is shown in Table 1 above. As can be expected, the sales are dominated by the classic split-type room air-conditioners. Because PNG distributors did not share any data with us, we had to rely on an in-field survey of malls and supermarkets. The results indicate about 40 different models of ACs. However, not all the technical specifications of those models were available. Consequently, the sampling of AC models for this assessment contained only 20 models and most were of the window/wall self-contained type.

The results obtained by the Asian Development Bank[16] indicated that there were four major appliance retailers and wholesalers in PNG in June 2012. It was found that the share of appliances with energy labels in PNG was quite low (< 50%). The report also identifies a range of international brands and manufacturing countries for each type of electrical appliance, as shown in Table 2 below. Considering these results, we believe that our sampling covered some models of higher quality,

[16] ADB/IIEC (2013), Assessment of medium and large air-conditioning technologies and public building in the Pacific, Promoting energy Efficiency in the Pacific (Phase 2).

namely those with higher EERs than those found in the real market.[17] The consequence is that our analysis will show less potential for achieving savings because fewer models would be eliminated by the MEPS.

Table 2: Data about Electrical Appliances Collected by PEEP2 from Four Major Retailers and Wholesalers in PNG (June 2012)

Electrical Appliance	Common Type	Indicative Energy Performance	Brand	Manufacturing Countries
Refrigerators	2-door Fridge/Freezer	30% - 40% are compliant with the Australian or New Zealand minimum energy performance requirements.	Westinghouse, Kelvinator, Fisher & Paykel, Sharp, LG, Whirlpool, Akira, Xingx, Samsung	Australia, New Zealand, Japan, South Korea, India, China, Singapore, Thailand
Air-conditioners	Split-type and Window Type	10% - 20% are compliant with the Australian or New Zealand minimum energy performance requirements.	LG, Kelvinator, Kelon, Midea, Gree, Sharp, Panasonic, Haier, Akira	South Korea, Australia, China, Japan, Indonesia, New Zealand

1.4 Market Shares by Brand

According to the data collected by our team, the main brands of window/mini-split ACs available in PNG are the four following: Gree, Midea, Sharp and Westpoint. Our team did the on-site inventory of the stock of air-conditioning equipment in five different stores, namely Courts, Trade Electrical (Esco), CHM, Brian Bell and BNBM. Two other brands, iFan and Onix, have also been inventoried, but only for one AC model each.

As mentioned, not all the technical specifications were available. So, our analysis has been done based on the EER instead of the SEER.[18]

The models surveyed in local markets were each assigned a price and a certain quantity in order to obtain a value close enough to the total import value by type in Table 1. Also, the total quantity was split according to the assumption that the more expensive the less sold in order to obtain the total quantity for the most recent data of 2017, which amounts to 29,733 units.

1.5 User Behaviour

In a 2011 Census Final Figures booklet, the PNG's National Statistical Office reported the final population counts from the 2011 National Population and Housing Census conducted July 11-17,

[17] It can be assumed that there may be a second-hand or informal market where older, less efficient and lower-quality appliances are traded in much smaller volumes.
[18] EER: Energy Efficiency Ratio. SEER: Seasonal Energy Efficiency Ratio.

2011.[19] Valuable data from this report has been extracted and used in our following assessment of the AC market in PNG.

In 2011, PNG had a total population of 7.3 million and 1.4 million households, with an average household size of 5.3 people. PNG's estimated population in 2019 was 8.8 million[20], 1.5 million more than in 2011, representing an increase of 21.6% over the 8-year period. Based on the above projection (Figure 2), it can be estimated that fewer than 3 percent of households in PNG owned an air-conditioner in 2019.

The annual number of hours of cooling is based on the Australian Greenhouse and Energy Minimum Standards Report, which has established this figure for a "hot zone" like PNG at 2,247 hours. So, the annual energy consumption value per model is calculated by simply multiplying the annual hours-of-cooling value by the electrical input power value in W.[21] This method of calculation was adopted because the average value of hours of use (HOU) in the cooling mode was unavailable (That average would have been established using a sample of households with ACs.). According to the World Bank, most consumers do not know the energy performance of their air-conditioners, but the consumers who own them are very aware of the high energy consumption and bills once they bought a unit; this can restrain their use. However, as in other countries, AC use is expected to steadily grow once people become more accustomed to using them. Hence, it is expected that the average HOU will probably come close to the average annual cooling hours, although the cost of electricity will be a restraining factor.

1.5.1 Sales Channels and Other Relevant Market Characteristics

Air-conditioners for domestic use are sold via the modern market and the informal market in the same way as refrigerators. Worldwide, approximately 70% are purchased from specialized electrical equipment retailers, 15% from large chains, 11% directly from brand distributors and 3% from other sources. Based on the collected data, the prices of air-conditioners in PNG range from USD 144 to USD 3,600.

1.5.2 Efficiency of New Models

It is difficult to determine the energy efficiency levels of the current range of models sold on the national market, due to the lack of data. Estimates were made based on the small survey sample, which indicated that the range of EERs is between 2.11 and 3.54 (A range is used here because it was impossible to determine a weighted average by size or brand.). Neither was it possible to gather any data on the seasonal energy efficiency index (SEER) of products on the market because PNG does not require manufacturers to provide this information.[22]

[19] National Statistical Office Papua New Guinea, "Final Figures Papua New Guinea, National Population & Housing Census 2011".
[20] World Population Review, Papua New Guinea Population 2019, http://worldpopulationreview.com/countries/papua-new-guinea-population/. Consulted on November 29, 2019.
[21] Note that this assumption may result in higher estimates of energy use because these units may be turned on, but they are not in the maximum cooling mode all the time (see below footnote 22).
[22] It should be noted that while the efficiency at full load (the EER) is the most important metric when considering the impact of room air-conditioners on peak power demand, most air-conditioners only operate at full load for a small

Once the thresholds for the minimum efficiency level are determined, Econoler will start assessing the potential impacts of the regulation by focusing on the following main parameters:

- energy savings for end-users;
- reduction in capacity costs associated with future electricity plants;
- reduction in gas consumption related to electricity production;
- reduction in greenhouses gas emissions; and
- other benefits associated with the regulation.

Stakeholders and line ministries will be consulted at a meeting to be held with the TS&LC (during the second workshop) and they will be invited to comment on and make recommendations about the technical energy performance standards. The government will publish a regulatory notice and specify the date on which the MEPS will take effect so that market players can begin to make plans accordingly.

A draft regulation will be prepared and discussed with the PNG government agency in charge, and then submitted to the Government of PNG, which will approve and enact the regulation. Econoler recommends that once the regulation is adopted and enacted, it be promulgated according to a suitable enforcement timetable so as to allow market actors sufficient time to adapt to the new EE performance requirements.

proportion of the time. Consequently, the SEER offers a better estimate of the annual energy efficiency of a room air-conditioner because SEER metrics are designed to account for partial load performance to produce a statistically representative metric of the annual energy efficiency.

2 BENCHMARKING ANALYSIS OF THE INTERNATIONAL BEST PRACTICES FOR S&L LEGISLATION

It is highly advisable to benchmark the technical minimum energy performance requirements of PNG's trade partner countries. Intra- and inter-regional harmonization of the MEPS within the regular international trade flows are expected to bring many benefits to market actors (as explained in Figure 3, below). The Consultant identified the main trade-partner organizations by analyzing customs information about the four priority types of energy-using equipment.

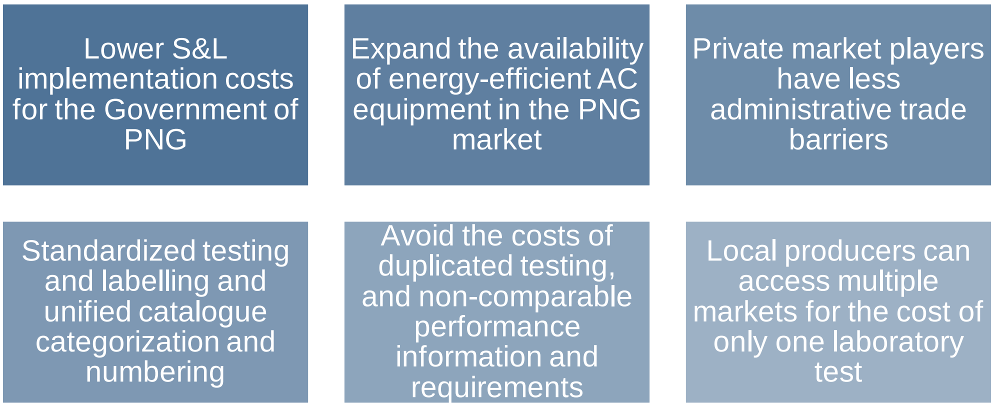

Figure 3: Benefits of Harmonizing MEPS with Trade Partner Countries

PNG is a member of Melanesian Spearhead Group (MSG), the Pacific Island Countries Trade Agreement (PICTA), the South Pacific Regional Trade and Economic Cooperation Agreement (SPARTECA), and the World Trade Organisation (WTO). According to the International Trade Centre (ITC), PNG's main imports partners are Australia, Singapore, China, Japan and Malaysia.[23]

During its survey of three major retailers and wholesalers in Port Moresby in June 2012 for REEEP, information on the proportion of energy labels for each type of electrical appliance and the respective country of origin of these labels was compiled. Note that the study only provided information on the electrical appliances which had affixed any type of energy label, which represent 10 to 20% of the air-conditioners (all sizes). Of those with energy labels, 95 to 100% had Au/NZ Energy Label and only one appliance had Hong Kong Energy label. The share of ACs appliances with energy labels in PNG was relatively low (< 20%). These findings provide a rough indication of the market share of ACs appliances sourced through Australian and New Zealand.

