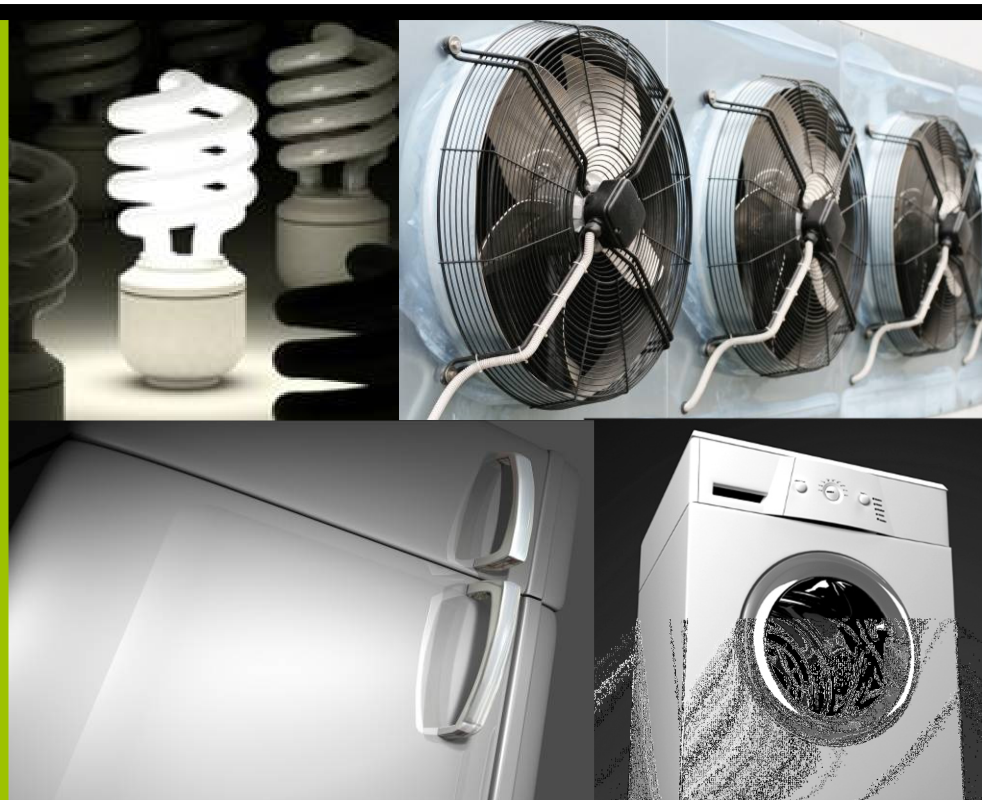

COOLING BENCHMARKING STUDY REPORT

June 2011

BY

Econoler, Navigant, CEIS and ACEEE

in Partnership with
The Collaborative Labeling and Appliance Standards Program (CLASP)

ACKNOWLEDGEMENT

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ABBREVIATIONS AND ACRONYMS

AC	**Air Conditioning**
AHU	**Air Handling Unit**
APF	**Annual Performance Factor**
CC	**Cooling Capacity**
CLASP	**Collaborative Labeling and Appliance Standards Program**
CSPF	**Cooling Seasonal Performance Factor**
EE	**Energy Efficiency**
EER	**Energy Efficiency Ratio**
EU	**European Union**
HSPF	**Heating Seasonal Performance Factor**
IEA	**International Energy Agency**
ISO	**International Organization for Standardization**
MEPS	**Minimum Energy Performance Standards**
NAFTA	**North American Free Trade Agreement**
RAC	**Room Air Conditioner**
S&L	**Standards and Labeling**
SEER	**Seasonal Energy Efficiency Ratio**
US	**United States of America**
VSD	**Variable-Speed Drive**

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EXECUTIVE SUMMARY

Room air conditioners (RACs) represent a major energy end usage in several countries and contribute significantly to the electrical grid peak load. Furthermore, the number of RACs is increasing rapidly due to rising living standards in several countries combined with a cost reduction in the price for AC equipment worldwide. These trends have resulted in a rapid increase in electricity demand and energy consumption in the commercial and residential sectors.

Even though RACs significantly impact energy demand and are traded worldwide, there is a lack of assembled information on market characteristics or on existing minimum energy performance standards (MEPS) and labeling schemes implemented in different economies. In addition, it is difficult to compare the performance criteria of air conditioners and policy measures for air conditioners across economies because of the differences in test procedures and protocols.

This cooling benchmarking study, which was funded by the Collaborative Labeling and Appliance Standards Program (CLASP), intends to provide policy makers and energy efficiency (EE) program managers with tools allowing for the comparison of the efficiency of air conditioning (AC) products under the different test procedures and EE metrics that are currently used in major world economies. In addition, a ranking tool has been developed to allow for performance comparisons of residential and commercial AC EE standards and labeling (S&L) programs implemented by countries around the world. The study focused on the comparison of EE performance and policy measures for air conditioners of a cooling capacity of up to 19 kW used in the residential and commercial sectors of the following eight economies: Australia, China, the European Union (EU), Japan, India, Korea, Taiwan, and the United States (US).

The scope of the AC products considered under this study included the following sub-categories: (i) non-ducted single split units (mobile or fixed split units); (ii) non-ducted single split unit heat pumps; (iii) ducted single split units; (iv) multi-split units; (v) single-packaged AC units; (vi) single and double duct units (portable air conditioners); and (vii) central AC units – Air Handling Units (AHUs), rooftop. Absorption units are excluded. The cooling mode of reverse cycle (heating and cooling) units is included in the study.

To achieve its overall goal, the study comprised four interrelated components: mapping, benchmarking, testing, and ranking. The mapping component of the study provides background information on the main characteristics of the RAC markets and the S&L programs implemented in the economies analyzed. Subsequently, these characteristics served as the basis for selecting the RAC models to include in the benchmarking, testing, and ranking components of the study. The benchmarking component allowed comparison of the efficiency of equipment in different economies by developing formulas for the conversion between the various metrics used around the world. To ensure the coherence of the formulas developed in the benchmarking component, the testing component conducted energy performance measurements of four selected RAC models under laboratory conditions and in line with the test procedures in force in the selected economies. The measurement results were compared to the theoretical conversion formulas developed by the benchmarking component to confirm their validity. Finally, based on the analysis of the S&L policy and regulation frameworks in the economies analyzed as well as input from S&L experts, a ranking tool was developed to compare the stringency and performance of RAC S&L programs between economies.

The main findings of each component are presented below:

Mapping Component

This component of the study provides a mapping of RAC characteristics in selected countries by comparing the market size and trends as well as the EE performance of the RAC products offered. The mapping component also reviews the existing S&L regulations or voluntary initiatives and their characteristics in each country. The main findings are summarized as follows:

- We can observe a general upward trend in the sales of RACs over the last 10 years in the EU and in the last five years in the US and India. In Japan, however, the RAC market has been relatively constant and even suffered a slight drop in 2009.
- In most of the countries analyzed, the RAC market is dominated by split units. One notable exception is India, where window and split units show almost equal shares in the market.
- In mature RAC markets such as the EU, Japan, and the US, inverter split units are widely available. The Japanese market is dominated by reversible RAC units that provide both cooling and heating functions. Inverter unit sales in China are also growing rapidly.
- The sales-weighted average Energy Efficiency Ratio (EER) of single and multi-split AC products has experienced an upward trend in the countries analyzed over the past decade. On the other hand, the sales-weighted average EER of window AC products has remained almost constant between 2006 and 2011 in the US, and it has decreased in the EU over the same period.
- The EER trend of the most efficient RAC products varies across the analyzed economies for which data were available. The EER of the most efficient split systems has been on an upward trend over the last decade in China, the EU, Japan, and the US. However, we can observe a reverse trend in some countries for products that are losing market share, such as unitary (window type) AC models. This is notably the case in the EU where the EER level of the most efficient unitary RAC products with a cooling capacity under 12 kW has declined between 2005 and 2011 after a boost over the 2002-2005 period. The trend observed for the most efficient RAC products is thus coherent with the sales-weighted average efficiency discussed above.
- The EER trend of the least efficient RAC products also varies across the economies analyzed. In the EU, the EER level of the least efficient unitary RAC products, which are losing market share, has decreased. This is coherent with the drop in efficiency of the most efficient unitary units and the sales-weighted efficiency observed for the same category of products. Moreover, in the EU the EER surged from 2002 to 2009 then declined from 2009 to 2011 for least efficient single and multi-split RAC units with a cooling capacity of 12 kW or less. This trend is different from the observed EER of the most efficient single split units with a cooling capacity of 12 kW or less, which has slightly decreased, while it has

increased for multi-split RAC units of the same capacity. This suggests that some manufacturers have chosen to offer only RAC single split products, with lower EERs than multi-split units. Flat and upward EER trends for least efficient RAC products have been observed in the US and China, respectively, over the last years. The trends of the EERs of the least efficient RAC products in China are improving, a finding similar to that made for China's most efficient equipment. This reflects the positive impacts that more stringent S&L regulations have had on the RAC market in China.

- The RAC stock grew rapidly in the countries analyzed, with a 75% increase in the EU and a 44% increase in China from 2005 to 2010. Growth has been moderate in Japan and the US, with 15% and 10% stock increases, respectively, over the same period.
- In some of the economies analyzed, such as China and Australia, the RAC MEPS level implemented has become more stringent over time with one or several updates. India and Taiwan are considering implementing more stringent requirements in the near future.

Benchmarking Component

The EER and the Seasonal Energy Efficiency Ratio (SEER) are the two main types of metrics in use internationally to rate the EE of ACs. The EER is the ratio of the cooling capacity to the electricity consumption when measured at full load (i.e., at the maximum deliverable cooling capacity of the AC). The EER is not representative of the seasonal energy performance because it does not take into consideration part load performance. In fact, ACs typically operate at full capacity for only a small number of hours in the cooling season; they run at part load or cycle on and off for the rest of the time. In order to address this shortcoming of the EER metric, the SEER has been created to provide a more representative measure of the EE performance of AC units over the cooling season. SEER metrics are increasingly being used as alternatives to the EER to set MEPS and labeling requirements. Japan has gone one step further and reports the Annual Performance Factor (APF) to consumers. This metric is defined as the weighted average of the Cooling Seasonal Performance Factor (CSPF) and of the Heating Seasonal Performance Factor (HSPF). The CSPF is similar to the SEER and used as part of Japanese, Chinese, and Korean test standards. The HSPF is conceptually similar to the SEER but developed specifically for the heating mode of products.

The benchmarking component of the project derives mathematical functions that can be applied to convert energy performance measurements of AC equipment in one economy into the comparable values that would have been recorded for the same products if they had been tested and rated in other economies. These conversion functions have been designed based on an in-depth analysis of the differences between methods to measure the energy performance metrics of ACs and the tolerances allowed in the reviewed economies. These conversion functions have been developed for both split non-ducted and split ducted ACs and for fixed-speed and variable-speed (inverter driven) units. As these split systems are the most common types of AC products sold in international markets, those conversion functions cover a large portion of the world market for AC products. Table 1 below presents the conversion coefficients that can be applied in the general conversion function SEER Y = α_ave * SEER X. In this formula, SEER X represents the rating observed in the source country, α_ave is the average conversion coefficient that should be applied, and SEER Y is the resulting efficiency in the target country.

Table 1: Average Seasonal Efficiency Conversion Coefficients for Non-Ducted Single Speed AC Units

Y Metrics	X Metrics	α_ave
Korea	China	99%
Japan CSPF	China	104%
US SEER Non-Ducted	China	99%
EU SEER Non-Ducted	China	112%
China	Korea	101%
Japan CSPF	Korea	105%
US SEER Non-Ducted	Korea	100%
EU SEER Non-Ducted	Korea	113%
China	Japan CSPF	96%
Korea	Japan CSPF	95%
US SEER Non-Ducted	Japan CSPF	95%
EU SEER Non-Ducted	Japan CSPF	107%
Korea	US SEER Non-Ducted	100%
Japan CSPF	US SEER Non-Ducted	105%
China	US SEER Non-Ducted	101%
EU SEER Non-Ducted	US SEER Non-Ducted	113%
Korea	EU SEER Non-Ducted	89%
Japan CSPF	EU SEER Non-Ducted	93%
US SEER Non-Ducted	EU SEER Non-Ducted	89%
China	EU SEER Non-Ducted	90%

The study has also derived minimum and maximum conversion coefficients for non-ducted single speed RACs to determine the range of plausible solutions to the conversion functions. While these maximum and minimum coefficients are not shown in Table 1 above, they are available in the benchmarking section of this report.

Additional parameters were also incorporated in the coefficients to reflect differences in the way ducted units are treated in the US versus elsewhere, and also to take into account the inclusion of energy use associated with low power modes in Europe. These additional elements that needed to be taken into account in the derivation of US and EU SEER conversion coefficients were managed through the application of an additional and broader uncertainty interval (i.e., through a lower level of confidence in conversion formula results).

Table 2 below presents the conversion coefficients applicable to variable-speed drive (VSD) AC units using the conversion function SEER Y = Cte + slope * SEER X, where SEER X and SEER Y are the seasonal efficiency metrics used in the source and target economies, respectively.

Table 2: Seasonal Efficiency Conversion Coefficients for Non-Ducted VSD Mini-Splits

Y Metrics	X Metrics	Slope	Cte
Japan APF	US SEER	0.865	0.733
EU SEER	US SEER	1.080	0.286
China SEER	US SEER	0.998	-0.258
Korea SEER	US SEER	1.014	0.559
US SEER	Japan APF	1.101	-0.521
EU SEER	Japan APF	1.187	-0.265
China SEER	Japan APF	1.102	-0.798
Korea SEER	Japan APF	1.111	0.062
Japan APF	EU SEER	0.793	0.556
US SEER	EU SEER	0.919	-0.216
China SEER	EU SEER	0.910	-0.426
Korea SEER	EU SEER	0.946	0.240
US SEER	China SEER	0.993	0.310
EU SEER	China SEER	1.064	0.668
Japan APF	China SEER	0.861	0.987
Korea SEER	China SEER	0.989	0.969
US SEER	Korea SEER	0.954	-0.338
EU SEER	Korea SEER	1.047	-0.189
Japan APF	Korea SEER	0.822	0.466
China SEER	Korea SEER	0.937	-0.491
Japan CSPF	China SEER	1.032	0.773
China SEER	Japan CSPF	0.926	-0.464
Japan CSPF	US SEER	1.051	0.384
US SEER	Japan CSPF	0.938	-0.273
Japan CSPF	EU SEER	0.975	0.088
EU SEER	Japan CSPF	1.024	-0.081
Japan CSPF	Korea SEER	1.025	-0.119
Korea SEER	Japan CSPF	0.972	0.141

Once established, the conversion formulas presented in Table 1 and Table 2 above were applied to current EE policy settings to compare the minimum energy performance requirements for the most common types of split RACs in the world's major economies. The main finding is that the Japanese Top Runner requirements are the most stringent existing requirements for split AC units, and these are between 17% (for more than 6 kW units) and 68% (for less than 3.2 kW units) more demanding than any current or proposed requirements in other economies.

The study does not intend to indicate that the Japanese requirements should be set as a world model, as the development of requirements also needs to take into account factors such as energy and equipment costs, consumer behaviors and usage patterns. This finding suggests that there are links between the high price of electricity, the stringency of MEPS requirements for ACs, and the strong government support for energy efficiency found in Japan. In fact, economies with high electricity rates or depending heavily on energy imports have a natural tendency to set more stringent MEPS for the benefits of their consumers and in response to their market reality.

Testing Component

The testing component highlighted the differences among test procedures for measuring the cooling capacity and the efficiency of ACs in cooling mode within the economies analyzed. Furthermore, it conducted testing for four samples under different test procedures in order to identify practical considerations with the test procedures and to provide real data to check the coherence of the conversion functions developed as part of the benchmarking component of the project. The main findings of the test procedures comparison are summarized as follows:

- Most of the economies included in this part of the study (the US, the EU, Japan, China, Korea, and India) base their test procedures for AC systems on the adaptation of two international standards: ISO 5151 and ISO 13253. The test procedures are based on two main test methods: the indoor air enthalpy method and the calorimeter room method.

- Several testing standards allow a choice between two different measurement methods. This study recommends use of the calorimeter room method whenever possible as it reduces the uncertainty of measurement compared to the enthalpy method. This is particularly important when EE classes are defined.

- While differences found among the test procedures used in different economies lead to various uncertainties of measurement, most of them do not allow the establishment of a systematic difference for the resulting EER.

- Differences among test procedures that have a systematic effect on the EER measurement include testing temperature conditions, the length of the refrigerant piping, and the fan correction for ducted units. The testing temperature condition effect was integrated in the conversion functions developed in the benchmarking component. This study recommends worldwide unification of the requirements on the length of the refrigerant piping used for the tests.

- The fan correction applied to ducted units may introduce large differences between the adjusted test results and real unit efficiency. This study therefore recommends a review of the existing testing standards to remove the fan correction when the fan is an integral component of the AC, and to make a fan correction only when the fan is not part of the unit.

- Power inputs in thermostat off, standby, and crank case heater modes should be considered in all SEER calculations in order to include all electrical energy used during the cooling season. This has already been incorporated in the recent revision of EU SEER calculation procedures.
- Testing variable-capacity ACs (inverters) can be a problem for third-party testing or market surveillance when contact with the manufacturer is not convenient (may not be allowed or communication might be difficult). For these units, the testing laboratory has to obtain additional information from the manufacturer to set the unit in the right mode, both for full load and part load rating conditions. If such information is not available, the laboratory cannot perform the test. Nevertheless, this study has demonstrated that if the testing laboratory has a facility where it is possible to set the load which the tested unit has to overcome, it is possible to test these units when the speed of the fan is known and the part load ratio is defined in the test procedure. This study recommends standardizing an alternative approach of setting the part load capacity on the indoor side of the test sample to allow uniformity across testing standards and laboratories.
- This study has confirmed that inverter units have poor latent heat removal characteristics at low load, and there is laboratory evidence that a small share of the units on the market do not have any latent heat removal characteristic even at high load. The study scope does not allow a clear conclusion on whether and how a humidity removal ratio should be incorporated as part of energy efficiency metrics requirements. We recommend that further research be conducted on this topic to determine the technical implications, the manufacturing cost, the deviation from comfort conditions in different climates, and the market requirements in dry or humid climates before deciding if this should be included in RAC testing procedures and in EER and SEER calculations.
- Laboratory testing confirmed the coherence of the conversion functions and of the various coefficients developed by the benchmarking team.

The findings from the testing component were used as input to the benchmarking team to fine-tune the proposed conversion coefficients between metrics.

Ranking Component

This component of the study focused on the elaboration of a ranking tool for RAC S&L policies, regulations, or initiatives. The ranking tool guides the user to collect the relevant data needed to assess their country's S&L programs, and provides evidence-based information on which to base policy decisions in order to improve programs or identify requirements for further study. The objective is to pull the market towards higher levels of AC efficiency and lay the foundation for strong and harmonized energy performance requirements at the global level.