PNG's situation does not share many commonalities with those in Australia, Singapore, China, Japan and Malaysia, or the EU since all these five countries and region have significantly higher levels of economic development and per capita energy consumption. Furthermore, there are cultural and linguistic dissimilarities, including for other potential trade partners such as Indonesia, Thailand, or Vietnam. Nonetheless, the Australia/New Zealand and China equipment energy efficiency

[23] http://www.intracen.org/country/papua-new-guinea/

program can be highly relevant for PNG because it affects the regional market and therefore indirectly affects the availability and development of equipment energy performance in PNG.

2.1 Australia

Product energy labelling started in Victoria and New South Wales in 1986 followed by a nationwide program established in 1989. Labelling regulations now form part of the broader Equipment Energy Efficiency (E3) program. The E3 program aims to increase the energy efficiency of appliances and equipment used in the residential, commercial and manufacturing sectors in Australia and New Zealand. Program objectives are to deliver cost-effective greenhouse gas abatement by addressing market failures and lower the cost to consumers of operating energy using appliances and equipment. The Australian labelling program is based on a star system, rated from zero to ten.

The Energy Rating Label provides consumers with energy performance information at point-of-sale on a range of products that are regulated under the Greenhouse and Energy Minimum Standards (GEMS) Act 2012. As at January 2020, eight products have mandatory Energy Rating Labels, six products have GEMS labelling requirements applying whilst no Energy Rating Label required, two products have voluntary labels and two products are labelled by industry groups. The program is managed by the E3 committee comprising officials from the Australian Government, State and Territory government agencies and the New Zealand Government. The E3 program is part of the National Framework for Energy Efficiency and overseen by the Ministerial Council on Energy. The Australian Gas Association (AGA), together with the Gas Appliance Manufacturers Association of Australia, developed voluntary energy labelling and minimum performance programmes for the two main gas-using appliances (gas water heating systems and space heaters) in Australia. As AGA is recognised as a standard-setting body for gas issues, the energy programmes were designed to comply with these standards. While participation in the labelling programme is notionally voluntary, all appliances comply as all suppliers are members of these associations.

In March 2019, the Minister of Energy published and adopted the 'Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination 2019'. It affects 23 different types of models with a cooling capacity less than 65 kW, from air-to-air unitary ACs (wall mounted, portable, ducted and non-ducted, etc.) to air-to-air single or multi-splits systems (ducted and non-ducted). The new format energy labels and SEER ratings (Table 3 and Table 4) will be mandatory for products being registered, imported or manufactured from 1 April 2020.[24]

Table 3: Australia's ACs Labelling Classification (with equivalent EER values)

SEER value (TCSPF or HSPF)	EER value (TCSPF or HSPF)	Stars
SEER< 2	EER< 2.16	0
2 ≤ SEER < 2.5	2.16 ≤ EER < 2.675	½
2.5 ≤ SEER < 3	2.675 ≤ EER < 3.18	1

[24] The Equipment Energy Efficiency (E3) program, Energy Rating, https://www.energyrating.gov.au/news/quantum-leap-labelling. Consulted on the 16th January 2020.

SEER value (TCSPF or HSPF)	EER value (TCSPF or HSPF)	Stars
3 ≤ SEER < 3.5	3.18 ≤ EER < 3.675	1½
3.5 ≤ SEER < 4	3.675 ≤ EER < 4.16	2
4 ≤ SEER < 4.5	4.16 ≤ EER < 4.635	2½
4.5 ≤ SEER < 5	4.635 ≤ EER < 5.1	3
5 ≤ SEER < 5.5	5.1 ≤ EER < 5.555	3½
5.5 ≤ SEER < 6	5.555 ≤ EER < 6	4
6 ≤ SEER < 6.5	6 ≤ EER < 6.435	4½
6.5 ≤ SEER < 7	6.435 ≤ EER < 6.86	5
7 ≤ SEER < 7.5	6.86 ≤ EER < 7.275	5½
7.5 ≤ SEER < 8	7.275 ≤ EER < 7.68	6
8 ≤ SEER < 8.5	7.68 ≤ EER < 8.075	6½
8.5 ≤ SEER < 9	8.075 ≤ EER < 8.46	7
9 ≤ SEER < 9.5	8.46 ≤ EER < 8.835	7½
9.5 ≤ SEER < 10	8.835 ≤ EER < 9.2	8
10 ≤ SEER < 10.5	9.2 ≤ EER < 9.555	8½
10.5 ≤ SEER < 11	9.555 ≤ EER < 9.9	9
11 ≤ SEER < 11.5	9.9 ≤ EER < 10.235	9½
11.5 ≤ SEER	10.235 ≤ EER	10

The MEPS requirements differs from one type on AC to another, but they are all above 2.5 SEER or 2.675 EER. Table 4 shows the MEPS for different types of ACs.

Table 4: MEPS for types of ACs in Australia

Kind of product	Product class	Characteristics	Value of *R*			MEPS SEER value	MEPS EER value
Air-to-air unitary air conditioners	1	Wall mounted unitary double duct air conditioners		R	≤ 65kW	3.10	3.28
	2	Portable unitary double duct air conditioners		R	≤ 65kW	2.50	2.68
	3	Wall mounted unitary single duct air conditioners		R	≤ 65kW	3.10	3.28
	4	Portable unitary single duct air conditioners		R	≤ 65kW	2.50	2.68
	5	Ducted or non-ducted, excluding product classes 1 to 4		R	< 10kW	3.10	3.28

	6	Ducted or non-ducted, excluding product classes 1 to 4	10kW ≤	R	≤ 39kW	3.10	3.28
	7	Ducted or non-ducted, excluding product classes 1 to 4	39kW <	R	≤ 65kW	2.90	3.08
Air-to-air single-split systems	8	Non-ducted		R	< 4kW	3.66	3.83
	9	Non-ducted	4kW ≤	R	< 10kW	3.22	3.40
	10	Ducted		R	< 10kW	3.10	3.28
	11	Ducted or non-ducted	10kW ≤	R	≤ 39kW	3.10	3.28
	12	Ducted or non-ducted	39kW <	R	≤ 65kW	2.90	3.08
Air-to-air single-split outdoor units (not supplied or offered for supply as part of a single-split system)	13	Supplied or offered for supply to create a non-ducted system		R	< 4kW	3.66	3.83
	14	Supplied or offered for supply to create a non-ducted system	4kW ≤	R	< 10kW	3.22	3.40
	15	Supplied or offered for supply to create a ducted system		R	< 10kW	3.10	3.28
	16	Whether supplied or offered for supply to create a ducted or a non-ducted system	10kW ≤	R	≤ 39kW	3.10	3.28
	17	Whether supplied or offered for supply to create a ducted or a non-ducted system	39kW <	R	≤ 65kW	2.90	3.08
Air-to-air multi-split outdoor units (whether or not supplied or offered for supply as part of a multi-split system)	18			R	< 4kW	3.66	3.83
	19		4kW ≤	R	< 10kW	3.22	3.40
	20		10kW ≤	R	< 39kW	3.10	3.28
	21		39kW ≤	R	≤ 65kW	2.90	3.08
Water-to-air air conditioners	22			R	< 39kW	3.50	3.68
	23		39kW ≤	R	≤ 65kW	3.20	3.38

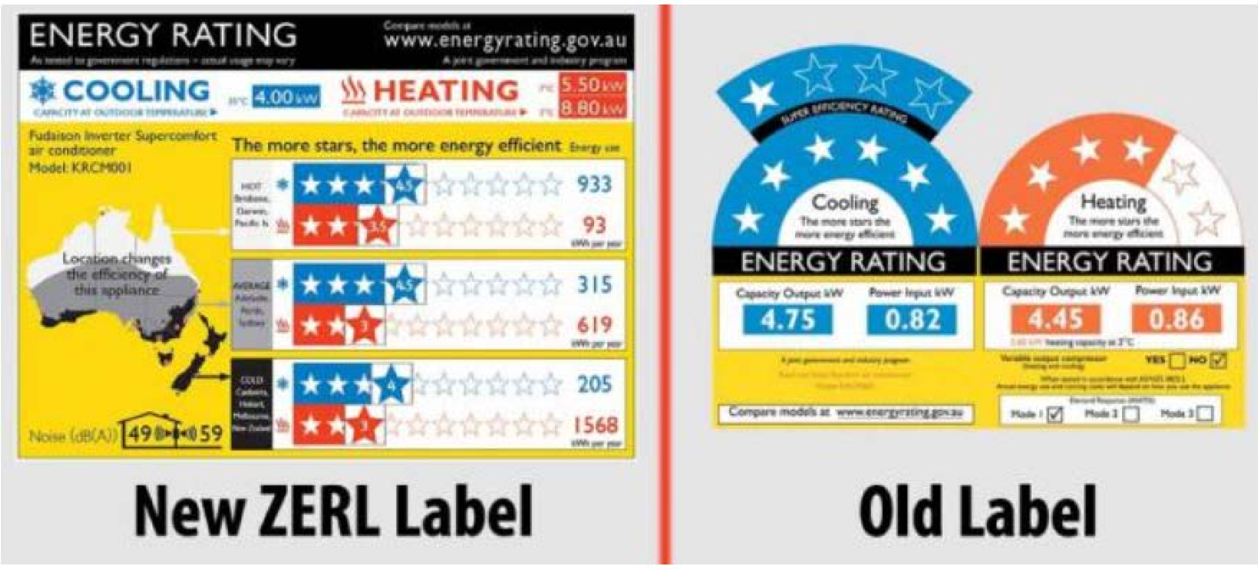

Figure 4: Old and New Versions of Energy Label in Australia

2.2 Malaysia

Malaysia has already introduced S&L for ACs of less than 7.1 kW. According to the Guide on Energy Minimum Standard Requirements for Air Conditioner with Cooling Capacity ≤ 7.1 kW,[25] published in March 2018, it gives the requirements for single-phase non-ducted single split wall mounted type vapour compression air conditioners with cooling capacity up to 7.1 kW. The MEPS requirements are set at 2 stars, which correspond to a value of Cooling Seasonal Performance Factor (CSPF) of 3.1 or 2.9 EER for ACs with a rating cooling capacity less than 4.5 kW, and 2.9 CSPF or 2.7 EER for ACs with a rating cooling capacity between 4.5 and 7.1 kW.

25 https://www.st.gov.my/contents/2020/Label%20Cekap%20Tenaga/Guidelines/Energy%20Efficiency%20Labelling%20Guideline%20for%20Air-Conditioner.pdf

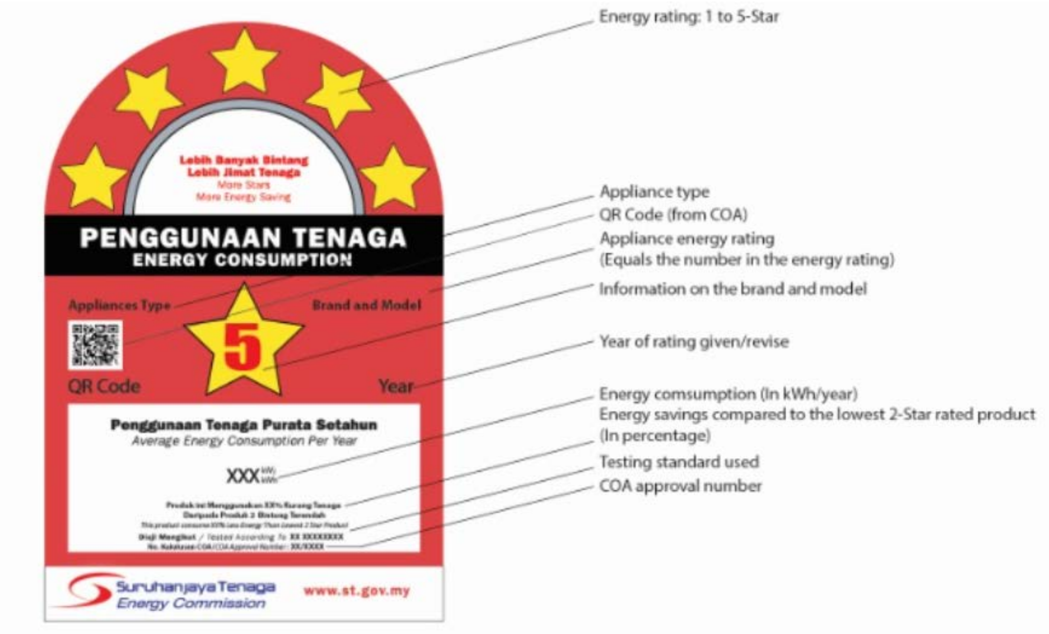

Figure 5: The Label Used in Malaysia

2.3 China

China already first introduced in 1998 (with subsequent changes) S&L for room ACs of less than 14 kW into different types of FSD, VSD, and unitary (window-type) ACs, with different MEPS and energy-efficiency labeling for each product category. The MEPS requirements are set at Grade 3, which correspond to the following values:

- 3.2 EER for **FSD room ACs (split type)** with a rating cooling capacity less than 4.5 kW, 3.1 EER for ACs with a rating cooling capacity between 4.5 and 7.1 kW and 3.0 EER for ACs with a rating cooling capacity between 7.1 and 14.0 kW;
- 4.3 SEER for **VSD room ACs (split, cooling only type)** with a rating cooling capacity less than 4.5 kW, 3.9 SEER for ACs with a rating cooling capacity between 4.5 and 7.1 kW and 3.5 SEER for ACs with a rating cooling capacity between 7.1 and 14.0 kW;
- 3.5 Annual Performance Factor (APF) for **VSD room ACs (split, reversible type)** with a rating cooling capacity less than 4.5 kW, 3.3 APF for ACs with a rating cooling capacity between 4.5 and 7.1 kW and 3.1 APF for ACs with a rating cooling capacity between 7.1 and 14.0 kW;

A recent paper is proposing to China new MEPS grade thresholds for room ACs, effective middle of 2020[26] that combines five grades covering both FSD and VSD room ACs, with Grade 5 set as the minimum threshold for FSD and Grade 3 as the minimum threshold for VSD.

[26] N. Karali, N. Shah, W. Y. Park, N. Khanna, C. Ding, J. Lin and N. Zhou, “Improving the energy efficiency of room air conditioners in China: Costs and benefits”. Publisher: Elsevier. Date of publication: 15 January 2020.

The mandatory comparative China Energy Label (CEL) sets minimum efficiency requirements for three grades of efficiency, with Grade 3 set at the MEPS level and Grade 1 reserved for the most efficient products, as shown in Figure 6 and Figure 7.

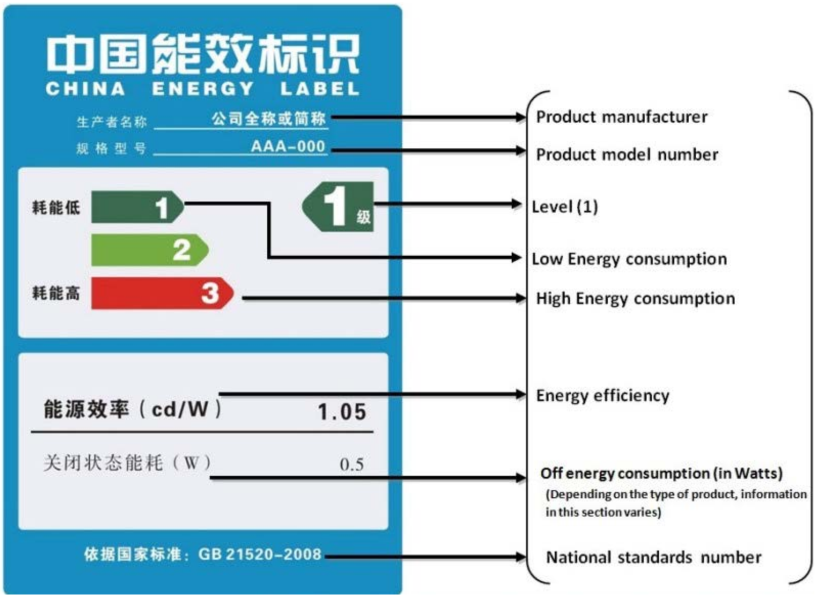

Figure 6: The CEL Used in China (2015 version)

Finally, several voluntary labels exist for air conditioners products such as the China Environmental Labeling, the Top Runner for variable speed room air conditioners, the Energy Efficiency Star for room air-conditioners and China Green Product[27].