In order to develop the ranking survey instrument, the ranking component team reviewed the Data Collection Sheet developed as part of the Mapping component. The most significant information was extracted from the sheet to serve as the basis for the ranking tool. Some data elements were excluded that are difficult for national experts to obtain. The first draft instrument covered four S&L program areas: MEPS program characteristics, MEPS technical characteristics, labeling program context, and labeling program quality. This draft was circulated to the project team and to a selected group of outside S&L experts. Converging to a final form involved extensive iteration as well as repeated rewording and restructuring to build a survey instrument that would be relatively easy to use, unambiguous, flexible enough to apply in highly varied national and international contexts, and robust enough to yield useful results. In this iterative process, the ranking tool was expanded to include MEPS stringency and the labeling area was split to address endorsement and comparison labeling programs separately.

The final survey instrument was built as a spreadsheet comprising eight tabs, including a summary sheet that determines the Overall Ranking Score by tallying the score from each of the subsequent tabs, which in turn cover seven key components used to determine the effectiveness of AC S&L programs, as provided below. A weighting factor is applied to the score from each individual worksheet tab. These scores are then summed and listed on a scale from 0 to 100 to determine the overall performance of the S&L programs of the ranked countries.

Once the basic structure and content of the ranking tool was developed, the ranking component team had a group of international experts on EE S&L assign relative weights (corresponding to importance) to each of the seven broad categories covering S&L program design and implementation, as well as to specific elements within each category.

The weighting values in the final ranking tool are based on input from experts representing government agencies, advocacy organizations, and consulting firms in Canada, China, India, Japan, and the US.

The scoring reflects generally accepted principles regarding best practice in S&L programs as reported in the literature, as well as input from CLASP staff, ACEEE's experience and, in some cases, comments from the expert reviewers.

The final overview sheet that summarizes the ranking for an economy is shown below.

	Ranking Criteria	Comments
17	**MEPS Stringency**	This tab evaluates MEPS program stringency.
20	**MEPS Program Characteristics**	This tab evaluates coverage and maturity of the standards program, frequency of revision cycles and enforcement mechanisms.
20	**Technical Characteristics of MEPS Rating Method**	This tab evaluates rating and certification methods.
7	**Endorsement Label Program Context**	This tab evaluates coverage of the endorsement labeling program, maturity of the program, revision cycles and enforcement.
11	**Endorsement Label Program Quality**	This tab evaluates labeling program quality from the consumer's perspective.
15	**Comparison Label Program Context**	This tab evaluates coverage of the comparison labeling program, maturity of the program, revision cycles and enforcement.
10	**Comparison Label Program Quality**	This tab evaluates labeling program quality from the consumer's perspective.

This Version 1.0 of the ranking tool can serve as a framework for ranking residential AC S&L programs, and can be modified to rank S&L programs targeting other product classes. As the tool is further refined, input from a broader range of S&L experts can be incorporated. Experts have already suggested additional topics for consideration in future improvements of the ranking tool. Following final completion of the project, the survey instrument and its instruction package will be made available to CLASP and to stakeholders on the global scene for use in any country where it might be deemed helpful.

INTRODUCTION

As part of its efforts to support transitioning to a world in which appliances, equipment and lighting are built for maximum Energy Efficiency (EE) and minimal contribution to global climate change, the Collaborative Labeling and Appliance Standards Program (CLASP) funded a study to provide tools and procedures allowing an international comparison of the EE performance and policy measures for air conditioners with a cooling capacity of 19 kW or less used in the residential and commercial sectors. CLASP is an international organization that promotes EE Standards and Labeling (S&L) in commonly used appliances and equipment.

Air Conditioning (AC) systems represent a major energy end-use in several countries, and contribute to the growth of energy consumption and peak load in the commercial and residential sectors. This trend is recently increasing due to rising living standards in several countries combined with a cost reduction of AC products. This tendency is contributing to an increase in greenhouse gas emissions across the world.

This study covered AC products offered in the global market as well as testing procedures and regulatory or voluntary initiatives introduced in different economies. In support of this study, information was collected for Australia, China, the European Union (EU), Japan, India, Korea, Taiwan and the United States (US). The main objective was to provide a meaningful comparison of the effectiveness of air conditioner models sold in major economies. This has been done through an analysis of the market characteristics, Minimum Energy Performance Standards (MEPS) levels and EE classes used for labeling schemes. In addition, conversion functions were developed allowing comparison of different efficiency metrics used across the world.

The project team included Econoler acting as team leader and experts from Navigant, CEIS and ACEEE. CLASP experts were also closely involved in work supervision and provided direction and advice to the project team. Several external experts and country representatives provided market information, advice and views on different issues related to the international comparison of AC equipment efficiencies.

This report summarizes the main findings of the four components of the project. The detailed reports prepared as part of this project for each component are listed below:

- Report 1: Mapping component. This report presents a review of AC products offered in different economies and some market characteristics.
- Report 2: Benchmarking component. This report presents an analysis to develop a series of conversion functions for metrics used in different economies around the world as well as a comparison of the relative stringencies of different MEPS and labeling schemes.
- Report 3: Testing component. This report presents the conclusions from a comparison of the testing of air conditioners under test procedures of various countries, and the actual testing of a limited sample of products under different test procedures.

Scope of the Study

In this study, the term Room Air Conditioner (RAC) includes:

- RAC products with a cooling capacity of up to 19 kW;
- Electrically driven vapor compression units. Absorption units are excluded;
- Cooling units only and the cooling function of reverse cycle (heating and cooling) units.

The scope of the study includes the following RAC sub-categories:

- Non-ducted single split units (mobile or fixed split units);
- Non-ducted single split unit heat pumps;
- Ducted single split units;
- Multi-split units;
- Single-packaged AC units;
- Single and double duct units (portable air conditioners);
- Central AC units (rooftop units).

1 Project Methodology

The study intends to provide policy makers and EE program managers with tools enabling comparison of the efficiency of AC products under different test procedures currently used in major world economies. Additional tools were developed to allow comparison of the performance of residential and commercial AC EE S&L programs conducted by countries around the world. The study included the four components described below: mapping, benchmarking, testing, and ranking.

1.1 Mapping

The goal of this component is to establish AC energy performance in selected economies by comparing market trends, performance, and existing S&L initiatives and their characteristics. This component included the following tasks:

- Select relevant economies to consider in the study based on the international experience of study team members and CLASP. The selection focused on economies where MEPS and labels have been implemented and/or are under preparation or revision. This list was validated with CLASP and eight economies were selected based on size and their overall value for a worldwide comparison scheme.
- Define and classify RAC sub-product categories to facilitate comparison of their EE. This resulted in the identification of the following RAC sub-categories: (i) non-ducted single split units (mobile or fixed split units); (ii) non-ducted single split unit heat pumps; (iii) ducted single split units; (iv) multi-split units; (v) single-packaged AC units; (vi) single and double duct units (portable ACs); and (vii) central AC units (AHUs, rooftop).
- Collect information on the AC market for each country using information available online or with the support of national organizations. The team collected stock, sales, and average energy performance data for each AC sub-category offered in the market. Data collection also included any existing MEPS or labeling schemes and their associated testing procedures. This information was requested for each RAC sub-category included in the scope of the study. All information was collected for available years from 2002 to 2009. Whenever possible, data on the stock, sales, and average energy performance of each AC sub-category were collected using government sources, industry association databases (e.g., Eurovent), or market research companies (e.g., GfK).
- Compare the markets and highlight the differences between economies. One of the objectives of this analysis was to identify the most efficient equipment available in each product category as well as the average capacity of the units sold and the market share of efficient products. The information collected for MEPS and labeling schemes was compared and provided an essential input for the benchmarking and ranking activity.
- The information collected on test procedures was analyzed as part of the testing component.

1.2 Benchmarking

The benchmarking component was aimed at overcoming the information comparability barrier by deriving conversion functions and coefficients that can be applied to compare AC energy performance ratings across economies. These conversion functions and coefficients can also be applied to compare MEPS or labeling class levels across economies. As part of this component, the following tasks were undertaken:

- Identify the differences in test procedures for several energy performance metrics, including the EER, the SEER, the APF, and the CSPF. These are all metrics used to establish the energy performance of ACs in the selected economies.

- Based on the differences in test procedures or the conditions identified, propose formulas that can be used for conversion purposes between each of the most important EE metrics currently in use for ACs around the world. Formulas were successfully developed for split non-ducted and ducted ACs, for fixed-speed as well as for variable-speed (inverter driven) units.

- Apply the conversion formulas to current EE policy requirements in the selected economies to compare their relative stringency on an equal basis.[1]

1.3 Testing

The testing component of this study features two goals: (i) the comparison of test procedures of the economies included in the scope of the study; and (ii) the testing of a limited sample of RACs under different testing protocols. The study team undertook the activities described below:

- Identify the differences among the test procedures used in the selected economies for measuring the capacity and efficiency of ACs in cooling mode. The study team also estimated the uncertainties of measurement that could be expected for each test method[2] as functions of the test conditions and type of AC. International Organization for Standardization (ISO) standards were covered as they are often used as reference test procedures in the development of test procedures in most of the studied economies.

- Test a limited number of samples in order to check the conversion coefficients developed under the benchmarking component to compare the rating of a given AC through the different efficiency metrics used in the economies included in the study. Four samples were selected in order to cover the most relevant segments of the market for appliances included in the scope of this study.

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[1] This comparison takes into account the energy efficiency requirements. However, it does not consider other factors such as cooling demand, usage patterns, and the cost of electricity, which are also relevant elements for assessing the level at which an energy efficiency requirement should be set.

[2] These estimations were not made for two economies for which the necessary data were not provided.

1.4 Ranking

Under this study, the goal of the ranking component was to provide policy makers with a tool to compare the stringency and efficiency of their AC MEPS or labeling programs to those implemented in other countries and/or regions. The study team undertook the following tasks:

- Enlist a group of international S&L experts to advise on the content and relative weighting of ranking parameters for S&L programs.
- Develop a concise ranking instrument to allow the experts to assign ratings to various S&L program components. Based on iterative feedback through several cycles, the study team converged on a seven-part ranking tool. The ranking tool was developed for diffusion to any interested stakeholder in the form of an Excel spreadsheet.
- Implement a Delphi approach to query internal and external S&L experts about the relative weights that should be assigned to each of the seven categories retained for the ranking tool. The team then assigned appropriate weighting for specific elements within each category.
- Test the rating tool using national data collected through the mapping component.
- Finalize packaging and instruction of the ranking tool so that it can be made available to any interested stakeholder for the evaluation of the stringency and efficiency of their S&L initiatives.

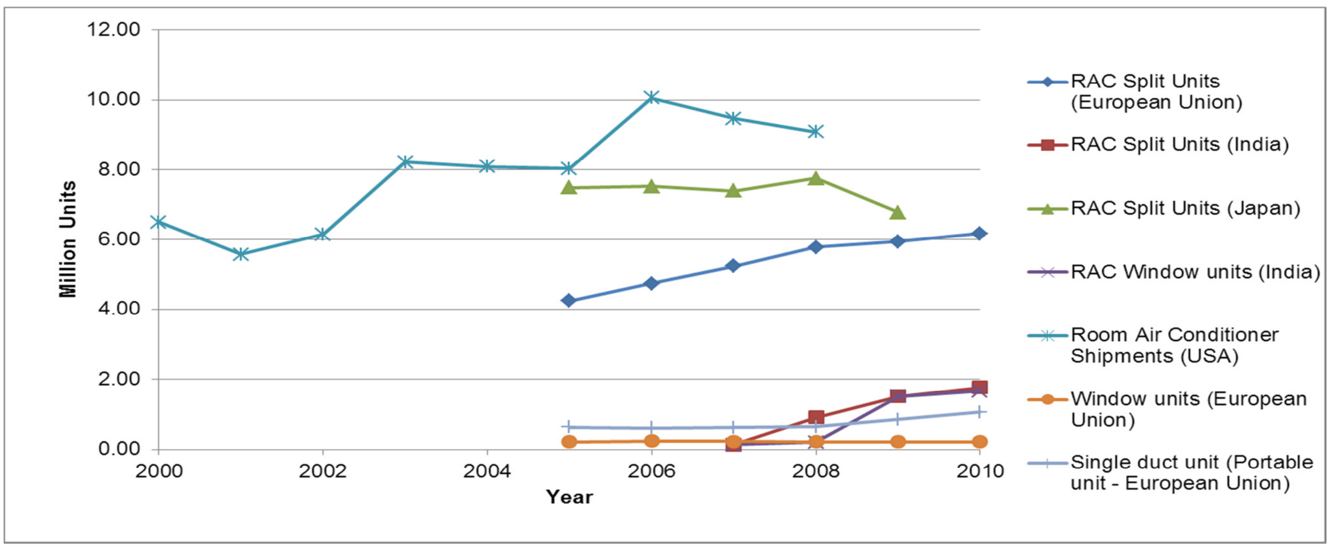
2 Mapping

2.1 AC Market Characterization

2.1.1 Supply of New AC Products

In most of the eight economies covered by the study, split units dominate the RAC market. For instance, out of the total domestic sales of 30.3 million split units sold in China in 2009, 30 million were for single split AC systems and 0.3 million for multi-split AC systems. In comparison, the sales of windows and moveable AC units were very low.[3] Inverter split unit sales were reported to be rising in China and had reached 18% of total sales by 2009. The RAC split unit market in the EU is growing steadily while the window unit market has been constant over the last six years. India shows a more diversified market as both RAC window and single split unit sales have recently experienced fast growth. The Japanese RAC market is dominated by reversible split AC units, which were developed in Japan.

Figure 1: RAC Market Trends from 2005 to 2010[4]



Despite the variation of RAC market characteristics depending on the economy, the market has been on an upward trend over the last five years in most economies. Figure 1 above presents the RAC market shipment progression over the last five years in the US, the EU, India, and Japan.

RAC split unit sales in Japan almost remained constant between 2005 and 2008. Thereafter, Japanese RAC sales slightly declined between 2008 and 2009 due to the economic recession. However, it is expected that the

3 All the information used in Section 2 is further described and referenced in the mapping component report.

4 Data on the sales of split units per sub-product – such as non-ducted split packaged AC systems (cooling only), non-ducted split packaged AC systems (heat pumps), single duct unit, single split, or multi-split – as a share of the total market per year were not available for all the economies included in the scope of this study. Therefore, it has not been possible to compare RAC markets among all economies.

market for ACs will recover and resume growth by 2015. In contrast to the trend observed in Japan, the sales of split AC units (cooling only and reversible units, including multi-splits) and portable units in the EU (2005 - 2010) as well as of window and split AC units in India (2007 - 2010) grew rapidly. Sales for window AC units in the EU (2005 - 2010) have remained constant. According to an economic and market analysis conducted in 2008, RAC sales are expected to increase within the EU.[5]

Additionally, the figure above suggests that the RAC market in the US has been on an upward trend over the last decade.[6] In fact, RAC shipments experienced a surge between 2000 and 2003, demonstrating an increase of 26% (from 6.496 to 8.216 million units). The figure slightly decreased to 8.032 million units in 2005 and, in 2006, the shipment volume went back up again to reach more than 10 million units, which later decreased to 9.086 million units in 2008. Over the same period, the trend observed for all RAC shipments was consistent with that observed in the residential and commercial sectors. However, in 2010, a US Department of Energy projection predicted that the yearly shipment volume would remain almost constant at approximately 9.5 million RAC units over the next three decades.

Cooling Capacity

According to data presented in a recent study by the International Energy Agency's (IEA) 4E Annex,[7] the product weighted average cooling capacity of products shipped in China in 2008 was 4.3 kW. This figure is higher than the result of an analysis of AC catalogue data of Chinese manufacturers carried out as part of this study, which found a product weighted average cooling capacity of 3.33 kW in 2011. Another study from CNIS reported that 89% of the market was in the range of 0 - 4.5 kW, 8% in the 4.5 - 7.1 kW range and 3% in the 7.1 - 14 kW range.[8]

In Europe, the product weighted average cooling capacity for RAC split units under 12 kW has remained fairly constant at 5.9 kW between 2009 and 2011. However, this is higher than the 5.6 kW average observed in 2002. On the other hand, the product weighted average cooling capacity for RAC unitary units under 12 kW has shown an upward trend over the last three years. From 2009 to 2011, the product weighted average cooling capacity increased from 3.7 kW to 5.6 kW.

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[5] See EuP (2008) *Preparatory Study on the Environmental Performance of Residential Room Conditioning Appliances (airco and ventilation)*, p.36.

[6] Residential air conditioners in the US fall into the two broad categories of "room air conditioners" and "central air conditioners." These are regulated differently and treated differently in the manner in which they are tested; however, the distinctions used do not correspond to those used outside of North America. Room air conditioners in the US refer solely to single packaged window/wall units (unitary types). By contrast, the term central air conditioners includes split and multi-split packaged non-ducted AC units that would be classified as room air conditioners in other parts of the world.

[7] The report was released in February 2011. It looks at both unitary (packaged) and split ACs sized up to 14 kW and makes a range of observations on the differences in performance of these products between countries. 4E is an IEA energy technology collaborative program.

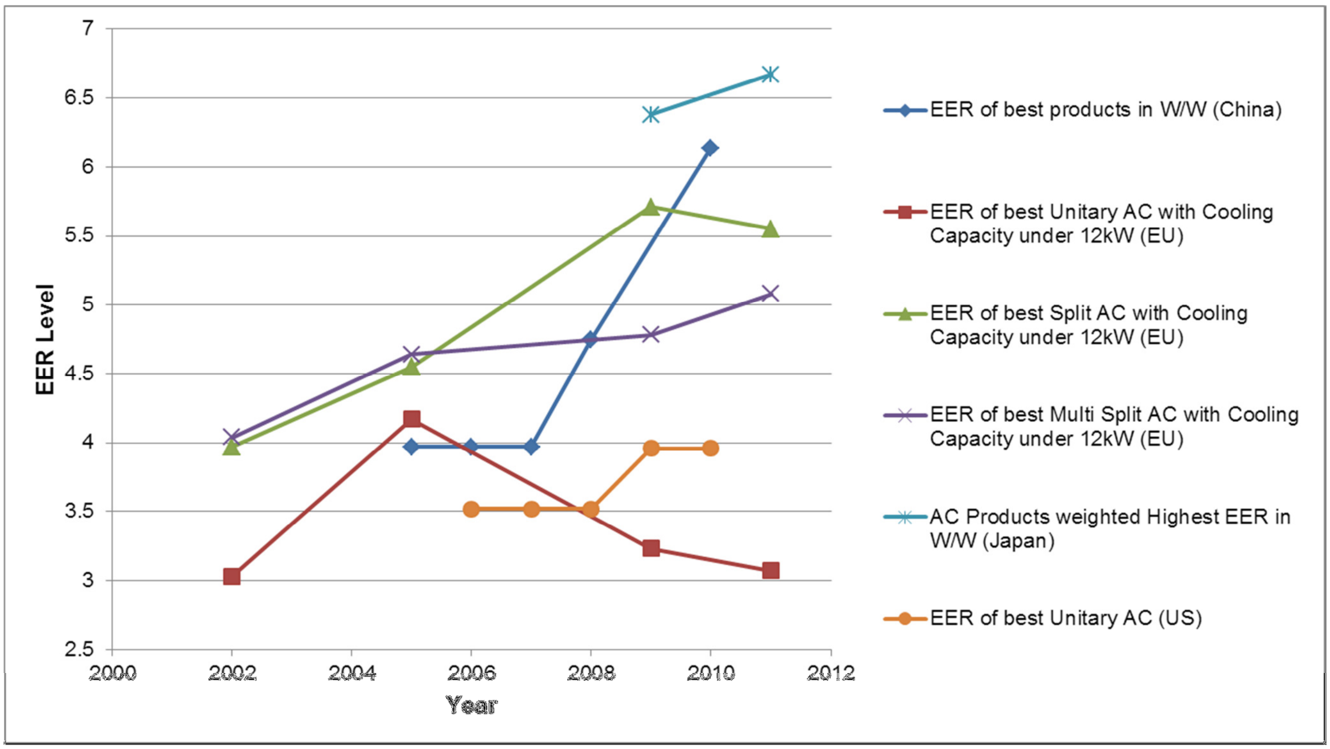
[8] CNIS, 2011.