2.4 Japan

Japan does not have MEPS for ACs. Instead, suppliers are required to achieve a sales-weighed average efficiency across their product range. The Top Runner Program has been adopted in the Law Regarding the Rationalization of Energy Use (“Energy Conservation Law”) to improve the EE performance of equipment with large energy consumption. The program sets target standard values that are equivalent to the highest energy consumption efficiency of products on the market for that particular product group at a particular point in time, with the aim of encouraging manufacturers, etc. to develop products with performances that exceed such standards. The These targets are set out in the Table 5 and have been compared with the 2004 Korean MEPS.

[27] Compliance & Risks, “Energy and Water Efficiency Labeling in China: Table - Quick Guide Reference Energy Labels”, February 2018, https://www.complianceandrisks.com//wp-content/uploads/2018/02/White-Paper-Energy-and-Water-Efficiency-Labeling-in-China-FINAL.pdf. Consulted on the 05th March 2020.

Table 5: Japanese Top Runner Targets compared with the 2004 Korean MEPS[28]

Cooling capacity range (kW)	2007 Korean MEPS (EER)	2007 Japanese targets (EER) for Cooling only models	2007 Japanese targets (estimate EER) for Reverse cycle models
All	2.94	2.67	2.57
0 – 2.5	3.33	3.64	4.74
2.5 – 3.2	3.33	3.64	4.41
3.2 -4.0	3.33	3.08	3.29
2.0 – 7.1	2.93	2.91	2.85
7.1 -10.0	2.93	2.81	2.79

For the EE Label in Japan, a conventional list of target items that comprised air conditioner has been set. Note that the air conditioner units with a cooling capacity of more than 4 kW have been excluded to the list.

[28] Australian Government, Department of the Environment and Heritage Australian Greenhouse Office, Proposed minimum energy performance standards regulations for single phase air-conditioners, https://www.energyrating.gov.au/sites/default/files/documents/200504-acmeps-ris_0.pdf. Consulted on the 05th March 2020.

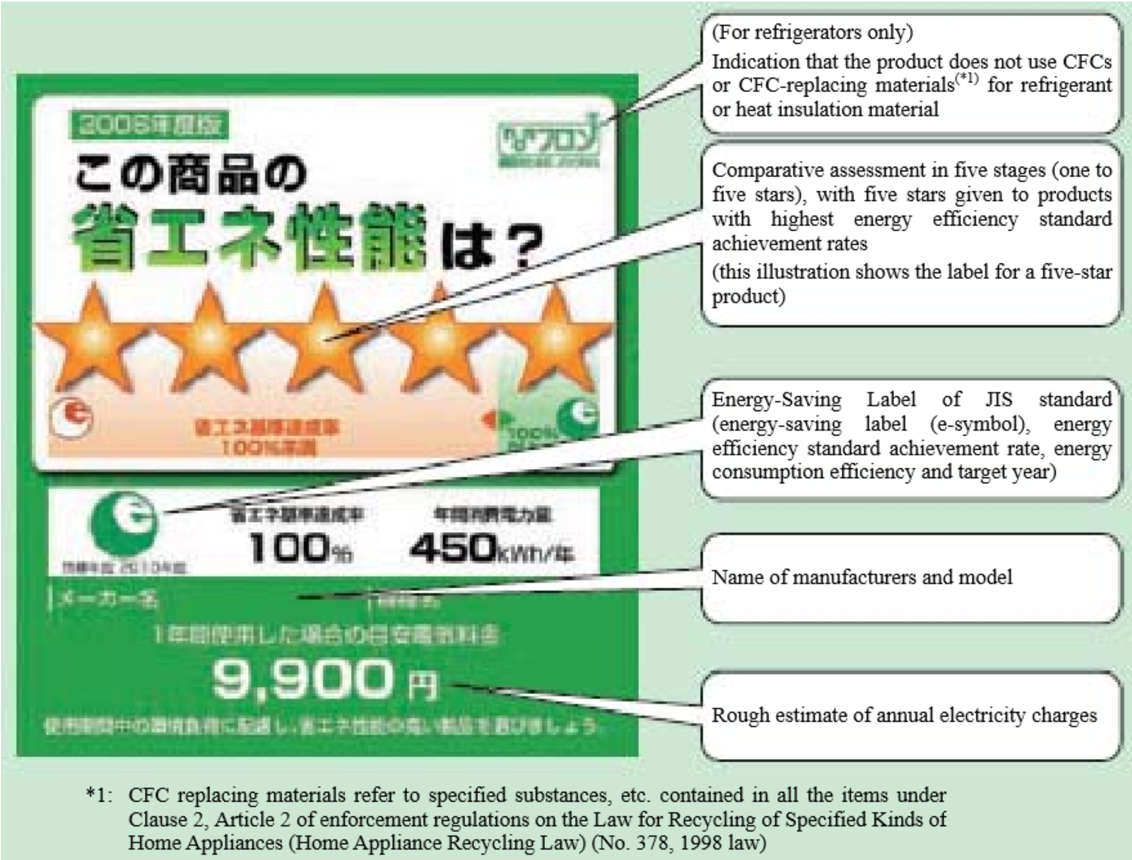

Figure 7: The Label Used in Japan (since October 1, 2006)[29]

2.5 European Union (EU)

The EU is very advanced in terms of energy policy and its context may not apply to PNG. Nevertheless, in regard to best practices and long-term goals, it seems appropriate here to present their achievements.

Some individual EU member states have very long histories of regulating the efficiency of end-use equipment dating back to the early 1960s. However, the advent of the European Community and later the European Union led to the repeal of most national regulations that were considered as barriers to trade within the European Economic Area. To fill the resulting policy vacuum, the European Commission passed a framework directive on the mandatory energy labelling of household appliances in 1992. This was followed by the promulgation of the implementing regulations for household refrigerators and freezers, clothes washers, washer-dryers, clothes dryers,

[29] Planning and Coordination Section, Urban and Global Environment Division, Bureau of the Environment, Tokyo Metropolitan Government, “Presentation: Outline of Tokyo Energy Efficiency Labeling System”, https://www.kankyo.metro.tokyo.lg.jp/en/about_us/videos_documents/documents_1.files/labeling_system.pdf. Consulted on the 05th March 2020.

dishwashers and household lamps. Labels for TVs, room air-conditioners and ovens followed prior to eventual recast of the labelling directive in 2010.

The Background to the EU Appliance Energy Labelling Scheme

Energy labelling has a long and erratic history in the EU. The timeline resulting in the development of a common EU-wide labelling scheme and MEPS is shown in Figure 8.

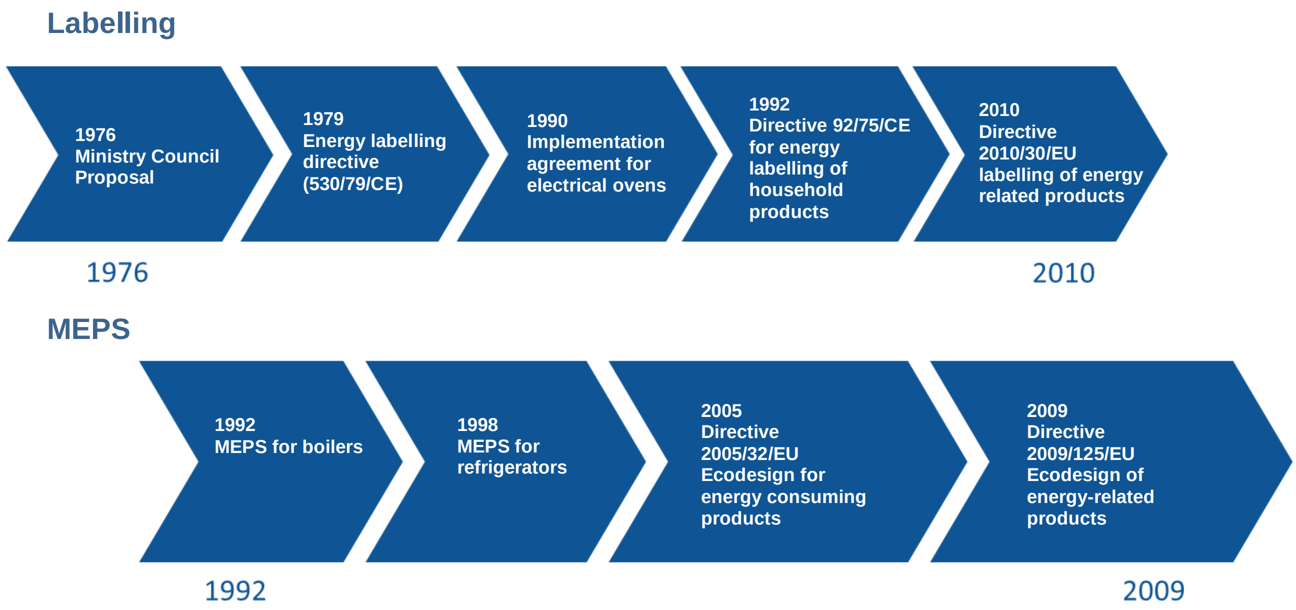

Figure 8: EU Policy Development for the MEPS and the Equipment Labelling Scheme

It took 21 years since the date when the Council first agreed on the need for a European cold appliance energy performance label for it to be introduced across the EU.