In Japan, the product weighted average cooling capacity for non-ducted split packaged AC systems (heat pumps) was estimated at 3.67 kW for 2011.

Trends in the EER of the Most Efficient Products

The analysis of trends in the EER of the most efficient products available in the market was conducted for certain economies only (China, the EU, Japan, and the US) because relevant data were not available in all analyzed economies to allow for such an analysis. Moreover, given that the objective was to compare trends, the analysis was based on EER data, which were not corrected for differences in test procedures and metrics. The trend of the EER level of the most efficient AC products varies across the studied economies, as presented in Figure 2 below.

Figure 2: Trends in the EER of the Most Efficient AC Products



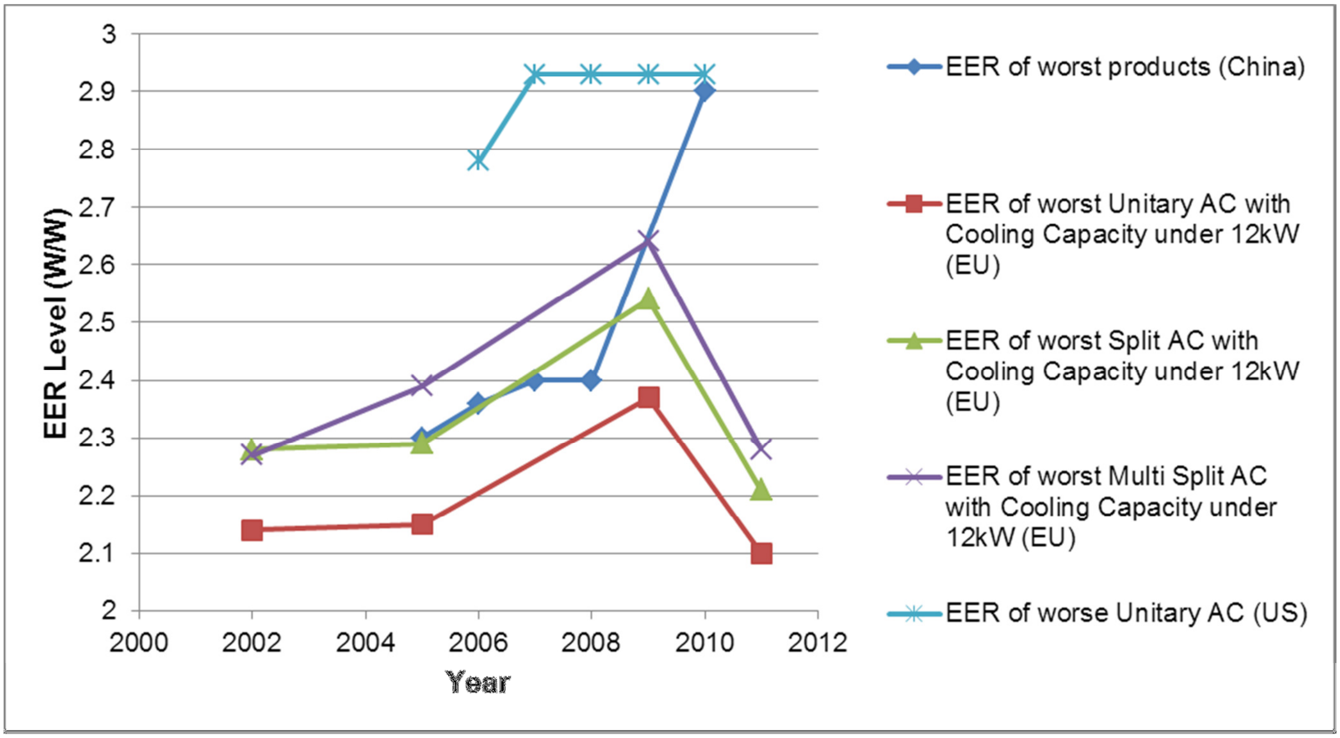
It can be seen from the figure above that the EER of the most efficient AC products has improved over the years in most economies. In the EU, the EER of the most efficient split and multi-split AC products with a cooling capacity under 12 kW improved between 2002 and 2011. In Japan, the EER of the most efficient AC products rose from 6.38 to 6.67 between 2009 and 2011. The same upward trend was observed in the US for the most efficient unitary AC products between 2006 and 2010. In China, the EER level of the most efficient products increased rapidly from 3.97 to 6.14 between 2005 and 2010. The best EER value of 6.14 W/W was found in a sample of 245 models from online catalogue data for China.

On the other hand, in the EU, the EER of the highest unitary (window) AC units with a cooling capacity less than 12 kW has decreased from 4.17 in 2005 to 3.07 in 2011. This suggests that unitary AC unit manufacturers that were providing higher efficiency products have withdrawn their offerings of energy efficient unitary products in order to concentrate on the growing split market segment.

Trends in the EER of the Least Efficient Products

A time series of the trends in the EER of the least efficient AC products in the selected economies is presented in Figure 3 below. The EER data used were not corrected for differences in test procedures since this section intends to analyze trends in the EER of the least efficient RAC products.

Figure 3: Trends in the EER of the Least Efficient AC Products



It can be seen from the figure above that in the EU, the EER of the least efficient AC products has not improved over the 2002 - 2011 period, unlike the upward trend noted for the most efficient products. From 2002 to 2009, the EER of the least efficient unitary, split and multi-split AC products with a cooling capacity less than 12 kW increased from 2.14 to 2.37, 2.28 to 2.54, and 2.27 to 2.64, respectively. Thereafter, the EER dropped to 2.10 for unitary AC units, 2.21 for split AC systems, and 2.28 for multi-split AC products. From the trend observed for unitary RAC units, it could therefore be suggested that the EU market has lost interest in these products leading some manufacturers to offer RAC products that only meet the minimum voluntary MEPS.

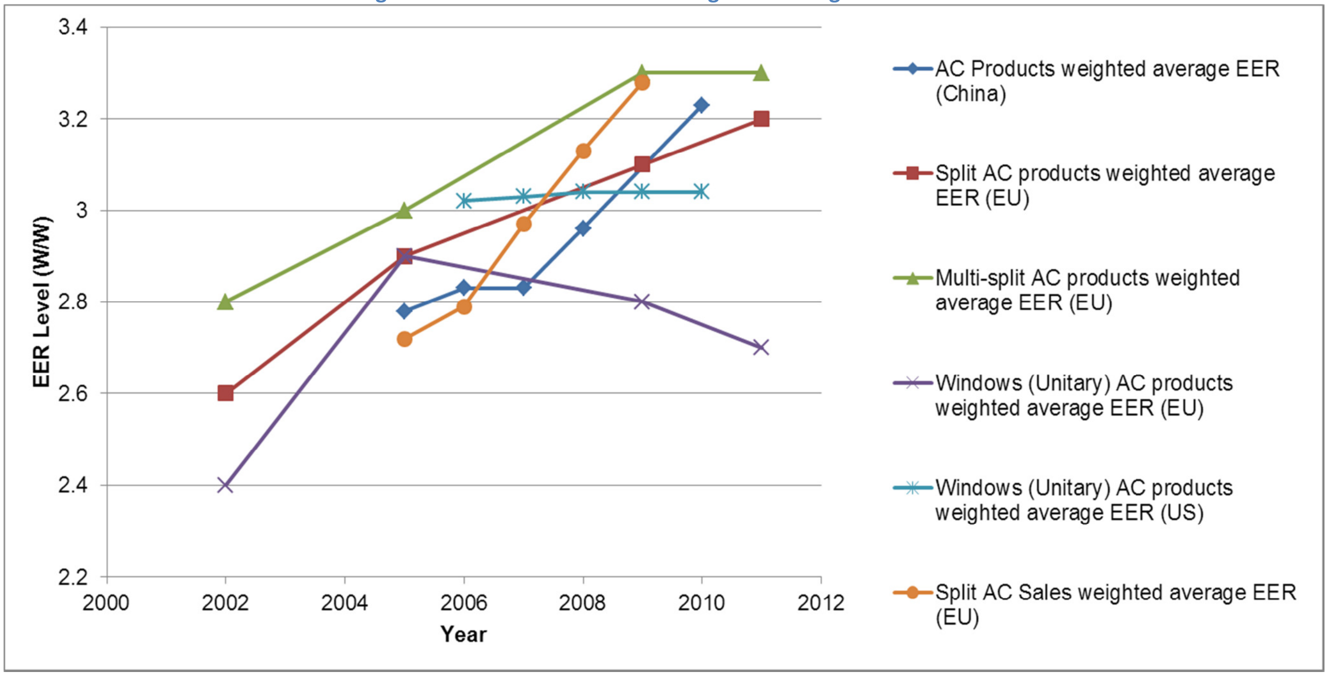
In the US, the EER level of the least efficient unitary AC products increased slightly from 2.8 to 2.9 between 2006 and 2007, and remained constant over the following years.

Unlike in the US and EU, the EER of the least efficient AC products in China experienced a slight increase between 2005 and 2008 followed by a rapid improvement, from 2.4 to 2.9, between 2008 and 2010. This likely reflects the positive impacts that more stringent S&L regulations had on the RAC market in China.

Trends in Product and Sales-Weighted Average EER

The product and sales-weighted average EER of AC products in some of the economies (China, the EU, and the US) is presented in Figure 4 below. The EER data used were not corrected for differences in test procedures among countries as this section is only intended to analyze and compare trends in product and sales-weighted average EER.

Figure 4: AC Product and Sales-Weighted Average EER Trends



As can be seen from the figure above, the product weighted average EER of split and multi-split AC products in the EU has consistently increased from 2002 to 2011. A similar trend is observed in China, where the product weighted average EER experienced an upward trend between 2004 and 2008. Unlike the case of AC products in China and split and multi-split AC products in the EU, the window AC product weighted average EER remained constant in the US between 2006 and 2010.

2.1.2 Stock of AC Products

In the economies covered by this study, the number of units in use has increased greatly over the past decade, as presented in the table below.

Table 3: Stock of RACs by Economy (million units) and Total Growth Between 2005 and 2010

Country	2005	2009	2010	2030	% (2005-2010)
China	160	N/A	230	N/A	44%
EU	40	N/A	70	130	75%
India	N/A	2.5	3.5	30	N/A
Japan	108	N/A	124	N/A	15%
US (only central air conditioners and heat pumps)	59.5	N/A	65.6	N/A	10%

The figures in Table 3 above show that from 2005 to 2010, the RAC stock grew faster in the EU (75% increase) than in China (44% increase) or Japan (15% increase). The stock of central ACs in the US also underwent moderate growth estimated at 10% between 2005 and 2010.

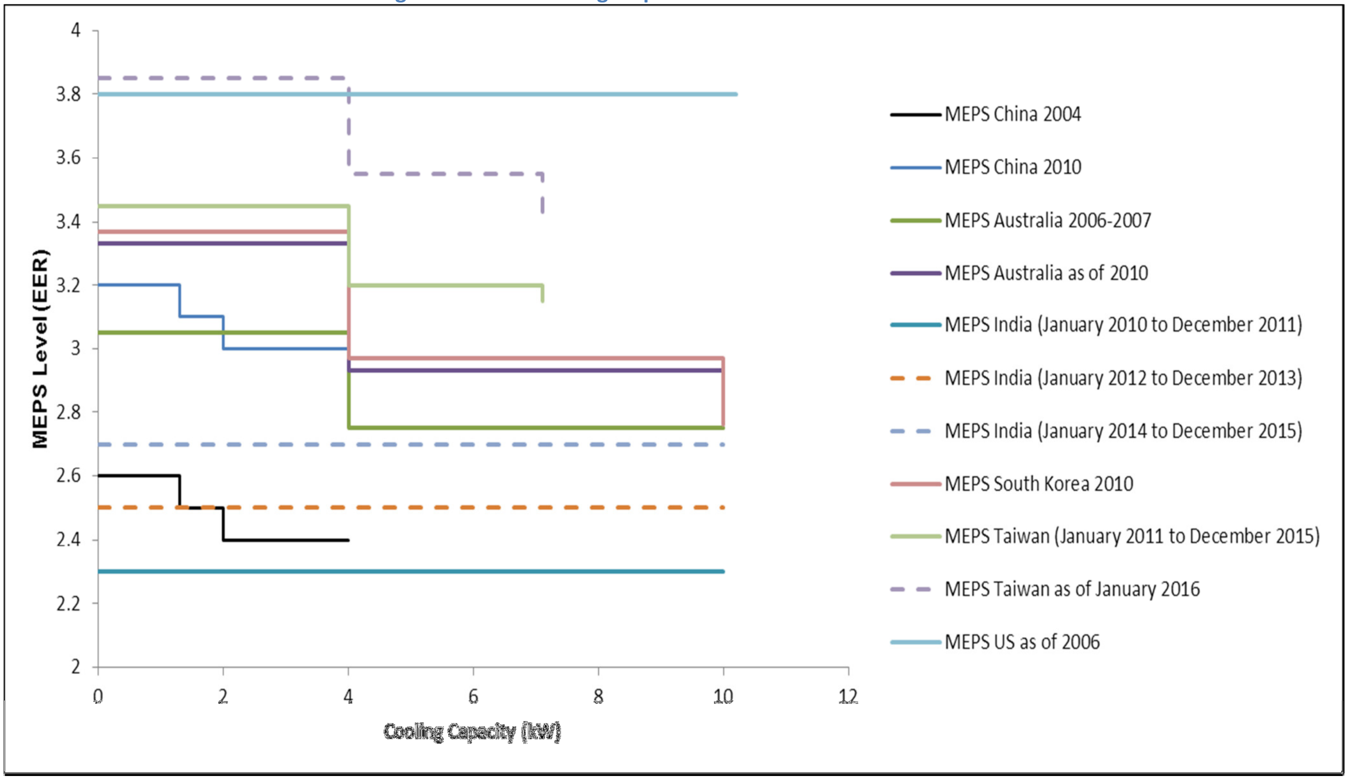
AC stock projections suggest that growth will continue between 2010 and 2030 in India and the EU. In India, rapid growth in AC stock is expected, with projections of growth from 3.5 million units to 30 million units between 2010 and 2030. The stock of AC products in the EU is projected to grow from 70 million units to 130 million units between 2010 and 2030.

2.2 Standards and Labeling Framework

2.2.1 Minimum Energy Performance Standards

Of the eight economies included in this study, only the EU does not currently have MEPS regulations for RACs. However, the EU is currently considering such measures under the Ecodesign of Energy-Using Products directive. Of the other seven economies, all currently use the energy efficiency ratio (EER) as the metric of energy performance except Japan, which has used the annual performance factor (APF) since 2010. Figure 5 below shows the MEPS levels currently in effect and those planned in the selected economies, except for the EU and Japan. The MEPS levels analyzed were not corrected to take into account test standard differences between countries because this section intends to illustrate the stringency changes of MEPS regulations in the analyzed countries.

Figure 5: MEPS for Single Split RACs in Selected Economies



The figure above suggests that the economies analyzed have used different approaches in establishing their MEPS levels. Some economies have established different MEPS levels according to the cooling capacity of single split ACs. Others have adopted a single MEPS level for single split ACs regardless of their cooling capacity. Despite the different approaches with regard to the establishment and implementation of the MEPS levels, we can observe a general trend toward more stringent requirements over the past years. Moreover, it is worth noting that the planned MEPS levels in economies such as Taiwan and India are more stringent than current levels in many other economies, as shown in the figure above.

In all of the analyzed economies, except in the EU, AC manufacturers or distributors are required to get a certification or registration of their AC products prior to their distribution on the market. Although the EU does not currently have MEPS regulations for RACs, the trade association Eurovent, whose members account for almost 90% of the EU RAC market, operates a voluntary certification system for AC products, including RACs. This scheme is mandatory for all Eurovent members and represents a condition providing that the energy efficiency of the product should be better than class G of the RAC energy efficiency label. In all of the economies analyzed, in the event of non-compliance, the consequences vary from registration or certification cancellation to product removal from the certification program website or market as well as high financial penalties.

2.2.2 Labeling Scheme

Each studied economy has established a mandatory label for RACs. However, some of the economies have a voluntary label as well. Among such economies, the US was the first to implement a labeling program in 1986 while Taiwan introduced the most recent program in 2010. Table 4 below summarizes the labeling programs in force in participating economies.

Table 4: Air Conditioner Labeling Program in Each Economy

Economy	Entry in Force	Approach	Description
Australia	Mandatory since 1987	Comparative (Categorical)	Six-star base label and ten-star super-efficient label. The more stars the more energy efficient.
China	Mandatory since 2005	Comparative (Categorical)	Five-class label with the 1st class being the most efficient and the 5th class being the least efficient.
EU	Mandatory since 2002	Comparative (Categorical)	Seven-letter (from A to G) base label with A being the most efficient and G the least efficient.
India	Mandatory since 2010	Comparative (Categorical)	Five-star base label. The more stars, the more savings.
Japan	Mandatory since 2006	Comparative (Categorical)	The unified energy-saving label has five stars. The more stars an AC has the more efficient it is.
Korea	Mandatory since 1992	Comparative (Categorical)	Five-grade labeling with the 1st grade the most efficient and the 5th grade the least efficient.
Taiwan	• Mandatory (energy efficiency rating label) since 2010 • Voluntary (energy conservation label program) since 2001	• Comparative (Categorical) • Endorsement	Five-class label with the 1st class being the most efficient and the 5th class being the least efficient.
US	• Mandatory (EnergyGuide) since 2007 • Voluntary (ENERGY STAR) since 1986	• Comparative (Continuous) • Endorsement	Range of energy use for similar appliances. The further the arrow to the right, the lower the operating cost of the appliance.

The table in Appendix 1 provides the technical characteristics about MEPS in the studied economies. For each economy, it provides information for each MEPS program on its maturity, establishment, implementation, enforcement, and the consequences in case of non-compliance.

2.2.3 Test Procedures

All economies except India have adopted the same international test standard (ISO 5151) as reference for measuring the EE of RACs. India is considering the adoption of ISO 5151 to harmonize its procedure with that implemented in other economies. Table 5 presents the test procedures in force in the studied economies.