The original EU cold appliance label, first issued in 1995, is shown in Figure 9.

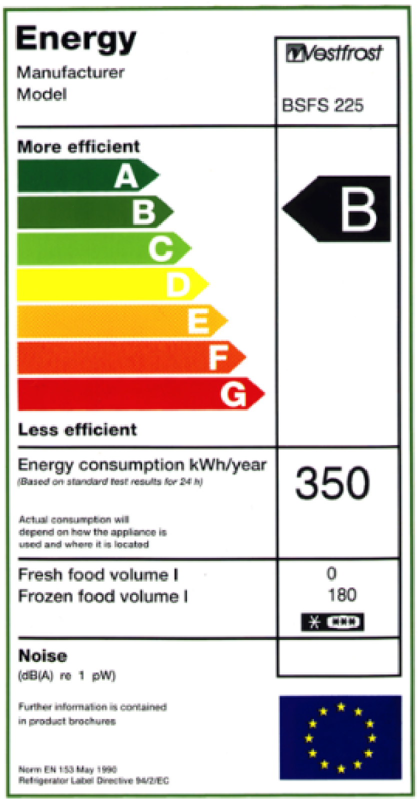

Figure 9: The Original EU Cold Appliance Energy Label Issued in 1995

Policy Motivation and Programmatic Support

The importance of energy efficiency for the EU's energy policy increased over the 1990s to 2010 and is becoming recognized as a central component of the Community policy. In general, the EU's energy efficiency policy was basically a matter over which its member states can determine within their national boundaries. However, as a consequence of the Treaty of Rome and the Single European Market energy efficiency policies which have implications for tradable goods, central coordination and harmonization is required. This need has created a role for the European Commission to propose and administer a number of actions dealing with tradable goods and most commonly electrical or gas appliances. None of these measures prevented the member states from implementing their own energy efficiency policies for tradable goods within their borders, provided that these national policies do not create barriers to the free trade of goods.

To support this effort, the European Union, or its predecessor, initiated a number of programs in the 1980s and 1990s, which were directly or indirectly concerned with the promotion of energy efficiency. The most important of these were the SAVE (Specific Actions for Vigorous Energy Efficiency) and PACE (Community Action Programme to improve the Efficiency of Electricity End-Use) programs.

Under the PACE program, a number of actions were taken in the domestic, commercial and industrial sectors based on the common principle that the energy savings they produce must pay for themselves over a reasonable period. The SAVE and SAVE-II programs ran from 1991-2002 and aimed to promote and remove barriers to energy efficiency. The mandatory minimum energy efficiency standards were usually proposed as a last resort by the Commission, whose preference was to negotiate voluntary agreements with the industries to improve their products' energy efficiency.

In general, the legislative measures proved to be much more successful in achieving tangible and quantifiable energy savings than the pilot actions and dissemination activities, although these are naturally useful supportive measures.

A typical PACE work sequence for household appliances was summarized as follows:

› Mandate CEN/CENELEC to produce a measurement standard for the appliance's energy consumption and performance.
› Study the range of appliances on the market, technical and economic potential for their efficiency to be improved, the impact of any efficiency improvement on manufacturers, consumers and the environment.
› Build consensus on the analysis of possibilities.
› Introduce labelling and market support for labelling.
› Provide other information supporting labelling, e.g., customized information.
› Develop and establish voluntary agreements and/or mandatory minimum energy efficiency standards with manufacturers.
› Monitor the actual use of the appliances and evaluate the efficiency policies' impacts.
› Carry out marketing activities to promote the more efficient use of appliances (e.g., a reduction in washing temperatures).

The legislative measures developed in this manner so far:

› mandatory minimum efficiency standards for domestic gas boilers, Directive (92/42/EEC, of 21.5.92)
› framework Directive (92/75/EEC of 22.9.92) for labelling of major domestic appliances followed by implementation directives for cold appliances (92/2/EC, date 21.1.94), clothes washers (95/12/EC, date 23.5.95), clothes dryers (95/13/EC, date 23.5.95), washer dryers (96/60/EC, date 18.10.96) and dishwashers (97/17/EC, date 16.4.97). An energy labelling directive for household lamps was approved on 27.1.98.
› Directive (93/76/EEC of 13.9.93) for the energy certification of buildings, the billing of heating on the basis of actual consumption, thermal insulation of new buildings, third-party financing, regular inspection of boilers, energy audits and industry.
› mandatory minimum energy efficiency standards for household refrigerators and freezers (96/57/EC of 3.9.96).

Limitations of the early EU policy framework

Despite the analytical strengths of the European standards and labelling setting process, the program as a whole had a number of weaknesses, as summarized below:

- Until the adoption of the Ecodesign Directive in 2005, there was no framework legislation enabling the MEPS to be set, which meant that each new MEPS regulation had to be negotiated and passed at a primary Directive level. This was time-consuming and the results were ad-hoc, which made it difficult to know what the outcome was likely to be with each new regulation at the time it was proposed.
- As a result, the Commission tended to prefer to negotiate voluntary agreements with industry. However, these were often set at significantly weaker efficiency levels than recommended in the independent studies due to the difficulty of negotiating a challenging efficiency requirement. Furthermore voluntary agreements often took a long time to negotiate and were liable to weaker compliance than MEPS due to the lack of formal penalties for non-compliance. Another weakness was that the agreements would usually only involve the members of the primary industry association and hence, seldom covered the entire market.
- The regulatory structure for establishing labels lacked a clear timeframe, which meant that negotiations and discussions often required an excessively long period (this is still a concern).
- Unlike the industries which were adequately represented in the regulatory process to set the MEPS, voluntary agreements and labels, those advocates championing more stringent efficiency requirements (such as energy efficiency and environmental advocacy organizations) were not. This imbalance resulted in the independent study recommendations being taken as the most ambitious potential policy outcomes, from which the final outcome was invariably negotiated downwards rather than the well-balanced outcome their authors intended.

The net result of these limitations was that new regulations during this period took too long to develop and their level of stringency was often significantly lower than would have been required for the best interests of consumers, the environment and society as a whole.

The situation was significantly improved with the adoption of the Ecodesign framework directive in 2005 and the development of standardized analytical tools, such as the Methodology for the Ecodesign of Energy-related Products (MEErP) (discussed below). It is no coincidence that the pace at which EU product policies were developed and implemented has dramatically quickened since the adoption of the Ecodesign directive.

Summary of EU policy status

In the EU MEPS covering 32 broad product groups have been implemented as regulations beneath Directive 2009/125/EU on Ecodesign of energy-related products and mandatory energy labels covering 13 product groups have been implemented as regulations beneath Directive 2010/30/EU labelling of energy related products. In addition, voluntary agreements covering 4 product types have been agreed with industry associations

3 CLASSIFICATION AND GROUPING OF THE NATIONAL AC SYSTEMS IN PNG

3.1 Introduction

To determine the most appropriate MEPS level, best practice requires analyzing the implications of different potential efficiency levels on the life cycle cost of target products from the consumer perspective. Accomplishing this requires a least life cycle cost analysis (LCCA) carried out using a combination of energy engineering analyses and product cost analyses. This process also involves considering the impacts of the analysis-based recommendations (i.e. the proposed standards) on domestic industry, when relevant, and conducting a national impact assessment. This chapter presents the findings from the LCCA for each product type and assesses the capacity of industry to meet the proposed standards.

The classification should be done according to the national MEPS and energy labelling standards and the CCMA's and international best practices. For instance, the PEEP2 project team gathered data[30] about four major retailers and wholesalers in PNG in June 2012. It was found that the share of appliances with energy labels in PNG was quite low (<50%) and the PEEP2 project team identified a range of international brands and countries of manufacture for each type of electrical appliance, as shown in Table 2 below.