Table 5: National Test Procedures for AC Products in the Countries Analyzed

Economy	National Testing Standard	Reference Test Standard
Australia	AS/NZS 3823	ISO 5151
China	General: GB/T 7725-2004 Unitary: GB/T17758-1999	ISO 5151[9]
EU	EN14511-2004	ISO 5151, ISO 13253
India	IS 1391	ISO 5151
Japan	JIS B 8616	ISO 5151, ISO 13253
Korea	KS C 9306	ISO 5151, ISO 13253
Taiwan	CNS 3615	ISO 5151
US	10 CFR 430, Subpart B, Appendix F	Consistent with ASHRAE Standard 16/69, ISO 5151

[9] GB/T 7725-2004 is not equivalent to ISO 5151-1994. However, the cooling capacity tests are conducted under ISO 5151-1994 T1 test conditions.

3 Benchmarking

3.1 Why Benchmarking Is Needed

Currently, the energy performance of ACs is measured in each economy using a designated test procedure and associated EE metrics. However, these are not identical across economies, making it impossible to directly compare EE metrics and policy settings. This means that policy makers and market actors are unable to ascertain how the EE of products sold in their markets compares with those in peer economies, which in turn inhibits policy and market harmonization efforts and constitutes a barrier to technology diffusion.

The benchmarking component of this study is aimed at overcoming this comparability barrier by deriving conversion metrics that can be applied to adjust AC energy performance measurements made in one economy to the comparable values that would be recorded for the same products were they to be tested and rated in other economies. The resulting analysis produced formulas that can be used for conversion between each of the EE metrics currently in use for air conditioners in selected economies. These formulas are successfully developed for both non-ducted and ducted split ACs, for fixed-speed and variable-speed (inverter driven) units – in other words, for the most common types of AC products sold in international markets. The scope of applicability and resulting margin of error from the use of these formulas are also assessed.

This is the first time that such a comprehensive exercise to develop conversion formulas for both full capacity and seasonally averaged EE metrics has been attempted. While the results are not perfect, they are found to be sufficiently robust to allow for a meaningful comparison of EE policy settings across the selected economies despite their current use of different energy performance test procedures. The conversion formulas are applied to current EE policy settings to assist policy makers by enabling comparison of the relative stringency of requirements for ACs in different economies.

3.2 Air Conditioner Energy Efficiency Metrics

There are presently two main types of metrics in use internationally to rate the EE of ACs: energy efficiency ratios (EERs) and seasonal energy efficiency ratios (SEERs). EER ratings are used to assess full load performance, and are used in many S&L schemes around the world. However, SEERs are a better measure of part-load performance and are increasingly being developed and applied to set MEPS and labeling requirements rather than EERs. This report sets out a basis for cross-economy comparison of both EERs and SEERs, as explained in the remaining portion of this section.

3.2.1 Energy Efficiency Ratio

The EER is the oldest and most widely used AC efficiency metric, and is calculated as the ratio of the cooling capacity to the electricity consumption when measured at full load (i.e., at the maximum deliverable cooling capacity of the AC). This is determined in all economies for a single representative test condition, which is specified by a single set of indoor and outdoor dry and wet-bulb air temperatures that have to be maintained during the test. In practice, the T1 test conditions specified in ISO 5151:1994 have been very widely adopted. Because of this, among the economies that have conditions in line with this standard, the only adjustment needed to convert between different EER test results is to take account of differences in permitted test tolerances. All the economies addressed in this study have EER test conditions fully aligned with ISO 5151:1994 except for the US, which is a North American Free Trade Agreement (NAFTA) economy. While the test procedure used in NAFTA economies shows standards that are almost in full alignment with ISO 5151 T1 test conditions, there are some slight deviations that introduce a degree of non-comparability in full load EER results. Thus, a correction factor needs to be applied to enhance the comparability of the EER test results produced using ISO T1 test conditions with NAFTA test conditions and any policy requirements based upon them.

In general, there could be a number of factors that produce differences in EER test results for a given unit, including variations in test conditions, standard operating conditions, and tolerances applied in the different jurisdictions. Thus, the objective of this study with respect to EER conversions is to develop conversion formulas that allow the EER recorded under the prevailing test procedure requirements in one specific region to be compared directly with the EER measured under the prevailing test procedure requirements used in another region. In practice, it is found that this can be done via the following linear relationship:

$EER_{ZONE1} = \alpha_{12} * EER_{ZONE2}$ and vice versa as: $EER_{ZONE2} = \alpha_{21} * EER_{ZONE1}$

3.2.2 Seasonal Energy Efficiency Ratio[10]

The EER metric only measures the efficiency of the unit at a sole designated design point, which is the maximum cooling capacity that the device is capable of delivering when measured under a single set of standardized temperature conditions. However, in practice, ACs typically only need to operate at full capacity for a small part of the cooling season, and will run at part load or cycle on and off the rest of the time when not in the off mode. Consequently, reliance on EE metrics based on a single full capacity design point ignores part load performance, which is a large portion of total operation performance, and will tend to yield efficiency performance rankings that are not representative of real seasonal energy performance. This is compounded because performance metrics based solely on full load conditions tend to encourage manufacturers to optimize full load performance at the expense of part load performance. To obviate this problem, SEERs have been created in order to provide an EE measure that is closer to the real EE performance of AC units in situ over the cooling season. SEERs include the impact of variations in the outdoor air temperature and the effect of the cooling load, which is also sensitive to building and user behavioral norms. These metrics typically require several test points to compute a seasonally weighted average efficiency and are intended to give results that are representative of how the AC would perform over a typical cooling season within a representative building type having typical operating characteristics.

Four economies have already adopted specific seasonal energy performance test standards for ACs. The US was the first to develop a SEER standard, followed by Korea and more recently Japan and China. The EU is poised to adopt a SEER metric, which is expected to come into effect in 2012 to coincide with and underpin the

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10 The term SEER is used generically in this section to apply to any energy efficiency metric that uses a weighted average of multiple test points.

entering into force of new efficiency regulatory requirements developed within the context of the EU's Ecodesign directive. Therefore, the SEER benchmarking work conducted in this report examines methods for conversion among seasonal EE test results produced in China, the EU (2012), Japan, Korea, and the US (and by implication other NAFTA economies that operate under regionally harmonized test procedures).

The objective of this study with respect to seasonal EE metrics is to establish relationships that allow SEERs to be converted among the five specific SEER metrics that are in common use in the selected economies. As SEER requirements have more test points and are designed to be representative of local climates, building types, and user behavior, they have more degrees of freedom than EER metrics and it is more complicated to derive formulas to convert from one to another. Nonetheless, the generic conversion formulas between SEER metric X and SEER metric Y can be expressed as:

SEER Y = α * SEER X

The conversion coefficient α is dependent on the technical features of the products being considered, and in particular on the means used to adapt the capacity of the unit to the required building load. The next section discusses the characteristics of seasonal efficiency metrics and the subsequent section covers the development of conversion formulas between metrics.

3.3 Characteristics of the Seasonal Efficiency Metrics

To be able to explain the EE metric conversion formulas and how they were developed, it is first necessary to understand the characteristics of the metrics themselves. This section describes the test specifications used in the seasonal metrics and the related algorithms that are used to derive the SEER metrics. The general principle used to establish the different SEERs is similar in the five economies. The US AHRI 210/240 test standard, which sets out the specifications used to establish the US SEER, is presented as an example. Variations in the methods used in the other economies are then discussed.

3.3.1 US SEER Metric

A single cooling load curve, intended to be representative of a typical US building in a single nationally representative climate, is used to represent the cooling period climate across the US and compute the SEER. The building cooling load (BL) is assumed to be a linear function of outdoor air temperature, as shown below.

$$BL(T_j) = \frac{T_j - 65}{95 - 65} \frac{P_c(FL, Rating)}{1.1}$$

Where Tj is the outdoor air temperature axis divided into discrete intervals (or bins) of 5°F (about 2.8°C) represented by the subscript j; BL(Tj) is the building cooling load for a temperature in bin j, in units of kW; Pc(FL, rating) is the rated cooling capacity at full load (FL) as measured at the full load test condition in units of kW. This full load test condition is the same as the condition used to produce the power and cooling capacity measurements for the EER ratings, and hence it is very close to ISO T1 conditions.

In order to be able to average the efficiency at different load and outdoor temperature conditions, the hours of occurrence of each outdoor temperature during the cooling season are summed for each of the bin intervals, and the median temperature of the interval bounds is taken to be representative of the bin as a whole. The fraction of the time spent at each outdoor temperature interval is shown in Table 6.

Table 6: Distribution of Fractional Hours within Cooling Season Temperature Bins, AHRI 210/240

Bin Temperature Range (°F)	65-69	70-74	75-79	80-84	85-89	90-94	95-99	100-104
Representative Temperature for Bin (°F)	67	72	77	82	87	92	97	102
Representative Temperature for Bin (°C)	19.4	22.2	25.0	27.8	30.6	33.3	36.1	38.9
Fraction of Total Temperature Bin Hours	0.214	0.231	0.216	0.161	0.104	0.052	0.018	0.004

The electricity consumption of the unit is computed from measurements recorded at predefined test points for a given load ratio and outdoor air temperature along the building load curve. These points vary with the means that the AC uses to match its cooling capacity to the required load (on-off cycling for single speed units, two-stage units and variable-speed drives). Then, the SEER is determined by calculating the ratio of the energy delivered to the electric energy consumption, as shown below.

$$\mathrm{SEER} = \frac{\sum_{j=1}^{8} \frac{q(T_j)}{N}}{\sum_{j=1}^{8} \frac{e(T_j)}{N}} \qquad \mathrm{SEER} = \frac{\sum_{j=1}^{8} BL(T_j).\frac{n_j}{N}}{\sum_{j=1}^{8} \dot{Q}_e(T_j, X(T_j)).\frac{n_j}{N}}$$

Where N is the total number of hours in the cooling season, $\dot{Q}_e$ is the electric power drawn by the unit, $\dot{Q}_e(T_j, X(T_j)).\frac{n_j}{N}$ is "the electrical energy consumed by the test unit during periods of the space cooling season when the outdoor temperature fell within the range represented by bin temperature T_j to the total number of hours in the cooling season (N), W" and $X(T_j)$ is the load ratio for the temperature in bin j.

In order to calculate the performance of the unit for each of the bins, the general principle is to derive the performance curves of the units from the performance values measured at a few test points. These performance curves give cooling capacity and electricity consumption as a function of outdoor air temperature for different AC capacity levels (either two capacity steps, or for the minimum or maximum speed of an inverter).

3.3.2 Specific Characteristics of Asian SEER Metrics

In the derivation of national load curves, the one climate condition used by Chinese, Japanese, and Korean standards differs from the one used by the US standard. In addition, the method these three countries use to compute the AC electricity consumption is simplified in order to decrease the number of required test points and thereby reduce the associated testing costs. To this end, several default assumptions are made to enable the AC performance at other design conditions to be modeled. In addition, while the US SEER only addresses the cooling mode, the principal Japanese metric addresses both the cooling and heating modes. In Japan, the metric reported to the consumer is the annual performance factor (APF), which is defined as the weighted average of the cooling seasonal performance factor (CSPF, an alternative name for the SEER used by the Chinese, Japanese and Korean test standards) and of the heating seasonal performance factor (HSPF, like the SEER but for the heating mode). The CSPF and HSPF are generally not reported directly to the consumer although they are measured and used to produce the APF. For cooling-only split ACs, the APF is equal to the CSPF, and then the calculation is simplified. However, most dwellings in Japan use reversible variable-speed drive (VSD) mini-split AC units as their primary heating means, and hence almost all ACs sold on the Japanese market are reversible. This means that to usefully benchmark the seasonal cooling performance requirements in Japan, it would be necessary to benchmark the APF value of reversible units and thus consider the heating mode as well. We will discuss later the practical limitations of this approach.

3.3.3 Specific Characteristics of the EU SEER Metric

The draft EU SEER test standard is similar to the US SEER test standard, except that it uses different climate conditions. In addition, the method used to compute the AC electricity consumption requires the use of a different number of test points. Lastly, in addition to accounting for power consumed during active operation for cooling, the draft European SEER also includes the impact of standby and other low power modes (such as the energy used to heat the crank case to separate liquid refrigerant from the lubricating oil). It is thus a slightly more comprehensive energy performance metric.

3.3.4 Comparison of the Number of Test Conditions for the SEER Metrics

Across the different SEER test standards, the number of test points (required or optional) varies depending on the calculation method applied and the permitted options. The number of testing points is summarized in Table 7 below.

Table 7: Number of Test Points (required and optional) in the Different SEER Test Standards Depending on the Capacity Control Characteristics of the AC under Test

US	Single Speed	Two Stages	VSD
Min	2	4	5
Max	4	6	7
China, Korea, Japan	**Single Speed**	**Two Stages**	**VSD**
CSPF	1	2	2
Europe	**Single Speed**	**Two Stages**	**VSD**
SEER	4	5	4

3.3.5 Differences in Permitted Test Tolerances

In the declared EER, every test standard has its own permitted tolerance which is used in the event of verification testing. Under a verification test, a unit is deemed to have an accurate rating if its manufacturer-declared energy performance is within the permitted tolerance of the independently-measured energy performance. The permitted tolerance introduces an extra layer of complexity when comparing declared EE ratings and EE policy settings across economies that apply different tolerances. Because of the commercial advantage of having better energy efficiency, there is a tendency for producers to declare their product performance to be as close to the highest value that is reasonably justifiable without legal basis for a challenge. As there is no systematic reason to believe that producers supplying one economy are any less able to manage their production tolerances (i.e., the degree to which there is a variation in the performance of each unit of the same product manufactured) than those supplying another, it is reasonable to take these tolerances into account when comparing efficiency levels across economies. The permitted tolerances in EER declarations are shown in Table 8. The same tolerances apply for the associated national SEER metrics.

Table 8: Maximum Permitted Tolerances in Declared EER Values in the Different Economies

	US	EU	China	Korea	Japan
Tolerances	0%	8%	10%	8%	10%

Depending on how well they know the performance of their unit, different manufacturers may declare performance closer to the tolerance limit. However, in principle, the average of all declarations should be above the indicated target by the same percentage X for every country, so that the difference in declared values should be, on average, the difference in the tolerances (100% + X% in the US, 92% + X% in Europe, and so on), where the first value chosen is 100% minus the permitted tolerance. Therefore, to take into account systematic differences in permitted tolerances across the five economies considered in the EER and SEER benchmarking analysis, the calculated value is simply corrected by the permitted tolerance of the specific economy, as shown in the case of Korea, where

Korea EER declared = Korea EER measured / 0.92.

3.4 Benchmarking Conversion Formulas

As the world's AC markets are dominated by non-ducted split-packaged units, called mini-splits in North America, these are the primary focus of the AC benchmarking efforts discussed in this summary report. These are far and away the most common type of residential ACs used around the world, and they are also in widespread use in non-residential buildings. In principle, the conversion functions are dependent on the means of capacity control used by the AC, such that AC units with fixed speed compressors are expected to behave quite differently from those that have compressors controlled with a VSD, also known as inverter units. Thus, the two cases are treated separately when developing the conversion formulas in the analysis presented below. The resulting EER and SEER conversion formulas developed within this study are then applied to benchmark the stringency of the existing MEPS programs in the selected economies (China, the EU, Japan, Korea, and the US) using SEER metrics to compare levels of ambition.

3.4.1 EER Conversion Formulas

A study by Henderson (2001), conducted within the rubric of a previous benchmarking project for Asia-Pacific Economic Cooperation (APEC), assessed EER test procedure differences. It showed that all of the economies under consideration within the current study are aligned with the ISO 5151 test conditions except for the US, which uses NAFTA test conditions. These conditions are very similar to the ISO 5151 test conditions except for a significant but modest variation in the indoor wet bulb temperature. However, Henderson demonstrated that it is viable to correct this variation by applying the following conversion formulas for the EER and cooling capacity (CC), respectively:

$$EER_{NAFTA} = EER_{T1} * 1.024 \quad \text{and} \quad CC_{NAFTA} = CC_{T1} * 1.032.$$

Where SI units are used[11] and T1 refers to the ISO 5151:1994 T1 test conditions. While applying this correction factor improves the comparability of EERs produced under the two principal sets of test conditions, the magnitude of the correction is actually very small (2.4%). There is a bigger effect from applying the tolerance corrections in line with the method described in Section 3.3.5.

These formulas enable conversion coefficients between the EER applied in the US and the ISO 5151 T1 EER to be computed.

Although these US to ISO EER conversion coefficients were established for central ACs sold on the US market using R22 refrigerant, the testing of split-packaged AC units using R410A refrigerant conducted within the current study produced results that are consistent with Henderson's formulation. Along with the lack of an obvious physical reason for believing that the conversion coefficients should be different for split-packaged units using R410A, we conclude that the EER conversions proposed by Henderson will be applicable to these units as well. As a result, we consider that US to ISO EER test results can be converted using the formula above while all other economies of interest for this study use EER metrics that are harmonized with the ISO 5151 EER metric.

[11] To convert from Btu/Wh to SI W/W values, the EER_{NAFTA} should be multiplied by 0.2931.

3.4.2 SEER Conversion Formulas for On-Off Mini-Split Units

This section summarizes the method used to convert between the various national SEER metrics for fixed-speed (on-off) mini-split units, and presents the associated conversion formulas for each economy considered in the study. More details on both are presented in the benchmarking component report.

The approach taken to derive these conversion formulas is partly based on theory, as embodied in the formulas specified in the national test procedures, and partly derived from the statistical analysis of product databases. Unfortunately, only limited information associated with the seasonal performance of single speed ACs was available from publicly accessible databases outside the US at the level of detail needed. However, while information from US databases is available at the level of detail needed for the conversion formula analysis for typical central ACs,[12] it does not indicate how the cooling capacity of the unit is controlled (i.e., whether it is an on-off or VSD mini-split). Nevertheless, due to the lack of information available elsewhere, the US data is used as the starting point for the present analysis.

For single speed units, there are two primary parameters that affect the US SEER value: the steepness of the slope of the increase in efficiency as a function of decreasing outdoor air temperature, and the drop in efficiency as a function of reducing loads. The former is characterized by two slopes that describe the variation in cooling capacity and electricity consumption as a function of the outdoor air temperature. For mini-splits, the average value of the slope is taken from the Asian SEER test standards[13] and has subsequently been confirmed by the testing conducted under this project. Within an outdoor temperature range from 29°C to 35°C, this formula projects an increase in EER of about 3% per degree Celsius of decrease in outdoor air temperature.

The impact of load on efficiency is characterized in all the SEER standards by the use of a degradation coefficient (Cd). The larger this coefficient is, the lower the resulting SEER is at part loading. A default value of 0.25 is used in all the SEER performance requirements. However, while the Asian test procedures use this as a fixed value that cannot be challenged, the US and EU standards allow additional measurements to be made to establish the actual magnitude of this coefficient for any given product. This provides manufacturers with an opportunity to report a lower Cd value if their product merits it.

In the case of the Asian standards, both the variation in EER with outdoor air temperature and the Cd coefficient are fixed, making the SEER directly proportional to the EER. However, in the US and Europe, there are more degrees of freedom because these parameters may vary. Consequently, it is necessary to estimate the likely variation induced by the supplementary degrees of freedom permitted in the US and EU standards.

The sensitivity of the EER as a function of the outdoor air temperature used in the conversion analysis is derived from US data, which shows that the value lies within the following limits:

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12 Within the scope of US standard product definitions, these include non-ducted single-packaged split AC units or mini-splits.

13 The Chinese, Japanese, and Korean standards use the same formula for this slope.

-1.9% EER / °C and -3.9% EER / °C

The same database is then used to derive ratios of the SEER to the EER and to analyze Cd values. The Cd values are found to lie within the following limits:

$0.04 \leq Cd \leq 0.25$

Additional parameters are also considered to reflect differences in the way ducted units are treated in the US versus elsewhere, as well as to take account of the inclusion of the energy use associated with low power modes in the EU. These analyses lead us to conclude that the default single speed model defined in the Asian test standards is acceptable for use as a model for converting SEERs to derive average conversion values. The additional unknown elements that need to be taken into account in the derivation of the US and EU SEERs are managed through the application of an additional, broader uncertainty interval (i.e., through a lower level of confidence in the conversion formula results). The recommended conversion formulas emerging from this process are presented in Table 9 for non-ducted AC units (typical mini-splits).

The SEER conversion formulas cited in this table should be applied using the formula Y = α * X, where α_min, α_ave and α_max are respectively the minimum, average, and maximum conversion coefficients that could be applied. It should be noted that these conversion coefficients incorporate the correction factors needed to take account of differences in the permitted tolerances, using the method previously described in Section 3.3.5.

Table 9: SEER Conversion Coefficients for Non-Ducted Single Speed Mini-Splits for China, the EU, Japan, Korea and the US to be Applied Using the Formula SEER Y = α * SEER X (units are in W/W)

To SEER Y	From SEER X	α_min	α_ave	α_max
Korea	China	N/A	99%	N/A
Japan CSPF	China	N/A	104%	N/A
US SEER Non-Ducted	China	91%	99%	115%
EU SEER Non-Ducted	China	86%	112%	128%
China	Korea	N/A	101%	N/A
Japan CSPF	Korea	N/A	105%	N/A
US SEER Non-Ducted	Korea	92%	100%	116%
EU SEER Non-Ducted	Korea	87%	113%	129%
China	Japan CSPF	N/A	96%	N/A
Korea	Japan CSPF	N/A	95%	N/A
US SEER Non-Ducted	Japan CSPF	87%	95%	111%
EU SEER Non-Ducted	Japan CSPF	82%	107%	123%
Korea	US SEER Non-Ducted	86%	100%	109%
Japan CSPF	US SEER Non-Ducted	90%	105%	114%
China	US SEER Non-Ducted	87%	101%	110%
EU SEER Non-Ducted	US SEER Non-Ducted	75%	113%	141%
Korea	EU SEER Non-Ducted	77%	89%	116%
Japan CSPF	EU SEER Non-Ducted	81%	93%	121%
US SEER Non-Ducted	EU SEER Non-Ducted	71%	89%	134%
China	EU SEER Non-Ducted	78%	90%	117%

In the case of Japan, the CSPF (the equivalent of the SEER) is presented here, as opposed to the APF, as there was no convincing data available that permitted the computation of a default HSPF value for single speed units; the data that was available showed large variations across different units.

Ideally, these conversion coefficients would be further refined in the future using more detailed and more statistically representative energy consumption and product parameter information for each product category.

3.4.3 SEER Conversion Formulas for Variable-Speed/Frequency Mini-Split Units

This section summarizes the method used to convert between the various national SEER metrics for variable-speed mini-split units, and presents the associated conversion formulas for each economy considered in the study. More details on both are presented in the benchmarking component report.

In order to compute the SEERs according to different test procedures for the same unit, it is necessary to compute the part load efficiency and reduced outdoor temperature efficiency for the load curves of the different metrics. As the only public information available in Japan is the APF (which is an annualized compound of the cooling and heating seasonal performance factors), it is not possible to make use of the publicly available performance data. The same issue occurs in the US and China where only SEER, EER, and cooling capacity data are available. In the case of the EU, the SEER values that will be applicable in the near future have not yet been tested and reported. Consequently, we need to base the analysis on other sources of data.

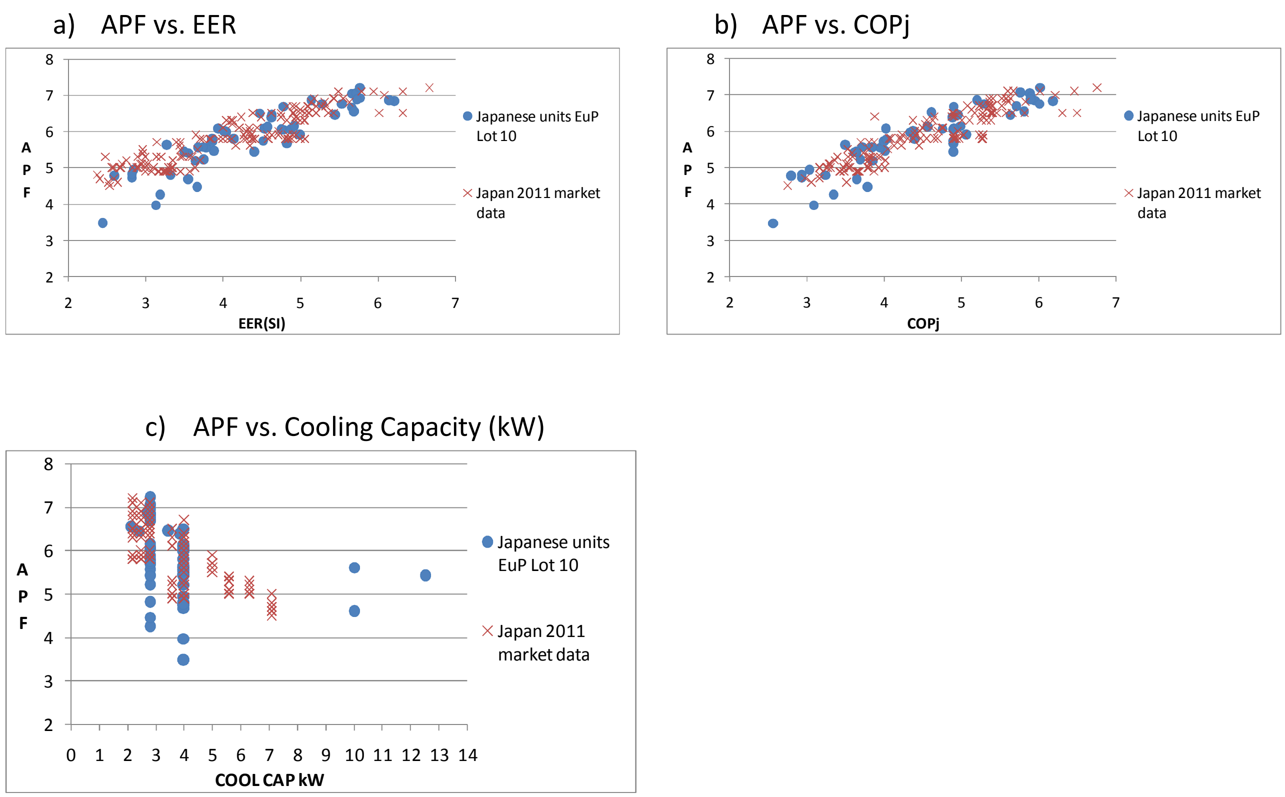
SEER Conversions for Non-Ducted Units

Within the scope of the EU Ecodesign Lot 10 Preparatory Study for DG Energy (EuP Lot 10 2009), Japanese manufacturers supplying the European market sent anonymous information regarding the average and best non-ducted mini-split VSD products available on the Japanese market from 1996 to 2006. These products had a cooling capacity rated between 2.8 and 4 kW, although the dataset also includes some larger single-split units with a rated capacity between 10 and 12.5 kW. In all cases, data for each of the five testing points required to compute the CSPF and the HSPF, and thus the APF, were made available. The current analysis makes use of this database of 52 models to characterize and represent VSD mini-split products.

The cooling mode information available in the database enables the direct computation of the Chinese SEER, the Korean CSPF, and the Japanese CSPF. The cooling mode performance model defined in the JRA4046 standard (which is also used in the Chinese and Korean standards) is presented below. It is considered to have two capacity stages: the rated capacity stage and the intermediate cooling capacity stage, with their respective cooling and electric power exhibiting the same variation with outdoor air temperature. In order to compute the APF, it is necessary to compute the HSPF in addition to the CSPF. All the required information is available for the 52 models in the database. In order to compute the US and EU SEERs, a certain number of hypotheses have to be made as these metrics require more testing points than are available under the JRA4046 test standard. The same hypotheses were used as are set out in the theoretical models specified in the Japanese and Chinese test procedures, although in the case of the US SEER, the Cd coefficient was assumed to be 0.1 in line with typical reported levels. In this first step, the auxiliary losses (standby power and crankcase heater energy use) are not modeled; consequently, the results obtained are only applicable to the EU $SEER_{on}$, which is the metric obtained when low power modes are not taken into account and not to the EU SEER as a whole which includes standby power and crankcase heater consumption.

The resulting conversion coefficients were then checked against the Ecodesign EuP Lot 10 model database, and an additional statistically derived correction factor was determined and applied in order to derive results that were applicable to the units presently available for sale.[14] The part load performance in the cooling and heating modes for all the models is adjusted by the same regression so that both distributions fit better, as shown in Figure 6.

Figure 6: Comparison of the EuP Lot 10 Database with 2011 Japanese Market Data, after EuP Lot 10 Correction

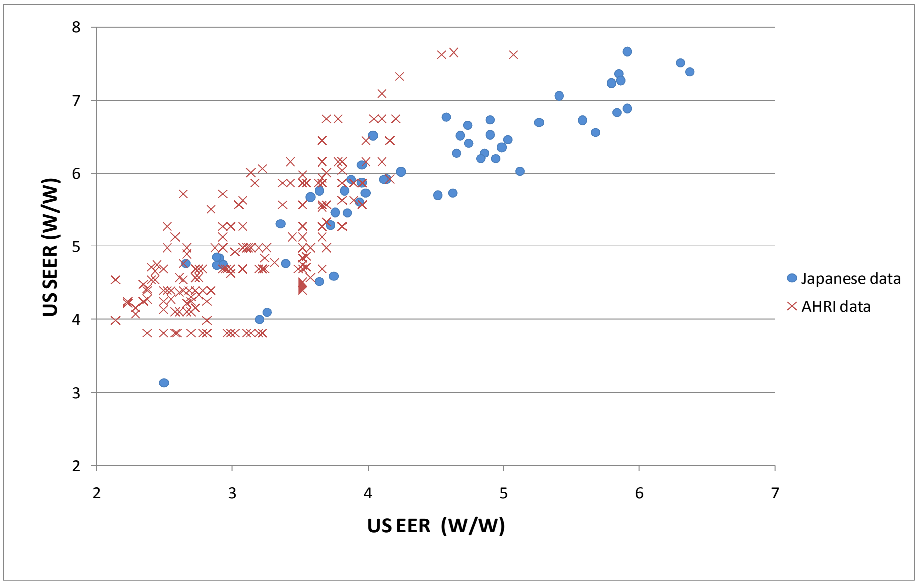


The products were also compared to the AHRI database of VSD mini-split heat pump products for this analysis. It was filtered to only include market active products (as of February 2011) within the HRCU-A-CB-O category.[15] This amounted to 306 products, as shown in Figure 7 below (US SEER (SI) vs. US EER (SI)).

[14] A database of several hundred Japanese products available for sale in 2011 was assembled within the current benchmarking study.

[15] HRCU-A-CB-O: split system: heat pump with remote outdoor unit, air source, free delivery.

Figure 7: Comparison of the EuP Lot 10 Database with 2011 US AHRI Data



Despite the fact that the cooling capacity coverage of products in our database mainly addresses smaller capacity units, the SEER range covers most of the products in the AHRI database. However, by comparison with the Japanese market, it appears that the US products can reach SEER values that are almost as large but without such high EER values at standard rating conditions. This is almost certainly driven in part by the dual legislative requirements in Japan, which set Top Runner performance requirements for both the EER and the APF.

The corrections for tolerances have been previously described in Section 3.3.5. It is to be noted that the models analyzed in the EuP Lot 10 database are compatible with products sold on the Japanese market, for which the declared performance is permitted to be only 90% of their independently validated value (due to the 10% tolerance allowed). Hence, the SEER conversion coefficients have been corrected to take account of this issue. For example, the US SEER equivalent to any given Japanese APF is assumed to be 10% lower than would be the case if converting the SEER without taking into account tolerances, due to the fact that tolerances are not permitted when validating US SEER declarations.

SEER Conversions for Ducted Units

Our analysis of ducted units is based on the very limited information available, which suggests that on average the additional correction needed to take account of the static pressure of the fans used in ducted systems lies between 1% and 4% of the rated input power (at T1 conditions), with 2.5% being the average value. Applying this correction decreases the US SEER by 7.5% +/- 4% compared to non-ducted units.

Resulting SEER Conversions

The final SEER conversion coefficients applicable to VSD AC units are presented in Table 10. These constitute our best estimates for the SEER conversions after considering all corrections previously described and including compensation for the differences in the permitted tolerances.

They should be applied using the linear formula Y = Cte + slope * X, where X and Y are the SEERs mentioned in the table, and Cte is the constant given in the same table.

Statistical information concerning the quality of the regressions is also reported. The statistical spread in the predictive values is derived from the dispersion in the database of AC models used to compute the regressions. It should be noted that any potential variations around the average correction factors used to take account of standby power and crankcase heater consumption considered in the European SEER are not included in the deviation estimates; data was not available on these parameters. Furthermore, for any product with characteristics significantly different from the models considered in the database, such as US VSD mini-splits with low rated EER but high SEER, caution is recommended with the use of these conversion coefficients.

For products similar to the VSD mini-splits found on the Asian markets, it is believed that the conversion coefficients are robust, within the deviations indicated in the table below.

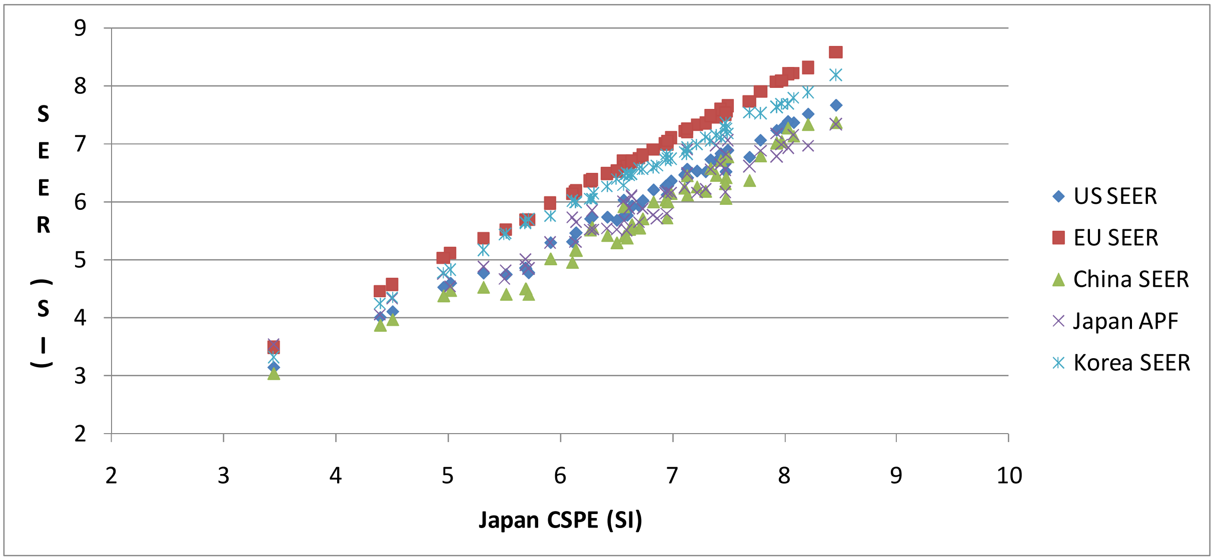
For ducted units and EU SEER values, we recommend that potential users check the low power mode value of a given model and make adequate corrections to the indicated value in order to improve conversion estimates. See corresponding details in the benchmarking component report.

Table 10: SEER Conversion Coefficients for Non-Ducted VSD Mini-Splits

Y	X	Slope	Cte	R2	Std dev	Dev min	Quartile 25%	Median	Quartile 75%	Dev max
Japan APF	US SEER	0.865	0.733	0.952	0.191	-7.1%	-1.7%	0.2%	2.7%	6.7%
EU SEER	US SEER	1.080	0.286	0.992	0.095	-4.5%	-0.7%	0.2%	0.9%	5.1%
China SEER	US SEER	0.998	-0.258	0.991	0.094	-5.2%	-1.1%	0.2%	1.4%	3.2%
Korea SEER	US SEER	1.014	0.559	0.967	0.184	-7.5%	-1.7%	0.3%	1.8%	10.1%
US SEER	Japan APF	1.101	-0.521	0.952	0.216	-7.0%	-2.4%	-0.2%	2.7%	9.0%
EU SEER	Japan APF	1.187	-0.265	0.942	0.259	-6.0%	-2.8%	-0.3%	2.7%	12.9%
China SEER	Japan APF	1.102	-0.798	0.949	0.223	-7.8%	-2.0%	-0.1%	2.5%	11.5%
Korea SEER	Japan APF	1.111	0.062	0.912	0.301	-8.2%	-3.3%	-0.1%	3.2%	17.9%
Japan APF	EU SEER	0.793	0.556	0.942	0.211	-8.4%	-2.6%	0.5%	2.7%	5.8%
US SEER	EU SEER	0.919	-0.216	0.992	0.088	-4.5%	-1.0%	-0.2%	0.7%	5.2%
China SEER	EU SEER	0.910	-0.426	0.968	0.176	-9.1%	-2.4%	0.0%	2.1%	8.3%
Korea SEER	EU SEER	0.946	0.240	0.991	0.097	-3.4%	-1.0%	-0.1%	0.9%	4.5%
US SEER	China SEER	0.993	0.310	0.991	0.094	-3.1%	-1.3%	-0.2%	0.9%	5.8%
EU SEER	China SEER	1.064	0.668	0.968	0.191	-6.2%	-2.1%	-0.1%	2.0%	11.3%
Japan APF	China SEER	0.861	0.987	0.949	0.197	-8.4%	-1.9%	0.2%	1.8%	7.1%
Korea SEER	China SEER	0.989	0.969	0.927	0.275	-8.8%	-3.0%	0.0%	2.6%	16.9%
US SEER	Korea SEER	0.954	-0.338	0.967	0.178	-7.5%	-2.0%	-0.5%	1.7%	9.5%
EU SEER	Korea SEER	1.047	-0.189	0.991	0.102	-3.7%	-1.1%	0.0%	1.0%	3.8%
Japan APF	Korea SEER	0.822	0.466	0.912	0.259	-10.1%	-3.1%	-0.2%	3.6%	8.3%
China SEER	Korea SEER	0.937	-0.491	0.927	0.267	-11.2%	-3.2%	-0.3%	3.1%	13.1%
Japan CSPF	China SEER	1.032	0.773	0.956	0.220	-7.1%	-2.4%	0.0%	2.1%	13.3%
China SEER	Japan CSPF	0.926	-0.464	0.956	0.208	-10.1%	-2.4%	-0.2%	2.5%	9.9%
Japan CSPF	US SEER	1.051	0.384	0.986	0.126	-5.6%	-1.0%	0.3%	1.3%	6.8%
US SEER	Japan CSPF	0.938	-0.273	0.986	0.119	-5.7%	-1.2%	-0.4%	1.0%	6.7%
Japan CSPF	EU SEER	0.975	0.088	0.999	0.037	-1.2%	-0.4%	-0.1%	0.4%	1.6%
EU SEER	Japan CSPF	1.024	-0.081	0.999	0.038	-1.5%	-0.4%	0.1%	0.4%	1.3%
Japan CSPF	Korea SEER	1.025	-0.119	0.996	0.065	-2.4%	-0.7%	-0.1%	0.6%	2.5%
Korea SEER	Japan CSPF	0.972	0.141	0.996	0.063	-2.3%	-0.6%	0.1%	0.6%	2.7%

Figure 8 below shows the various SEERs (or APFs) compared to the Japanese CSPF computed from the Japanese model database using the conversion formulas from Table 8 above.