Table 6: Data about Electrical Appliances collected by PEEP2 from Four Major Retailers and Wholesalers in PNG (June 2012)

Electrical Appliance	Common Type	Indicative Energy Performance	Brand	Countries of Manufacture
Refrigerators	2-door Fridge/Freezer	30% - 40% are compliant with the Australian or New Zealand minimum energy performance requirements.	Westinghouse, Kelvinator, Fisher & Paykel, Sharp, LG, Whirlpool, Akira, Xingx, Samsung	Australia, New Zealand, Japan, South Korea, India, China, Singapore, Thailand
Air-conditioners	Split-type and Window Type	10% - 20% are compliant with the Australian or New Zealand minimum energy performance requirements.	LG, Kelvinator, Kelon, Midea, Gree, Sharp, Panasonic, Haier, Akira	South Korea, Australia, China, Japan, Indonesia, New Zealand

[30] PNG Country Information and Database, http://ee-pacific.net/index.php/database/country-information/papua-new-guinea#04

3.1.1 Product Type Categories

The market for domestic refrigeration appliances in PNG is presumably similar to that in Australia, New Zealand, and other Pacific states. Therefore, the same product categorisation used in the Australian scheme should be directly applicable in PNG. However, it is expected that the lowest energy performance models will be much lower in PNG than in other neighboring countries with established S&L programs and rigorous MVE regimes. For Australia/New Zealand, the S&L policy regulating ACs lists 23 product categories/classes based on design and capacity. Econoler's survey of the PNG market counted approximately 6 product category/classes based on design and capacity. Therefore, it can be assumed that while the implementation and alignment of requirements may be similar, PNG's market and policy will be much simpler.

3.1.2 Life Cycle Cost Analysis

Single-packaged split room air conditioners dominate the global room air conditioner market and are by far the most commonly found room air conditioner technology in all markets including PNG. Hence, the analysis is focused on these products because they represent the lion's share of the room air conditioner market and there is a broad range in their energy efficiency and potential energy performance.

Furthermore, the majority of split systems sold are also reversible, i.e. they can be used to provide space heating and cooling. A very minor design change is required to convert a cooling only split system into a reversible unit. Increasingly, this is becoming the default option. Furthermore, the *heating*-mode efficiency correlates closely with the *cooling*-mode efficiency since the design aspects that affect efficiency are directly related. In principle, any assessment of the impact of energy efficiency design changes on cooling performance should also consider the impacts on heating performance if the life cycle cost changes are to be correctly determined. However, given that the cooling mode is known to dominate air conditioner energy use in PNG and that the SEER is directly correlated with the SCOP, it is considered sufficient to focus the analysis on the cooling mode only. This also includes the impact of auxiliary energy consumption such as standby power loads as explained in the following paragraph.

While the efficiency at full load (the EER) is the most important metric when considering the impact of room air conditioners on peak power demand, most air conditioners only operate at full load for a small proportion of the time. Consequently, the SEER offers a better approximation of the annual energy efficiency of a room air conditioner because SEER metrics are designed to account for partial load performance to produce a statistically representative metric of annual energy efficiency. However, as mentioned, the data available were insufficient to consider the SEER and that is why the EER was considered instead.

The techno-economic energy engineering analysis treats every possible combination of the design options considered to produce a cloud of energy efficiency/life cycle cost pairs. To understand the least life cycle cost associated with each SEER value, the *lowest values* in the cluster should be selected.

It should be noted that this exercise is carried out from the consumer perspective, which means that the costs considered in the life cycle cost analysis are the equipment purchase, installation and maintenance costs and consumer energy bills. Additional societal or opportunity costs such as carbon and peak power reduction shadow prices are not considered. Consequently, the energy efficiency levels associated with the least societal cost is expected to be significantly higher than those associated with the consumer least life cycle cost.

3.2 Determining the Threshold for the Minimum Energy Performance Standards

The data collected about PNG's refrigeration and air-conditioning (RAC) market and end-usage equipment were not sufficient to characterize the current energy consumption patterns of this technology covered by the scope of the MEPS program, but some analysis were made nonetheless. To determine the thresholds, the following three types of analysis are to be made:

1. Technical analysis to characterize the current energy consumption patterns of each equipment type and assess the availability of the technologies in the international market and barriers to their introduction into PNG.
2. Economic analysis to examine the incremental pricing of more energy-efficient technologies, the current and projected costs of supplying electricity to the market by the PNG government. The economic analysis will need to be done from the perspectives of the customers, the PNG government and society to paint a clear picture of the intended impact of the MEPS on the market for each main group of stakeholders. Our senior international economists will be centrally involved in making these analyses.
3. Regional benchmarking to make sure the thresholds are in line with those of PNG's trade partner countries.

3.2.1 Threshold for the MEPS

As the sales data in PNG have been collected with difficulty through the crossing of different sources of information, the strategy suggested by the UNFCCC (i.e. the baseline threshold set at minimum 85th percentile of models available) should be implemented. In effect, the last strategy would have been to set the baseline threshold at minimum 90th percentile of models available if no sales data at all were available. Our analysis shows that the MEPS have the most important effect on energy savings, compared to labelling, with app. 80% of the combined (MEPS and labelling) effect. Therefore, the appropriate threshold is very important.

Based on the UNFCCC recommendations and analysis of the available data, the appropriate EER threshold for AC MEPS for PNG is fixed at 2.2 EER (2.08 SEER), which is slightly above the lowest labelling category in Australia/New Zealand. This will help in alignment with regional requirements as the higher ratings are the same.[31] Although the simulation was made with a threshold at 2.2 because the ACs models sampling does not contain any models below 2.0 EER, it is reasonable, as mentioned, to believe that many models in the PNG market are indeed below 2.0 EER, because as shown in a previous survey (Table 2), most of the models in the market did not comply with the Australia/New Zealand MEPS. Our projections are thus conservative.

The MEPS requirements differs from one type on AC to another, but they are all above 2.04 SEER or 2.20 EER. Table 4 shows the MEPS for different types of ACs. Table 7 presents the MEPS for each kind of products based on the Australia/New Zealand MEPS system. One can make a comparison with the later with Table 4 above.

Table 7: Proposed MEPS for Different Types of ACs in PNG

Kind of product	Product class	Characteristics	Value of *R*			MEPS SEER value	MEPS EER value
Air-to-air unitary air conditioners	1	Wall mounted unitary double duct air conditioners		R	≤ 65kW	2.52	2.69
	2	Portable unitary double duct air conditioners		R	≤ 65kW	2.04	2.20
	3	Wall mounted unitary single duct air conditioners		R	≤ 65kW	2.52	2.69
	4	Portable unitary single duct air conditioners		R	≤ 65kW	2.04	2.20
	5	Ducted or non-ducted, excluding product classes 1 to 4		R	< 10kW	2.52	2.69
	6	Ducted or non-ducted, excluding product classes 1 to 4	10kW ≤	R	≤ 39kW	2.52	2.69
	7	Ducted or non-ducted, excluding product classes 1 to 4	39kW <	R	≤ 65kW	2.36	2.53
Air-to-air single-split systems	8	Non-ducted		R	< 4kW	2.96	3.14
	9	Non-ducted	4kW ≤	R	< 10kW	2.61	2.79
	10	Ducted		R	< 10kW	2.52	2.69
	11	Ducted or non-ducted	10kW ≤	R	≤ 39kW	2.52	2.69
	12	Ducted or non-ducted	39kW <	R	≤ 65kW	2.36	2.53

[31] Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination 2019, Australia Ministry of Energy, 25 March 2019.

Air-to-air single-split outdoor units (not supplied or offered for supply as part of a single-split system)	13	Supplied or offered for supply to create a non-ducted system		R	< 4kW	2.96	3.14
	14	Supplied or offered for supply to create a non-ducted system	4kW ≤	R	< 10kW	2.61	2.79
	15	Supplied or offered for supply to create a ducted system		R	< 10kW	2.52	2.69
	16	Whether supplied or offered for supply to create a ducted or a non-ducted system	10kW ≤	R	≤ 39kW	2.52	2.69
	17	Whether supplied or offered for supply to create a ducted or a non-ducted system	39kW <	R	≤ 65kW	2.36	2.53
Air-to-air multi-split outdoor units (whether or not supplied or offered for supply as part of a multi-split system)	18			R	< 4kW	2.96	3.14
	19		4kW ≤	R	< 10kW	2.61	2.79
	20		10kW ≤	R	< 39kW	2.52	2.69
	21		39kW ≤	R	≤ 65kW	2.36	2.53
Water-to-air air conditioners	22			R	< 39kW	2.84	3.02
	23		39kW ≤	R	≤ 65kW	2.60	2.77

3.2.2 Labelling Categories

The labelling scheme as defined by the labelling categories helps the consumers in differentiating between different products regarding their energy performance. **Erreur ! Source du renvoi introuvable.** presents the proposed labelling categories for ACs in PNG, which is the same as the one in Australia/New Zealand MEPS. The fact that this labelling scheme has a wide range of categories (some of them are not represented in the Australian market because the MEPS are higher), helps with the harmonization with PNG.

Table 8: Proposed Labelling Categories for ACs in PNG

Australian's ACs Labelling Classification		PNG's ACs Labelling Classification (based on the Australia's one)		
SEER	**Stars**	**SEER**	**EER**	**Stars**
SEER< 2.0	0	N/A	N/A	N/A
2.0 ≤ SEER < 2.5	½	1.75 ≤ SEER < 2	1,90 ≤ EER < 2.16	½

Australian's ACs Labelling Classification		PNG's ACs Labelling Classification (based on the Australia's one)		
2.5 ≤ SEER < 3	1	2 ≤ SEER < 2.5	2.16 ≤ EER < 2.68	1
3 ≤ SEER < 3.5	1½	2.5 ≤ SEER < 3	2.68 ≤ EER < 3.18	1½
3.5 ≤ SEER < 4	2	3 ≤ SEER < 3.5	3.18 ≤ EER < 3.68	2
4 ≤ SEER < 4.5	2½	3.5 ≤ SEER < 4	3.68 ≤ EER < 4.16	2½
4.5 ≤ SEER < 5	3	4 ≤ SEER < 4.5	4.16 ≤ EER < 4.64	3
5 ≤ SEER < 5.5	3½	4.5 ≤ SEER < 5	4.64 ≤ EER < 5.10	3½
5.5 ≤ SEER < 6	4	5 ≤ SEER < 5.5	5.10 ≤ EER < 5.56	4
6 ≤ SEER < 6.5	4½	5.5 ≤ SEER < 6	5.56 ≤ EER < 6.00	4½
6.5 ≤ SEER < 7	5	6 ≤ SEER < 6.5	6.00 ≤ EER < 6.44	5
7 ≤ SEER < 7.5	5½	6.5 ≤ SEER < 7	6.44 ≤ EER < 6.86	5½
7.5 ≤ SEER < 8	6	7 ≤ SEER < 7.5	6.86 ≤ EER < 7.28	6
8 ≤ SEER < 8.5	6½	7.5 ≤ SEER < 8	7.28 ≤ EER < 7.68	6½
8.5 ≤ SEER < 9	7	8 ≤ SEER < 8.5	7.68 ≤ EER < 8.08	7
9 ≤ SEER < 9.5	7½	8.5 ≤ SEER < 9	8.08 ≤ EER < 8.46	7½
9.5 ≤ SEER < 10	8	9 ≤ SEER < 9.5	8.46 ≤ EER < 8.84	8
10 ≤ SEER < 10.5	8½	9.5 ≤ SEER < 10	8.84 ≤ EER < 9.20	8½
10.5 ≤ SEER < 11	9	10 ≤ SEER < 10.5	9.20 ≤ EER < 9.56	9
11 ≤ SEER < 11.5	9½	10.5 ≤ SEER < 11	9.56 ≤ EER < 9.90	9½
11.5 ≤ SEER	10	11 ≤ SEER	9.90 ≤ EER	10

3.2.3 Life Cycle Cost Analysis

When examining the energy efficiency design options applicable to improve the energy efficiency of products on the PNG market, the following are considered:

- Options that are available within the most common products currently on the market (increasing EER);
- Options that can be evaluated for energy savings under the existing energy performance test procedures for the appliance category;
- Options that can be integrated into current products (i.e. do not imply changing basic product configurations to include additional energy saving options as part of a system redesign).

The choice of working refrigerant used by these appliances is R134a, which reflects the choices available to other markets in the region.

Cost Analysis

The cost analysis was conducted based on the fact that better, more efficient products already exist in the market, and that the cost differential between a functional unit and a more efficient unit is negligible. Therefore, the most important factor is how fast the MEPS can be adopted and a labeling program implemented. The analysis focused on the pace of adoption for more energy efficient units, and the removal of less efficient units from the PNG market. The table below summarize the adoption pace and assumptions for two scenarios: one with the MEPS set at 2.2 EER, and one with the MEPS set at 2.9 EER.

Table 9: Simulation Parameters for Energy Savings Previsions

Assumptions: MEPS = 2.2 EER or 2.9 EER	Period	Slow Adoption	Fast Adoption
Labelling	2021-2025	10.00%	15.00%
Labelling	2026-2030	15.00%	20.00%
Labelling	2031-2035	20.00%	25.00%
Labelling	2036-2040	25.00%	30.00%

The results can be seen in Figure 10, showing the projected current baseline or business as usual, and the potential cost savings (in USD) of a comprehensive S&L program for PNG in the 2021 to 2040 period. The results show a potential user cost savings of USD $2 million to $3.7 million in 2021, rising to USD $3.7 million to $6.5 million by 2040, as compared to the current baseline.

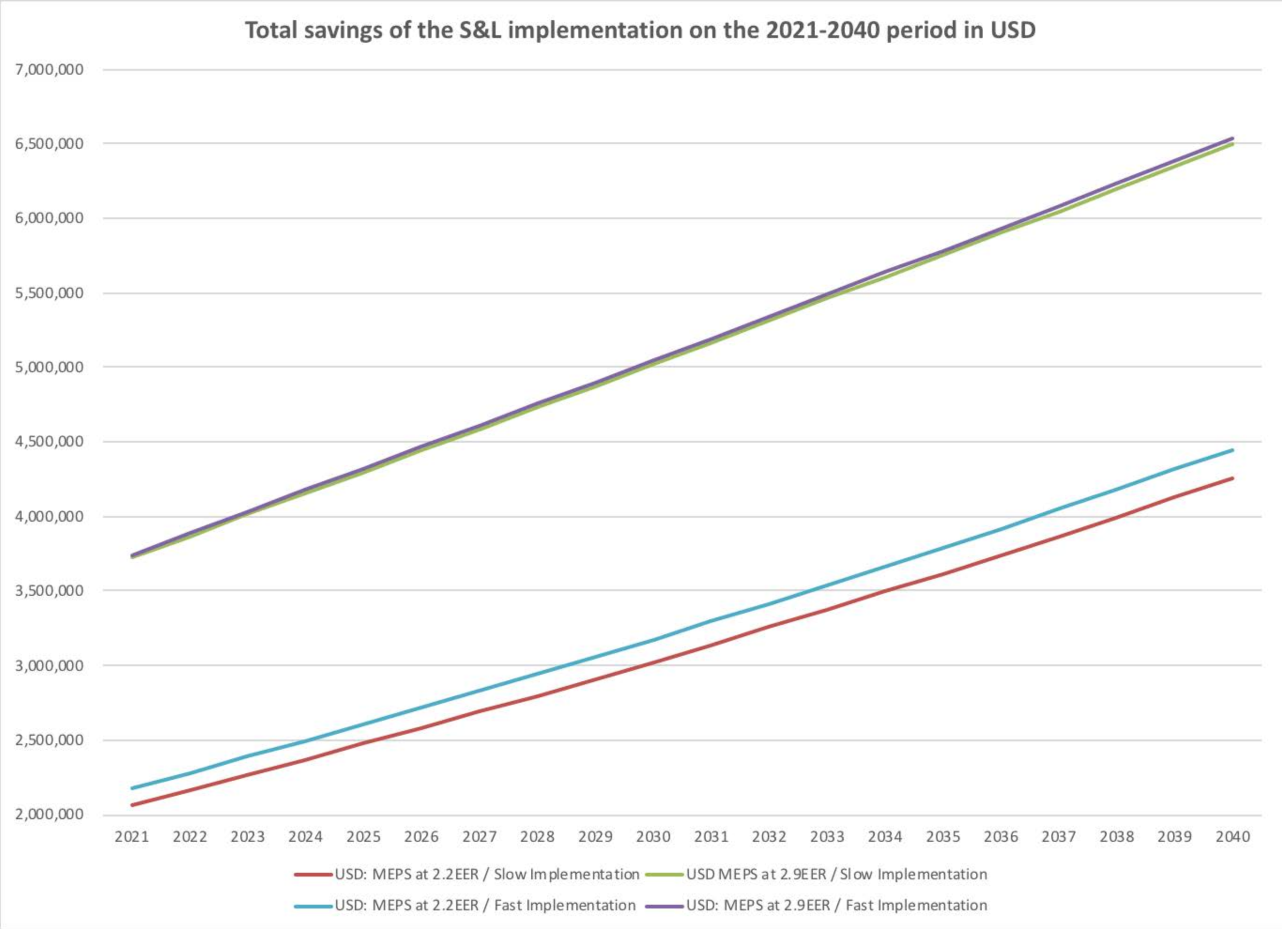

Figure 10: Total Savings for Four Different Scenarios (see Table 9: Simulation Parameters for Energy Savings Previsions

3.2.4 National Economic Impacts

The projected national economic impacts of the various policy scenarios compared with the base case scenario are illustrated in Figure 10. The results show that the more ambitious the energy savings expected in the scenarios, the greater the savings in energy bills for consumers, but it would impact the market more significantly, as well as requiring a more stringent inspection and enforcement regime. As air conditioner sales are projected to increase substantially over the next twenty years as part of the government's energy access targets, any increase in sales costs can be justified by the reduction in energy bills and consumption from 2021 onward under all but the base case scenario. It should be noted that the energy and cost savings projections for this period are on the conservative side, as the products on the market are believed to be less energy efficient than the base case, and therefore the savings and reduction in energy demands may be higher in actuality.