Figure 8: SEERs for the US, EU, Korea, Japan, and China Metrics, Computed for the Database of Japanese Models



It is interesting to note that:

- The maximum APF value is 7.3, which is close to the best product on the Japanese market (APF 7.2, see Annex 1 of the benchmarking component report);
- The maximum US SEER value is about 7.6 (or about 26 in Btu/Wh), which is indeed the best product available on the US market;
- From the TopTen website (www.top10.cn), where it is possible to find the best products sold on the Chinese market, the best product available has a China SEER of 7.33 (in the category VSD mini-splits with a rated cooling power below 2.8 kW), which also matches the information in the graph.

These findings confirm that although the SEER metrics may differ, the highest performing VSD mini-split products sold in each market have very similar efficiency levels when the conversion algorithms developed in this study are applied.

3.5 Application of the Conversion Formulas to Compare the Stringency of Energy Efficiency Policy Settings

The conversion coefficients developed in the preceding sections are applied in this section to compare the ambition of AC policy settings across the different economies on an equal basis. The EE thresholds in the policy settings vary as a function of a number of product parameters, including:

- Cooling and heating capacity;
- Whether the product is ducted or non-ducted;
- In some cases, whether the product is a fixed-speed or variable-speed product;

- Other economy-specific product features including whether it is dimension constrained or not (Japan) and the total equivalent global warming impact of the refrigerant used (EU).

The MEPS requirements and associated parameters are described in the benchmarking component report. Comparisons of the MEPS requirements converted to each common SEER metric are reported in Table 11 and Table 12 for fixed-speed and VSD (inverter) mini-splits, respectively. Each row in the table shows what the MEPS indicated in each column would be were the requirements to be tested and rated under the test procedure specified in the row title. The same data is shown graphically in Figure 9 and Figure 10.

Table 11: Comparable SEER/APF MEPS Requirements by Economy under Each National Test Procedure, for Fixed-Speed, Non-Ducted Mini-Split AC Units (W/W)

	US	EU						China	Korea	Japan	
	2006	2013	2013	2014	2014	2014	2014	2008	2004	2012	2012
	< 19 kW	< 12 kW, GWP<150	< 12 kW, GWP>150	< 6 kW, GWP<150	< 6 kW, GWP>150	6 – 12 kW, GWP<150	6 – 12 kW, GWP>150	Fixed-Speed < 4.5 kW	Fixed-Speed < 4 kW	(free-dimension) < 3.2 kW	6 – 28 kW, wall
To US Norm	3.80	2.88	3.20	3.68	4.09	3.44	3.82	3.17	3.37	7.13	4.81
To Japan CSPF Norm	3.98	3.02	3.35	3.85	4.28	3.60	4.00	3.33	3.54	7.47	5.05
To China Norm	3.83	2.90	3.22	3.71	4.12	3.47	3.85	3.20	3.40	7.19	4.86
To Korea Norm	3.80	2.87	3.19	3.67	4.08	3.43	3.81	3.17	3.37	7.12	4.81
To EU Norm	4.28	3.24	3.60	4.14	4.60	3.87	4.30	3.57	3.80	8.02	5.42
To Japan APF Norm	3.58	2.74	3.03	3.47	3.84	3.25	3.59	3.01	3.19	6.60	4.50

In the table above, the same relationship between the CSPF and the APF is used for VSD mini-split units.

Figure 9: Comparison of SEER Levels for MEPS, for Fixed-Speed, Non-Ducted, Mini-Split AC Units for China, the EU, Japan, Korea, and the US

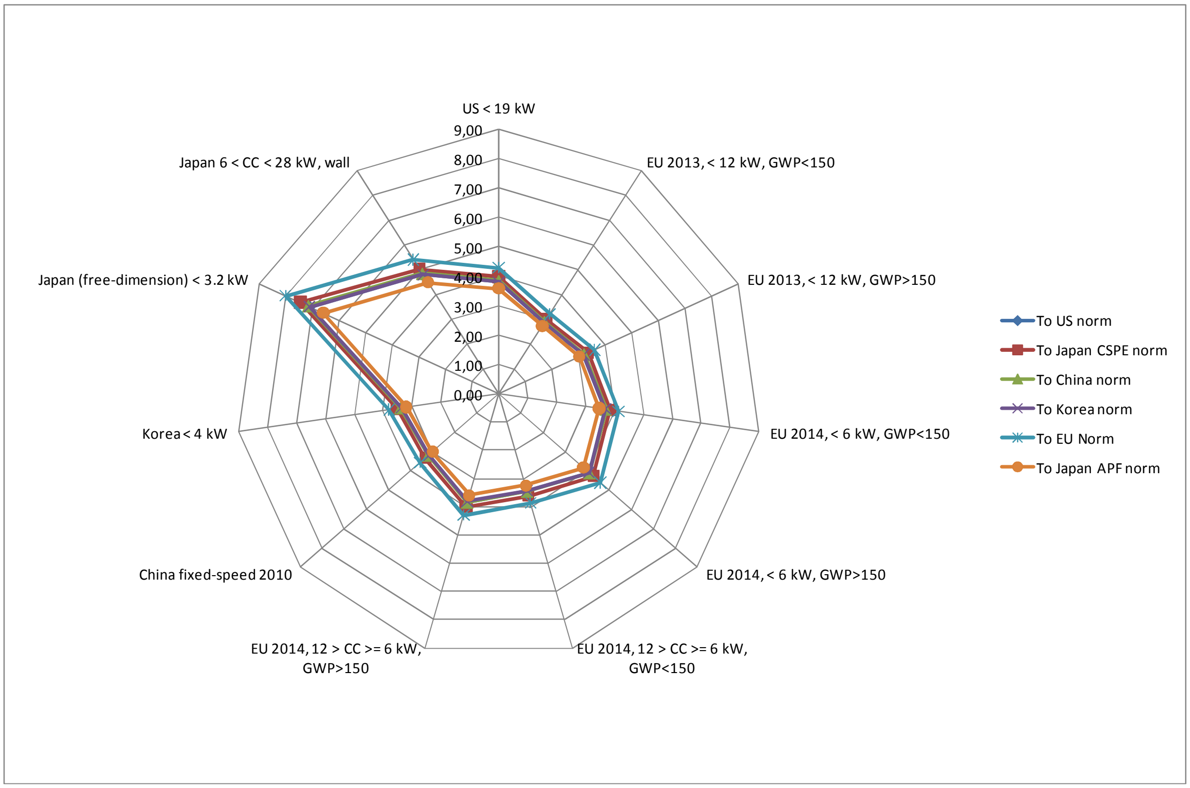
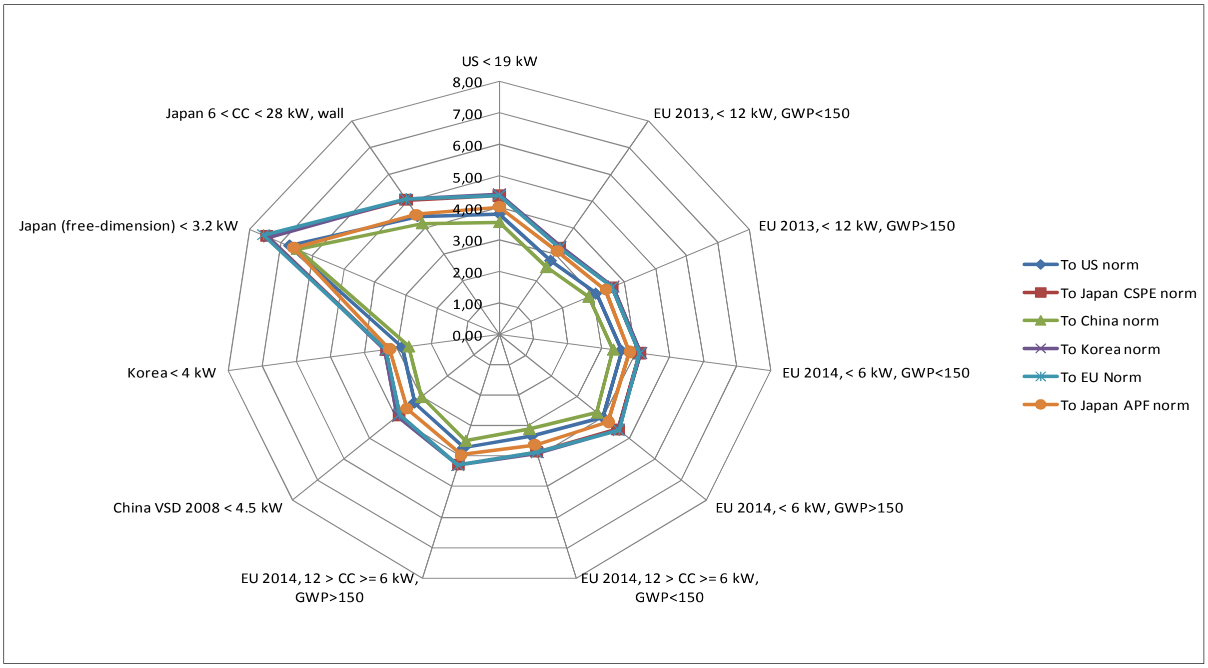


Table 12: Comparable MEPS Requirements by Economy under Each National Test Procedure, for Variable-Speed, Non-Ducted, Mini-Split AC Units for China, the EU, Japan, Korea and the US

	US	EU						China	Korea	Japan	
	2006	2013	2013	2014	2014	2014	2014	2008	2004	2012	2012
	< 19 kW	< 12 kW, GWP<150	< 12 kW, GWP>150	< 6 kW, GWP<150	< 6 kW, GWP>150	6 – 12 kW, GWP<150	6 – 12 kW, GWP>150	VSD < 4.5 kW	VSD < 4 kW	(free-dimension) < 3.2 kW	6 – 28 kW, wall
To US Norm	3.80	2.76	3.09	3.59	4.01	3.34	3.74	3.29	2.88	6.75	4.43
To Japan CSPF Norm	4.38	3.25	3.60	4.12	4.57	3.86	4.28	3.87	3.34	7.47	5.05
To China Norm	3.53	2.52	2.85	3.34	3.76	3.10	3.49	3.00	2.67	6.48	4.16
To Korea Norm	4.41	3.31	3.65	4.16	4.59	3.90	4.31	3.94	3.37	7.39	5.06
To EU Norm	4.39	3.24	3.60	4.14	4.60	3.87	4.30	3.86	3.34	7.57	5.08
To Japan APF Norm	4.02	3.13	3.41	3.84	4.20	3.62	3.97	3.57	3.24	6.60	4.50

Figure 10: Comparison of SEER Levels for MEPS, for Variable-Speed, Non-Ducted, Mini-Split AC Units for China, the EU, Japan, Korea, and the US



4 Testing

The testing component of this study has been designed to achieve two main goals:

- Establish the differences among the test procedures used in selected economies for measuring the capacity and the efficiency of ACs in cooling mode. This study also estimates the uncertainties of measurement that can be expected for each test method as functions of the test conditions and type of AC considered. In the cases of Australia and Taiwan, this comparison has not been performed due to limited information about the procedures used. International Organization for Standardization (ISO) standards have been covered, as they are often used as working document in the development of test procedures in most economies.

- Test a limited sample of RACs in order to check, as far as possible, the conversion formulas developed as part of the benchmarking component to compare the rating of a given AC across several economies. Four samples have been selected to cover the most representative appliances included in the scope of this study.

This section describes and compares the test procedures covered by the study. Additionally, it presents and analyzes the results of testing activities performed on four AC units (fixed- and variable-capacity non-ducted units as well as fixed- and variable-capacity ducted units).

4.1 Test Procedures Comparison

Test procedures generally specify how to measure the EER and cooling capacity using stipulated test conditions. Seasonal performance test conditions and calculations along with EE classes and requirements are generally described in other documents (e.g., specific standards or regulations), which serve as reference to the test procedure standards. However, this is not always the case as some economies, like the US and China, have a unique document describing test procedures and seasonal efficiency calculations. This testing component deals with test procedures only; the comparison of seasonal EE calculations is covered in the benchmarking component.

It was not possible to retrieve the test procedures for all economies covered by the study. Consequently, the testing component covers only economies for which it has been possible to access complete and up-to-date documents. However, the economies studied are representative of the worldwide situation regarding test procedures as they include major economies such as the US, the EU, Japan, China, Korea, and India.

In addition, the ISO 5151 and ISO 13253 standards have been covered as many economies base their own test procedures on these two international standards.

The study focused on the calorimeter room method and the indoor air enthalpy method, which are most widely used for small and medium-sized ACs. Other methods like the compressor calibration method, the outdoor air enthalpy method, and the refrigerant enthalpy method are not normally used for the type of ACs targeted under this study, except as secondary test methods.

This section first presents the differences found between test procedures used in each selected economy. It also covers differences that can be found when testing the same AC in different laboratories (mainly due to installation settings not fully described by the standards). Finally, this section analyzes the measurement tolerances and uncertainties declared by the testing laboratory. The test procedures of each economy covered in the framework of the study are described in detail in the testing component report.

4.1.1 Comparison between Test Procedures

There are two main testing methods to measure the energy performance of ACs:

- Calorimeter room method: An energy balance is maintained in the indoor side room, where the sum of the energies given to the room are equal to the total cooling capacity of the AC when the air dry and wet bulb temperatures have remained constant for a sufficient time. The calorimeter can be either of the calibrated type (single wall separating the rooms from the outside) or of the balanced ambient type (two walls separating the room from the outside, with air between them maintained at the same dry bulb temperature as inside the room). The balanced ambient type is much more accurate than the calibrated type as heat losses through the walls are almost zero.

- Indoor air enthalpy method: The air enthalpy is measured at the inlet and the outlet of the indoor section of the AC, as well as the mass air flow through the indoor section. The air flow multiplied by the enthalpy variation gives the total cooling capacity.

The advantages and disadvantages of each method are given in Table 13.

Table 13: Differences between the Two Main Measurement Methods

Measurement Method	Advantages	Disadvantages
Calorimeter Room	High accuracy (up to 5% for the EER) Low risk of systematic error Easier to simulate a given part load ratio	Very expensive facilities Higher testing time Higher cost of maintenance (high number of measuring devices) → Higher cost of the tests
Indoor Air Enthalpy	Less expensive laboratory Shorter testing time → Lower cost of the tests	Lower accuracy (up to 10% for the EER) Higher risk of error (measurements of the air flow and of the air humidity at the outlet)

In practice, when the calorimeter method is not a mandatory requirement, the air enthalpy method is more often selected for initial cost reduction and productivity improvement – the cost of the testing facilities is lower and the time spent on tests is shorter.

The possible effect of the use of the calorimeter test method compared to the impact of the indoor air enthalpy method on the resulting EER is further discussed in Section 4.1.3 of this report.

After reviewing the different test procedures for the cooling mode, the immediate conclusion is that the calculations described in the different standards for each test method to calculate the total cooling capacity are identical or equivalent. The cooling capacity is calculated using the energy balance for the calorimeter room method or the air flow measurement and air enthalpy for the indoor air enthalpy method. The test sequence is almost the same for each method, including stabilization time and the data acquisition period.

Several differences in the installation of the AC, the test procedure, or the test conditions may lead to discrepancies in the results relative to cooling capacity or the EER measured for the same AC sample.

The main differences found between the test procedures are summarized in Table 14, Table 15, and Table 16 below.

Table 14: Main Differences Between Test Procedures: Test Conditions, Installation, Calculations

Economy	Standards Rating Conditions Outdoor Dry Bulb (wet bulb)[1]/indoor Dry Bulb (wet bulb) (^{0}C)	Refrigerant Piping Length (m)	Fan Motor Correction (ducted units)
US	35/26.7 (19.4)	7.6	NO
EU 2011	35/27 (19)	5	YES
Japan	35/27 (19)	5 up to 6 kW 7.5 over 6 kW	YES
China	35/27 (19)	7.5	YES
Korea	35/27 (19)	5	NO
India	35 (30)/27 (19)	5	NO
ISO 1994/1995	35/27 (19)	7.5	YES[2]
ISO 2010/2011	35/27 (19)	5 to 7.5	NO[3]

[1] If not given, the outdoor humidity has not been controlled.

[2] The cooling capacity is modified only if the correction is greater than the specified uncertainty of measurement.

[3] No correction is done for a unit with integrated fan. For units without integrated fan, an estimated fan power for equipment without an indoor fan (pfan) is used.

Table 15: Main Differences Between Test Procedures: Uncertainties of Individual Measurements

Economy	Dry Bulb Temperature	Wet Bulb Temperature	Air Volume Flow	Static Pressure Difference	Electrical Inputs
US	± 0.1°C	± 0.1°C	±5%	± 2.5 Pa	± 1.0%
EU 2011	± 0.2°C	± 0.4°C	±5%	± 5 Pa / ± 5%	± 1.0%
Japan	± 0.2°C	± 0.2°C	± 5%	± 5 Pa / ± 5%	± 0.5%
China	± 0.2°C	± 0.2°C	+ 5%	± 5 Pa / ± 5%	± 0.5%
Korea	± 0.1°C	± 0.1°C	N/A	± 2 Pa	± 0.5%
India	± 0.1°C	± 0.1°C	N/A	± 1 Pa	± 0.5%
ISO 1994/1995	± 0.2°C	± 0.2°C	± 5%	± 5 Pa / ± 5%	± 0.5%
ISO 2010/2011	± 0.2°C	± 0.2°C	± 5%	± 5 Pa / ± 5%	± 0.5%

Table 16: Main Differences Between Test Procedures: Variation Allowed for Test Readings from Specified Test Conditions (variations of arithmetical mean values/maximum variation of individual readings)

Economy	Indoor Dry Bulb Temperature	Indoor Wet Bulb Temperature	Outdoor Dry Bulb Temperature	Outdoor Wet Bulb Temperature	Air Volume Flow	Static Pressure Difference	Voltage
US	± 0.3°C / ± 1.0°C	± 0.2°C / ± 0.5°C	± 0.3°C / ± 1.0°C	± 0.2°C / ± 0.5°C	N/A	N/A	± 2%
EU 2011	± 0.3°C / ± 1.0°C	± 0.3°C / ± 1.0°C	± 0.3°C / ± 1.0°C	± 0.3°C / ± 1.0°C	± 5% / ± 10%	- / ±10 Pa	± 4% / ± 4%
Japan	± 0.3°C / ± 1.0°C	± 0.2°C / ± 0.5°C	± 0.3°C / ± 1.0°C	± 0.2°C / ± 0.5°C	± 5% / ± 10%	± 5 Pa / ±10 Pa	± 1% / ± 2%
China	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	± 5% / ± 10%	± 5 Pa / ±10 Pa	± 1% / ± 2%
Korea	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	N/A	± 10 Pa / or ±10 Pa	± 2%
India	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	N/A	N/A	± 2%
ISO 1994/1995	± 0.3°C / ± 1.0°C	± 0.2°C / ± 0.5°C	± 0.3°C / ± 1.0°C	± 0.2°C / ± 0.5°C	± 5% / ± 10%	± 5 Pa / ±10 Pa	± 1% / ± 2%
ISO 2010/2011	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	± 0.3°C / ± 0.5°C	± 0.2°C / ± 0.3°C	± 5% / ± 10%	± 5 Pa / ± 5 Pa	± 1% / ± 2%

Differences in Temperature Conditions

Small variations in the outdoor and indoor air temperature conditions give differences in the results. The effects of these variations are dealt with in the benchmarking component report.

Refrigerant Piping Length

Depending upon the economy and sometimes on the type of AC, the length of the refrigerant piping may be between 5 m and 7.5 m. There is not enough available data to give an evaluation of the effect of this difference of length, which is due to the extra pressure drop in the piping and sometimes also to the additional refrigerant charge required by the manufacturer. Some manufacturers have provided estimates of the effect, proposing that the EER could be 1% to 3% less when using 7.5 m instead of 5 m.

Fan Motor Correction for Ducted Units

In some economies (see Table 14 above), a correction is performed to enable a comparison between ducted units with and without integral fan. The correction is done on the effective power input, with a fraction of the input of the fan motor excluded from (for integral fans) or included in (for units without fans) the total power absorbed by the unit.

This fraction is expressed in watts as: $\frac{q \times \Delta p_e}{\eta}$ where:

η is 0.3 by convention;

Δpe is the measured available external static pressure difference, expressed in pascal;

q is the nominal air flow rate, expressed in cubic meters per second.

For a ducted indoor unit, the same power is also included in (for integral fans) or excluded from (for indoor units without fans) the total cooling capacity in most of the economies.

The correction can vary between a few watts for small ACs and several hundred watts for large appliances. It is likely to reach differences ranging from 1% to 5% for the EER at full load ratio.

The difference can be much greater for low part load ratios, such as with the EU 21% part load ratio, where the fan correction for a ducted unit can lead to a difference of more than 10% between EER results (calculated with or without the correction).

For the effective power input and the EER, the correction is much greater when the outdoor unit is also ducted.

For ducted units, the fan correction is by far the greatest systematic source of differences between economies for the EER measurement. This suggests that harmonization of test procedures between economies for the fan correction will be beneficial to make comparison between efficiency metrics more accurate.

Uncertainty of the Individual Measurements

Table 15 presents a comparison of the requirements for the main measurement devices. Although some differences appear between the different economies, and given that some requirements are unlikely to be fulfilled (e.g., ± 0.1ºC for the measurement of the wet bulb temperature), the differences in uncertainties of measurement for the individual readings are not very important and do not appear as a great source of differences among the economies.

Allowed Variations from Test Conditions

Table 16 presents a comparison of the requirements for allowed variation in the individual and average values of the readings for different parameters measured.

For temperature conditions, some differences appear but they are relatively small and modern laboratories are able to meet the most stringent requirements in almost all cases. Therefore, it is probably not a source of large differences in the resulting EER.

One notable difference is the larger tolerance for voltage in the case of the EU. There is no data available to estimate the possible effect of a variation of ± 4% in voltage. In any case, it would not be a systematic source of difference with other test procedures.

4.1.2 Other Possible Sources of Differences

Some details with respect to the installation of AC samples in the testing set-up are not covered or are not described in sufficient detail by the test procedures. These can be a source of differences among laboratories, and sometimes among economies, where these relate to the use of different test methods required in each case.

This may apply to non-ducted ACs when tested using the calorimeter room method or the air enthalpy method.

Using the calorimeter method, it is easy to set the maximum air flow rate for the indoor unit. This is not so easy for the air enthalpy method, where a discharge plenum has to be installed at the air outlet of the unit, between the unit and the air flow measuring apparatus. A static pressure of zero pascal has to be maintained in this plenum.

There is a high risk involved when modifying the normal air flow of the unit, first due to the presence of the plenum itself, and second by setting a static pressure slightly different from zero pascal due to the uncertainty of the measurement and control loop to maintain this value (normally ± 5 Pa). In addition, the presence of the plenum can make the adjustment of the louvers difficult at the air outlet of the unit.

This possible modification of the indoor air flow rate is greater for indoor units with several air outlets (cassettes, some wall or console types) due to the complex shape of the discharge plenum.

The changes in the normal air flow of the unit caused by the plenum can alter the performance of the unit in ways that are difficult to predict, thereby introducing additional measurement uncertainties when testing with the air enthalpy method.

The effect of this possible difference on the EER is not systematic and cannot be quantified. However, it is important to keep this effect in mind when analyzing test results of equipment with a complex air flow.

4.1.3 Uncertainty of Measurement of the EER

Each test method has a maximum measurement uncertainty required by the corresponding testing standard. This maximum uncertainty applies to the total cooling capacity measurement and has a value of 5% for the calorimeter room method and a value of 10% for the indoor air enthalpy method. These values can also be applied almost directly for the determination of uncertainty of the EER measurement, as the measurement of the electrical input is normally performed with a very small uncertainty. Results of round robin tests concerning both methods confirm these maximum uncertainties of measurement.

Most of the selected economies require testing at part load conditions. For small AC products, the cooling capacities can be very low, with the most difficult case probably being the 21% part load ratio prescribed in the EU's prEN 14825. It is generally recognized that, for the measurement of a product with a nominal cooling capacity of less than 2 kW, the measurement uncertainty increases very quickly as the part load cooling capacity decreases. Furthermore, it is almost impossible to realize measurement of products of less than 1.5 kW of capacity with a reasonable uncertainty. This applies to all test methods. While this is not a systematic source of possible differences in the measurement of the EER in different economies, it must be considered when analyzing test results or historical data.

4.2 Equipment Testing

4.2.1 Choice of Samples

The samples and tests to be performed have been chosen to provide real data in order to check, as far as possible, the conversion formulas proposed by the benchmarking component of this study.

This study mainly focuses on small domestic AC products. In accordance with the benchmarking objective, two kinds of RACs have been selected that together represent the majority of models sold worldwide:

- Wall-mounted non-ducted split ACs from 2.0 kW to 4.0 kW; and
- Split or packaged ducted ACs from 8.0 kW to 12.0 kW.

Each type of appliance can have a fixed-speed or an inverter controlled compressor.

Fixed-capacity ACs are still widely sold in many of the economies in this study. On the other hand, ACs with inverter driven compressors have been gaining market share in some economies, such as Japan and the EU. Inverter driven RACs can continuously vary the compressor's frequency, and thus regulate the cooling capacity to exactly cover the room load. The unit adapts itself continuously to the part load of the room and has no energy losses due to On/Off cycling, except for a very low part load ratio. The inverter RAC efficiency is deemed to improve at part load.

The improvement of the efficiency at part load in the case of inverter control is the result of two opposing phenomena:

- With a reduced refrigerant flow rate at part load, the heat exchangers of the appliance become oversized. The temperature difference across them decreases, causing the pressure ratio to decline, which in turn leads the efficiency of the compressor to rise. The poorer the full load efficiency of the heat exchangers, the larger the resulting improvement at part load.

- With reduced speed (refrigerant flow rate) and a lower compression ratio, the compressor isentropic efficiency will in turn slightly decrease, as well as the efficiency of the inverter itself. These two effects tend to reduce AC efficiency.

With very efficient small ACs, the part load improvement is deemed to be small or even null because heat exchangers are already oversized at full load. With very low efficiency products or with larger products, the heat exchangers may not be oversized at full load because size and cost are more important factors. The part load gain will likely be higher for these products.

The capacities of the samples to be tested in this study have been chosen in order to characterize typical products, within the capacity range of the products under the scope of this study, while taking into consideration the practical limitations of part load testing.

The following samples have been chosen:

- Sample 1: split wall-mounted AC of 3.5 kW, with fixed compressor speed.

- Sample 2: split wall-mounted AC of 3.5 kW, with inverter driven compressor. Two units of the same model have been selected in order to measure, with lower uncertainty, the EER at 21% part load ratio for the EU testing. This is needed because it is very difficult to measure a cooling capacity lower than 1.5 kW with an acceptable uncertainty of measurement. Both samples have also been tested at full load conditions in order to validate that their capacities were similar.

- Sample 3: split ducted AC of 10.5 kW, with fixed compressor speed.

- Sample 4: split ducted AC of 10.5 kW, with inverter driven compressor.

For the two fixed-speed samples, the units were obtained directly from the market as neither special customizing nor the knowledge of special starting procedures was required for the tests.

For sample 4, the sample had to be obtained directly from the market, without any information about how to fix the compressor’s frequency or the fan speeds for the different test conditions required for testing. As a result, tests following the US procedure could not be performed as these require additional information from the manufacturer that was not available from the documents delivered with the unit.

4.2.2 Test Conditions

In accordance with the entire team participating in this study, three economies were selected due to their market relevance: the US, Japan, and the EU. These economies use different power supply conditions (voltage and frequency), making it unlikely that manufacturers are producing units able to operate in all of these regions. However, it is reasonable to assume that the specific nature of the energy source will not have an impact on appliance efficiency itself, but rather on the specific design of the power electronics.

In order to get comparable results, all tests have been performed with a voltage of 230 V and a frequency of 50 Hz. To minimize the number of tests, only the mandatory tests have been performed and the default values for the optional tests have been used for the calculations.

The power input for the thermostat off, standby, or crankcase heater modes have also been measured as they are included in the calculation of the EU SEER.

Table 17: Modes Defined in the EU's prEN 14825

MODE	Description
Active Mode	The mode corresponding to the hours with a cooling or heating load of the building and whereby the cooling or heating function of the unit is switched on.
Thermostat Off Mode	The mode corresponding to the hours with no cooling or heating load of the building, whereby the cooling or heating function of the unit is switched on but is not operational, as there is no cooling or heating load.
Standby Mode	The unit is switched off partially and can be reactivated by a control device or timer.
Off Mode	The unit is completely switched off and cannot be reactivated, neither by control device nor by timer.
Crankcase Heater Mode	The mode corresponding to the hours where a crankcase heater is activated.

4.2.3 Test Results

Test results are not detailed here but are available in the testing component report. Nevertheless, we give some relevant information about the difference of treatment for each sample.

Sample 1 – Fixed-Capacity, Non-Ducted

For this sample, 0.08 kg of refrigerant was added to the factory charge due to the refrigerant piping length being greater than 5 m. The tests under EU and Japanese conditions were performed with the factory refrigerant charge. A test under the 29°C outside air condition was performed for the Japanese testing procedure even though it was not mandatory. This allowed a comparison with the default calculation procedure to estimate the 29°C outside air condition as part of a real test. It showed a measured EER that was 6% higher than estimated.

Sample 2 – Inverter, Non-Ducted

For this sample, full information was available from the manufacturer to set the unit in the correct conditions of compressor frequency and fan speed in order to achieve the requirements of the US test procedures. It was thus possible to conduct testing under each of the three standards targeted for testing. Two similar units were tested to assess differences of efficiency at lower loading.

Sample 3 – Fixed-Capacity, Ducted

For this sample, 0.16 kg of refrigerant was added to the factory charge due to the refrigerant piping length being greater than 5 m for the test under US and Japanese conditions. The tests under EU conditions were performed with the factory refrigerant charge.

A test under the 29°C outside air condition was performed for the Japanese testing procedure even though it was not mandatory. This allowed a comparison with the default calculation procedure to estimate the 29°C outside air condition as part of a real test. It showed a measured EER that was 4.4% lower than estimated.

Fan motor correction does not apply to the US standard but it has been calculated for the test performed according to the EU and Japan standards. The final result for the effective EER (incorporating fan correction) was roughly 3% higher than the measured EER.

Sample 4 – Inverter, Ducted

For this sample of ducted, inverter AC units, no information was available from the manufacturer to set the unit in the correct conditions of compressor frequency and fan speed in order to achieve the requirements of the various test procedures.

This unit had an automatic detection of the test mode for the full load test that fixed compressor frequency so as to produce the rated cooling capacity.

For testing under the Japanese and EU standards, an alternative approach was used through which the laboratory fixed the energy input to the testing room in order to adjust the part load ratio of the tested unit. This approach yielded results close to the exact procedure but required more time for getting a steady state condition in the testing room.

It was not possible to perform the test for the US conditions, which required detailed information from the manufacturer on the correct settings for the test. For the tests at part load conditions, the procedure did not provide the part load ratios to achieve or the compressor and fan speeds. Consequently, it was not possible for the laboratory to adjust the unit to the part load that would have been achieved by the unit based on manufacturer settings.

The fan motor correction was also applied to this sample under the Japanese and EU testing standards.

For the EU duct correction, the impact was significant with the effective EER varying from +/- 1.5% at full load conditions to +/- 13.8% at the lowest part load conditions. This confirmed that the duct correction can have a significant effect on the final value of the EER calculated.

Other Power Inputs

The power inputs in the different modes defined in the EU's prEN 14825 were measured for each sample. The results of these measurements are summarized below:

- In thermostat off mode, the indoor unit fan was running permanently for all samples. This seems acceptable for ducted units as they have to maintain their air change and filtering function, but it is less obvious for non-ducted units where fans could be switched off when there is no load present. Therefore, the control strategy for the indoor fan can be improved for non-ducted units.
- In the case of sample 3, power inputs in thermostat off and standby modes were measured with the crankcase heater disconnected.
- For sample 3, the only sample with a crankcase heater, the crankcase heater was never switched off during the measurement (8 hours according to the standard, but we measured it for 15 hours). This means that either the unit had no thermostat to switch the heater off when it was not needed, or the control of the heater was not running properly. In general, the crankcase heater control strategy is one of the design characteristics to which manufacturers should pay attention. They can try to implement control functionality that will ensure that heaters are used only for the time required to accomplish their main function.

4.2.4 Analysis of Test Results

These test results provide a set of measured data to check the hypotheses formulated by the benchmarking component to propose EER and SEER conversion formulas between efficiency metrics. This use of the test results is described in the benchmarking component of this study.

The experience gained during these tests is also a source of useful information in order to compare test procedures.

Variable-Capacity Air Conditioners

For fixed-capacity ACs, it is possible to adjust the unit correctly and perform all the tests with the information published in the installation manual; no additional information is required from the manufacturer. For variable-capacity ACs (inverters), the manufacturer has to provide additional information to the testing laboratory in order to set the unit in the right mode, both for standard rating conditions and part load conditions.

This can clearly be a problem for third-party testing or market surveillance, when contact with the manufacturer may not be allowed or communication might be difficult. This is common to the three economies considered for the tests. Nevertheless, we have shown that it is possible to test these units if the testing laboratory has a test facility that can set the load which the tested unit has to overcome, the speed of the fan is known, and the part load ratio is defined in the test procedure. It is therefore possible to perform these tests for the EU and Japan. For the US test procedure, however, the part load ratio is unknown, so the data required to test for intermediate and minimum cooling have to be provided by the manufacturer.

We recommend that the alternative approach of setting the part load capacity on the indoor side of the test sample be standardized to allow uniformity across laboratories. The only difference with the existing methods would be to increase the tolerance for the variation allowed for the test readings from specified test conditions (variations of arithmetical mean values and maximum variation of individual readings). This increase in tolerance is required because the control device of the sample under test has to maintain the indoor air dry bulb temperature instead of the laboratory testing equipment. From the experience gained during these tests, it is recommended that the maximum variation allowed for the arithmetical mean values of the indoor air dry and wet bulb temperatures be twice the value given in the existing standards. It is not necessary to change the requirements for the outdoor air temperature conditions. This revision would increase the uncertainty of the measurement of the EER by about 1%, which seems acceptable considering the added advantage and flexibility offered by this alternative part load testing method.

Corrections for Ducted Fans

As we found during the tests, the increase of the EER due to the fan correction in the EU and Japan is a few percent for fixed-capacity units. However, it can be much larger at part load conditions.

To have a better appreciation of the effect of this correction, we have calculated the difference for the EU SEER with and without this correction for two of the samples tested.

Table 18: Effect of the Fan Motor Correction on the EU SEER

Sample	SEER Without Fan Correction	SEER with Fan Correction	Difference (%)
3 - Fixed-Capacity	2.95	3.03	+ 2.7
4 - Variable-Capacity	4.04	4.29	+ 6.0

The increase of the SEER is quite significant, especially for inverter units, and does not reflect any real energy efficiency increase. The fan correction is only intended to make ratings comparable between ducted and non-ducted units.

Dehumidifying Capacity

For both inverter samples, the dehumidifying capacity decreases quickly with the load, being null for the lowest part load ratios.

The two inverter units tested in the framework of this study have some humidity removal capability at the higher end of their part load operation range. However, several inverter models currently sold worldwide, and some models that CEIS has tested over the years, have no dehumidifying capacity at standard rating conditions (full load) or at part load conditions. Accumulated figures over years of testing suggest that somewhere between 5% and 10% of inverter units on the market have no dehumidification capability. This is problematic when dehumidification is required for a given application.

This raises the question as to whether the humidity control capability of units should be included in future revisions of the testing standard. This could be introduced as a minimum latent heat removal ratio at different part loading. However, the incorporation of such requirements should be considered carefully taking into consideration technology limitations, the production cost for manufacturers, the willingness to pay from consumers, the variation of temperature and humidity outside of the comfort zone in the house, and specific market requirements. One specific question raised by humidity control is whether the inclusion of humidity control requirements in inverter units is technically feasible while maintaining the large portion of energy efficiency benefits brought about by this technology. For instance, if manufacturers respond to this requirement by cycling units on and off at the higher range of the loading, making them run more like an on-off unit, this will largely reduce the gain expected from inverter units. Furthermore, it is unclear whether the lack of capability for humidity removal gives a cost advantage to manufacturers or whether it is just a design decision without a large impact on unit cost.

ASHRAE Fundamentals, the most used reference for indoor comfort in North America, provides a rather wide margin for acceptable ranges of operating conditions for internal space in summer. At a 24°C interior temperature, the higher range of acceptable humidity is close to 70% relative humidity. It would be interesting to understand what the deviation would be from the range of acceptable indoor conditions caused by different designs of RACs before concluding whether humidity requirements constitute a major issue in the real range of operations in houses.

More importantly, the absence of humidity removal capabilities will only be problematic in some climates. This raises the question of how to develop a global standard procedure that will not result in distorting the real market requirements.

This study was not intended to answer questions pertaining to the decision to incorporate humidity removal characteristics in energy efficiency testing procedure and metrics. It is recommended that further research be conducted in this area to determine if this should be considered for future revision of testing standard procedures.

Parasitic Power Inputs for the EU SEER

In order to have a better appreciation of the effect of the parasitic powers (thermostat off, standby, crankcase heater input powers) on the EU SEER, we have calculated the degradation of the SEER for each sample.