3.2.5 Impact on National Industry

Further, as there is no manufacture of room air conditioners in PNG, and all products are imported the implementation of an S&L program should not impact any local industry groups, other than repair shops. For importers of new room air conditioners in PNG, implementation and enforcement of MEPS would require these enterprises to specify higher efficiency products that those that they are importing now from the same suppliers or manufacturers, without having to switch to another brand or supplier. This is because all of the leading brands sold in PNG have products with EERs much higher than the proposed MEPS levels. Typically, it should take 6 to 12 months for importers to secure turn over their current inventory and stock only products that comply with prospective minimum energy efficiency requirements.

4 ENERGY SAVINGS AND GREENHOUSE GAS EMISSION REDUCTIONS

Based on the findings from the baseline analysis, PNG's energy profile, and the *Determination of standardized baselines for energy-efficient refrigerators and air-conditioners*,[32] a standardized baseline of AC-related GHG emissions has been developed. Then, based on the assumptions regarding country-specific penetration rates for AC equipment (in the above MEPS and labelling analysis), an estimate of GHG emission reduction potential associated with the enforcement of the MEPS and labelling scheme was made.

Electricity generation capacity in PNG is about 250 megawatts (MW)[33] and the annual electrical consumption was approximately 3,237 GWh in 2016, with ACs' consumption accounting for about 486 GWh, or 15%. In our baseline scenario, this consumption will rise to over 1,100 GWh, accounting for over 20% of the national energy consumption by 2034 without an effective S&L program. Hydropower currently accounts for about half of the electricity generated and diesel for a third, with the rest generated from gas and geothermal energy plants, which are principally used in the mines.[34] According to PNG Power Ltd., two major hybrid (hydropower and thermal) grid systems, namely the Port Moresby System and the Ramu Systems, provide approximately 80% of PNG's electricity.

The Institute for Global Environmental Strategies (IGES) regularly publishes a List of Grid Emission Factors providing information for research and analysis regarding emissions from electricity generation. It provides two types of grid emission factor: (1) the official grid emission factors published by host country governments; (2) a grid emission factor that refers to a CO_2 emission factor (tCO_2/MWh) associated with each unit of electricity supplied by an electricity system. The latter is one of the parameters needed to determine the baseline emission level for CDM projects in the renewable energy sector (hydro, wind, solar PV, and geothermal power, etc.) and the waste heat/gas recovery sector. Although PNG does not provide any official grid emission factor, IGES has provided the grid emission factors for PNG. The average factor of 7 CDM projects over the 2006-2012 period has been set at **0.679 tCO_2/MWh**.

By applying this emission factor to the energy savings and cost analysis, the GHG emission reduction results have been obtained, as shown in the following table:

Table 10: Forecasts of the Energy Savings and GHG Emission Reductions (2021-2040)

MEPS	Labelling	Consumption	Savings (2021-2040)		
		(GWh)	GWh	Million USD	ktCO2
Baseline		22,306	N/A	N/A	N/A
2.2	10.00%	19,507	510	62.2	346
2.2	15.00%	19,472	545	65.2	370
2.9	10.00%	19,163	855	102.0	580

[32] file:///L:/OPS_VMP/1.VMP/2341P%20PNG%20-%20EE%20on%20RAC%20sector%20regulations%20developement%20options%20-%20UNIDO/PROP%20TECH/Métho/Ref/am-tool-29-v1.pdf
[33] https://www.adb.org/sites/default/files/linked-documents/CAPE-PNG-6-Energy-Sector-Assessment.pdf
[34] https://www.adb.org/sites/default/files/linked-documents/CAPE-PNG-6-Energy-Sector-Assessment.pdf

2.9	15.00%	19,150	867	102.5	589

As shown in the above table, the cumulative emission savings range from 346 ktCO_2 to 589 ktCO_2, which would be equivalent to the effect of planting between 1,700,000 and 2,900,000 trees or taking between 75,000 and 125,000 cars off PNG's roads.[35] Obviously, these savings and reduction depend on various parameters (e.g. level of MEPS) and thus on the level of political commitments in the implementation phase.

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[35] https://www.epa.gov/energy

CONCLUSION AND NEXT STEPS

As discussed, the PNG government has taken actions to improve the policy framework and to address a number of power sector challenges, including very low access to electricity services. In its 2010-2030 Development Strategic Plan, the Government set a target to reach 70% of electricity access by 2030. In order to help achieve this target a National Electrification Roll Out Plan is to be developed. However, while this ambitious target will help PNG see significant increases in energy access, it will also result in significant increases in energy demand. In the PNG Development Strategic Plan, 2010–2030 (PNGDSP), the Government estimates that the peak demand for electricity in 2021 will be about 700 MW and increase to over 1,400 MW by 2030[36].

Meeting this demand will require substantial new power generation resources, but it will also require substantive demand-side management measures to downgrade the country's energy intensity. Consequently, as with many developing countries throughout the world, it is essential for PNG to improve its energy efficiency (EE). Since about half of the electricity produced in PNG comes from non-renewable sources, there could be significant benefits of adopting EE measures such as Standard & Labelling (S&L) Programs, focusing on products with high energy saving potentials and high penetration rates, such as air conditioners.

Specific to the PNG, it was necessary to establish a baseline of the AC market in order to establish the most effective and impactful market transformation or S&L programmes. This is because a market baselines provides the necessary level of detail about the market at a specific point in time, and can be invaluable in the establishment of MEPS, energy labelling or other EE policy measures. The benchmark level for the baseline is based on availability and quality of data. Where efficiency parameters and sales data for all models in a market, are known, then baseline thresholds can be less stringent as compared to the case where only the model data is available.

In the case of PNG, it was not possible to obtain market data directly. However, the baseline was established through the crossing of different sources of information. Thus, the establishment of AC MEPS for PNG followed the recommended strategy by the UNFCCC for such conditions. Based on the UNFCCC recommendations and analysis of the available data, the appropriate EER threshold for AC MEPS for PNG is in the range of 2.2 to 2.9, with the higher EER corresponds to Australia/New Zealand's 2019 labeling requirements for 1-Star rating for appliances in this category, which can help in alignment with regional requirements.[37]

The recommended approach would be to begin with the establishment of MEPS at the lower level supported by the product labeling regime, with the full and transparent intention of moving the MEPS requirements to the higher EER within a short time period (2 to 3 years). Establishing the EER at the lower level accomplishes two important objectives:

- It introduces the MEPS and labeling program into the PNG market

[36] Government of Papua New Guinea, Department of National Planning and Monitoring. 2010. Papua New Guinea Development Strategic Plan, 2010–2030 . Port Moresby.

[37] Greenhouse and Energy Minimum Standards (Air Conditioners up to 65kW) Determination 2019, Australia Ministry of Energy, 25 March 2019.

› It eliminates the worst performing appliances without significantly changing how the products enter PNG market.

Once the S&L program is established and accepted by stakeholders, the transition to the higher MEPS level would be less of a market disruption than starting the program at a higher requirement level immediately at the outset.

It should be noted that starting the program at a lower level would result in the energy and cost savings at the lower end of the projection. However, the faster the program can transition from the lower MEPS to the higher MEPS level, the closer to the maximum cumulative savings it will achieve. In addition to the direct energy and emissions savings, implementing the S&L program in PNG can result in these additional benefits:

› Diesel imports reduction through lowering energy demand;
› Energy bills reduction for consumers;
› Infrastructure costs avoided–reduced capital and maintenance costs;
› Livelihood improvement through access to better quality products;
› Energy efficient products –Ensuring Pacific Islands Countries and Territories (PICTs) do not have to accept inefficient products banned from sale elsewhere;

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