Table 19: Effect of the Parasitic Power Inputs on the EU SEER

Sample	SEER Without Parasitic Power Correction	SEER with Parasitic Power Correction	Difference (%)
1 - Fixed-Capacity, Non-Ducted	3.71	3.56	- 4.0
2 - Variable-Capacity, Non-Ducted	6.23	5.70	- 8.5
3 - Fixed-Capacity, Ducted	3.53	3.03	- 14.2
4 - Variable-Capacity, Ducted	4.69	4.29	- 8.5

5 Ranking

The ranking component of this study focused on the elaboration of a ranking tool for RAC S&L policies, regulations, or initiatives. The ranking tool guides the user in collecting the relevant data needed to assess their country's S&L programs and provides evidence-based information on which to base policy decisions to improve programs or identify requirements for further study. The objective is to pull the market towards higher levels of AC efficiency and lay the foundation for strong and harmonized energy performance requirements at the global level.

5.1 Ranking Tool Development

This section describes the ranking tool development process.

5.1.1 Determination of the Initial Tool Structure

In order to develop the ranking survey tool, the ranking component team reviewed the CLASP Data Collection Sheet developed as part of the larger Cooling Benchmarking and Mapping component effort. The most significant information was extracted from the sheet to serve as the basis for the survey questionnaire. Some data elements were excluded as it was felt that they would be difficult for national experts to obtain.[16] The first draft instrument covered four S&L program areas: MEPS program characteristics, MEPS technical characteristics, labeling program context, and labeling program quality. This draft was circulated to the project team and to a selected group of outside S&L experts. Converging to a final form involved extensive iteration as well as repeated rewording and restructuring to build a survey instrument that would be relatively easy to use, unambiguous, flexible enough to apply in highly varied national and international contexts, and robust enough to yield useful results. In this iterative process, the ranking tool was expanded to include MEPS stringency, and the labeling area was split to address endorsement and comparison labeling programs separately.

The final survey instrument was built as a spreadsheet comprising eight tabs:

- Overall
- MEPS Stringency
- MEPS Program Characteristics
- MEPS Program Technical Characteristics
- Endorsement Label Program Context
- Endorsement Label Program Quality
- Comparison Label Program Context

[16] Examples of excluded data are sales totals by equipment efficiency and capacity for all products sold in the economy.

- Comparison Label Program Quality

The overall worksheet tallies the score from each of the subsequent tabs covering seven key components of residential AC S&L program effectiveness as listed above. A weighting factor is applied to the score from each individual worksheet tab. Then, these scores are summed and listed on a scale from 0 to 100 to determine the overall performance of the S&L programs of the ranked countries.

5.1.2 Weighting of the Various Ranking Elements

Once the basic structure and content of the ranking tool was developed, the ranking component team contacted an initial list of international experts specializing in EE S&L, identified with input from the project team. Experts were asked to assign relative weights (based on importance) to each of the seven broad categories covering S&L program design and implementation as well as to specific elements within each category. The form of the individual worksheet tabs was made as consistent as feasible. Particular attention was given to make the organization of each worksheet parallel and to use identical layouts and mental "cues" on each tab. This included features such as:

- Tab Name filled out at the top of the worksheet. In general, the tab name is highlighted in the same fill color as the tab itself.
- Instructions for assigning relative weights to each category (and sub-category, where applicable) follow immediately below.
- Grey background cells indicate each place where an entry is requested.
- Check-sum cell (yellow) at the bottom of the left-most column for each tab. Respondents were instructed that their total point assignment should (auto) sum to 100 points for each tab. This means that the value entered for each category, such as MEPS program characteristics, is the percentage weight they would assign to that characteristic. The 100 point check-sum cell normalizes scores across panelists. This makes it easier to develop a composite ranking representing the weighted opinions of all respondents.
- On the Overall tab, the background colors in the second column reflect the subject matter tab covering that area of interest. For example, light blue is used for Technical Characteristics of MEPS Rating Method in the Overall tab.
- Comments (third visible column) augment the general instructions with notes for specific rows of the worksheet.

Experts were asked first to assign relative weightings to the seven categories in the Overall tab. They then turned successively to the seven subject area tabs identified above. For each, the general structure paralleled that of the Overall tab, with participants asked to assign scores to each of a number of categories, using the grey-highlighted cells for their entries. Several iterations were required to converge on a ranking form that is usable by policy makers and interested stakeholders who have general familiarity with S&L programs.

In order to validate the initial model, a second series of experts were invited to participate in the review and testing of the tool on specific countries. This method yielded three additional national ranking tools. The responses from experts in China, Japan, and North America (Canada and the US) were collated and used to improve the ranking tool.

CLASP staff then initiated another round of review and testing with targeted international experts in order to complete the weighting exercise. This approach yielded additional input used to refine the final weighting used in the S&L program ranking tool. The weighting values in the final ranking tool are based on input from experts representing government agencies, advocacy organizations, and consulting firms in Canada, China, India, Japan, and the US.

Finally, values or scores were fixed for each possible response corresponding to the specific elements of the S&L programs covered in the seven topic worksheets. The scoring reflects generally accepted principles regarding best practice in S&L programs as reported in the literature as well as input from CLASP staff, ACEEE's experience and, in some cases, comments from the expert reviewers. Details pertaining to the weighting scores assigned by experts are presented in Appendix 2 to this report.

5.1.3 Final Ranking Tool

As outlined above, even though the process to build the tool was comprehensive and iterative, the final ranking tool is a relatively simple spreadsheet consisting of eight individual worksheet tabs. Table 20 to Table 27 show each of the pages of the ranking form along with the assigned weights or scores associated with each element of the ranking. The first tab, the Overall Ranking, weights the total scores from each of the seven subsequent worksheets to derive the final Overall Ranking Score.

5.2 Detailed Presentation of the Tool

This section presents the detailed presentation of the tool categories as well as the weighting associated with each element.

5.2.1 Weighting of the Main Ranking Categories

Based on input from international experts and members of the project team, each category is weighted according to its overall importance to result in successful (effective) S&L program design and implementation. Table 20 provides a snapshot of the Overall Ranking tab with the weight assigned to each category in the final ranking tool based on the median of the values assigned by the expert panel.[17]

There was general agreement that a strong MEPS program was the most important factor in an effective S&L program, although the degree to which MEPS outweighed labeling efforts varied widely. The following range of weighting factors was observed among participating experts:

- MEPS Stringency: 10% to 30%

[17] Median values were rounded to allow for a score of 100.

- MEPS Program Characteristics: 15% to 40%
- MEPS Technical Characteristics: 5% to 30%
- Overall MEPS: 45% to 80% of overall weight

In general, endorsement labels were rated at lower importance than MEPS and comparative labels, although one respondent rated endorsement labels as more important than comparative labels and another rated them of equal importance (20% each). Responses were mixed on which program elements were most important with some favoring program context, others program quality, and still others rating them equal. The range of weight given to the various labeling elements was as follows:

- Endorsement Labeling Program Context: 0% to 10%
- Endorsement Labeling Program Quality: 5% to 20%
- Overall Endorsement Labels: 10% to 20% of overall weight

The widest variation in proposed weightings was found in the comparative labels category. It is possible that the assigned rankings reflect the respondents' perceptions of the role and effectiveness of comparative labels relative to MEPS and endorsement labeling in their own countries, which could explain some of the results observed. The one respondent according a weighting of zero for Comparison Label Program Context and Quality indicated that while Comparison Labels are an important tool for other product categories, consumers are unlikely to see or use comparison labels when purchasing residential ACs, which are primarily installed equipment sold by contractors.

- Comparative Label Program Context: 0% to 25%
- Comparative Label Program Quality: 0% to 20%
- Overall Comparative Labels: 0% to 35% of overall weight

Table 20: Overall Ranking Criteria Worksheet with Weight Assigned to Each Category

	Ranking Criteria	Comments
17	**MEPS Stringency**	This tab evaluates MEPS program stringency.
20	**MEPS Program Characteristics**	This tab evaluates coverage and maturity of the standards program, frequency of revision cycles and enforcement mechanisms.
20	**Technical Characteristics of MEPS Rating Method**	This tab evaluates rating and certification methods.
7	**Endorsement Label Program Context**	This tab evaluates coverage of the endorsement labeling program, maturity of the program, revision cycles and enforcement.
11	**Endorsement Label Program Quality**	This tab evaluates labeling program quality from the consumer's perspective.
15	**Comparison Label Program Context**	This tab evaluates coverage of the comparison labeling program, maturity of the program, revision cycles and enforcement.
10	**Comparison Label Program Quality**	This tab evaluates labeling program quality from the consumer's perspective.

5.2.2 MEPS Stringency

To rank the stringency of a MEPS program, two components are considered: the method or basis for setting the MEPS level, and the stringency of the rating required for compliance. Given differences in climate, AC saturation, and usage and product availability among countries, the appropriate MEPS level will vary from country to country. As such, it is not appropriate to base a country's ranking solely on the value of the MEPS requirements – e.g., the minimum seasonal energy efficiency ratio (SEER) or energy efficiency ratio (EER). An effective MEPS program uses a robust methodology to establish the appropriate MEPS level for the country or region.[18] For the purpose of international comparison, the stringency of the MEPS levels compared to other countries or regions are also an important consideration. Table 21 shows the MEPS Stringency tab from the ranking tool with the final weighting for each category and the scoring for each response.

The MEPS Stringency tab was developed based on feedback from the first set of reviewers and CLASP staff. Only the second set of reviewers provided input on the relative weighting of the two categories. Three of the

[18] The four categories used to describe different methods for setting MEPS stringency levels and the weighting assigned to each are based on Wiel and McMahon (2001). CLASP "Energy-Efficient Labels and Standards: A guidebook for Appliances, Equipment and Lighting. The four approaches are "Techno-Economic," Statistical, Product Class Average and Best Practices.

four experts agreed on the relative importance of each category, assigning a 70% weighting to the Basis for Setting MEPS Stringency Level and the remaining 30% to Stringency of MEPS Rating. The fourth expert also split the weight 70%/30%, but reversed the categories (i.e., assigned 30% to basis for setting the MEPS level and 70% to the stringency of the level).

Table 21: MEPS Stringency Worksheet with Assigned Weightings for each Stringency Factor

MEPS Stringency			
Ranking Criteria			**Comments**
70	**Basis for Setting Stringency Level**		How is stringency level for products established?
	10	Minimum Market Disruption	Only clears the market of the worst products
	20	Statistical analysis of available products	
	50	Adopting best available international level	"Best practice"
	70	Techno-economic analysis of potential	Specifically including life-cycle cost (LCC) methods
30	**Stringency of MEPS Rating**		
	Stringency of MEPS (Seasonal Rating Method)		
	10	Weak	<SEER 10 USA or SEER 3.0 metric
	20	Average	Between SEER 10 USA/3.0 Metric & 14 USA/4.0 metric
	30	World-class	At least SEER 14 USA or SEER 4+ metric
	OR		
	Stringency of MEPS (Steady-State Rating Method)		
	10	Weak	<EER 11 USA or EER 3.2 metric
	20	Average	Between EER 11 USA/3.2 Metric and 13 USA/3.3 metric
	30	World-class	At least EER 13 USA or EER 3.3 metric
	Score for MEPS Stringency		

5.2.3 MEPS Program Characteristics

This section of the ranking tool covers program design elements that factor into the effectiveness of a MEPS program. For the most part, these elements are administrative rather than technical. Table 22 reflects the MEPS Program Characteristics worksheet with the weights assigned to each category (highlighted in grey) and the points associated with each response. There was broad agreement among expert reviewers that Program Scope was the most important characteristic of an effective MEPS program, followed by the frequency of review/revision and the mechanism for enforcement. Opinion was most divided on the importance of a national database of complying products. Indeed, some experts gave this element no weight, others gave it moderate weight, and one considered it among the most important characteristics.

Table 22: MEPS Program Characteristics Worksheet with Assigned Weightings for Each Program Element

MEPS Program Characteristics			
Ranking Criteria			Comments
30	MEPS Program Scope		
	0	No MEPS program	
	3	Voluntary program covers < 30% of unit sales	
	6	Voluntary program covers 30% - 50% of unit sales	
	10	Voluntary program covers >50% of unit sales	
	15	Mandatory program, excludes product classes with large sales volume	
	30	Mandatory program, covers all product classes with large sales volume	
5	Maturity of MEPS Program		
	1	≤ 2 years (just starting)	
	2	2 - 10 years	
	4	10 - 20 years	
	5	> 20 years	
20	How often is rating method reviewed for updating?		
	0	No regularly scheduled review and update	
	10	Scheduled updates on cycle longer than five years	
	20	Scheduled updates on cycle of five years or less	
15	What is the lag time between adoption of a standard and its implementation?		
	0	Not defined in program for this economy	
	5	> 5 years	
	10	3 - 5 years	
	15	<3 years	
10	Is there a mandatory national database of products that comply with MEPS?		
	0	No	
	10	Yes	
20	How is the MEPS program enforced in the market?		
	0	No enforcement mechanism	
	5	Honor-based manufacturer declaration of compliance	
	10	Shaming of violators, public disclosure	
	15	Low financial penalty	
	20	High financial penalty and/or product recalls	
	Score for MEPS Program Characteristics		

5.2.4 MEPS Rating Method Technical Characteristics

A successful MEPS program must incorporate rigorous rating and certification requirements to ensure that covered products meet the specified MEPS levels as well as achieve anticipated energy savings and manufacturer compliance. Elements of a strong MEPS program for RACs include independent development of product rating methods, oversight of product testing, adoption of rating methods that are climate-appropriate and which allow for comparison across common product types, and reporting of relevant information to consumers. Table 23 shows the MEPS Rating Method Technical Characteristics tab with weights and points assigned to each category and response.

Based on input from the first set of experts, this tab was revised to clarify questions about the rating method and to make it easier for users to find the information needed to complete the ranking. The final set of experts provided their input on the revised worksheet. Experts were in general agreement with respect to the weighting of categories, except for two outliers. One outlier gave the highest weights to how the rating method was established and how products are rated and tested, and another outlier placed much higher weight on the technical specifics of the rating method.

Table 23: Technical Characteristics Worksheet with Weightings for Each Element of MEPS Rating Method

MEPS Rating Method Technical Characteristics			
Ranking Criteria			Comments
20	**Who establishes the rating method for the country?**		
	0	Manufacturers and/or trade association	
	10	Non-government third party, such as ANSI process	
	20	Government agency	
20	**How are new products rated?**		
	5	Honor system w/out oversight by manufacturer association	
	10	Honor system w/weak oversight by manufacturer association	
	15	Honor system w/strong oversight by manufacturer assoc.	
	20	Certification required for sale	
15	**Who does the testing for certification?**		
	5	Manufacturers, or non-accredited labs	
	10	Accredited labs paid by manufacturer	
	15	Accredited labs paid by rating agency	
	15	Government agency (internal)	
10	**Does rating method allow comparing different equipment types & sizes?**		
	10	Yes, can compare the major types available in the economy	e.g., ducted to ductless
10	**What is the basis for the rating method?**		
	0	Derived from moderate temperature test, ~ 28°C = 82°F	
	5	Derived from high temperature test, at least 35°C = 95°F	
	10	Uses both high and moderate outdoor temperatures	
15	**Appropriate test temperature for national climate?**		
	0	No, international standard based on much hotter/cooler climate	
	15	Yes, local or international conditions that match climate well.	
10	**What is the basis for information reported to consumers?**		
	0	No MEPS information reported to consumers	
	3	Steady-state at moderate or high temperature	
	6	Seasonal integration instead of steady-state	
	10	Seasonal integration **and** high-temperature steady-state	
	Score for MEPS Rating Method Technical Characteristics		

5.2.5 Endorsement Label Program Context

As noted above, the ranking tool includes two tabs covering endorsement labeling programs, primarily voluntary programs designed to showcase higher efficiency products. The Program Context tab covers issues related to program design and implementation. For RAC equipment, experts agreed that program scope and the frequency of program updates were the most important criteria, followed by who has responsibility to ensure compliance and program communication. Table 24 provides a snapshot of the Endorsement Label Program Context tab of the ranking tool. As shown above, the weight assigned to each category is highlighted in grey and the points associated with each response are indicated next to each possible response.

Table 24: Endorsement Label Program Context Worksheet with Assigned Weightings for Each Program Element

Endorsement Label Program Context			
Ranking Criteria			Comments
25	Program Scope		
	0	No program	
	5	Program covers product types accounting for < 30% of sales	
	15	Program covers product types accounting for 30% - 50% of sales	
	25	Program covers product types accounting for >50% of sales	
5	Label Program Maturity		
	0	No program	
	2	≤ 2 years (just starting)	
	4	2 - 10 years	
	5	>10 years	
20	Update cycles		
	0	None	
	5	≥ 5 years	
	15	< 5 years	
15	Who is responsible for compliance?		
	0	No one (e.g., no budget)	
	5	Manufacturer organization	
	10	Third party	
	15	Govt. agency	
10	Consequences of non-compliance to manufacturer/importer		
	0	Almost no penalty	
	3	Shaming of violators, public disclosure	
	6	Low financial penalty	
	10	High financial penalty and/or product recalls	
10	Are Label Program resources adequate?		
	0	Essentially zero time, funds or staffing available	
	5	Some resources, but quite inadequate	
	10	Adequate staff and/or funding to do program well	
15	Label Program communication		
	7.5	Communications and outreach program included	Check all that apply
	7.5	Brand management campaign included	
	Score for Endorsement Label Program Context		

5.2.6 Endorsement Label Program Quality

While the Program Context tab focuses on program design and implementation, the Endorsement Label Program Quality tab evaluates the quality and effectiveness of the program from the perspective of participants (consumers and industry). Unlike the parts of the ranking tool discussed above, much of the information needed to complete this component of the tool requires research with program participants. Indeed, programs will not score well if they do not conduct research to determine the level of label recognition, the perceived value of the label, and the ease of use.

While a low score does not necessarily mean that recognition of the label is low or that the label is difficult to use, it does indicate a shortcoming in program design (i.e., the lack of a mechanism for evaluation and improvement). Without this data, the labeling program cannot accurately measure its impact. Label recognition and ease of use were considered the most important indicators of program quality by expert reviewers. Table 25 provides a snapshot of this tab with category weighting and scores indicated.

Table 25: Endorsement Label Program Quality with Assigned Weightings for Each Factor of Program Quality

Endorsement Label Program Quality			
Ranking Criteria			
35	**How widely is the label recognized by potential purchasers?**		
	0	Data not collected by program	
	15	<25% recognize label	
	20	25% - 50% recognize label	
	30	50% - 75% recognize label	
	35	>75% recognize label	
20	**Perceived value of endorsement**		
	0	No participant research conducted	Value of endorsement to consumers and industry as indicated by reported use or industry participation
	5	Little value reported	
	10	Modest value reported	
	20	High value reported	
25	**Ease of use by consumers**		
	0	No consumer research conducted	Ease of use as reported by consumers and/or as demonstrated through tests of consumer comprehension
	5	Difficult to understand and use	
	15	Moderate ease of use/understanding	
	25	High level of use and understanding	
20	**Endorsement level stringency**		
	5	>60% of available models pass	
	10	30% - 60% of available models pass	
	15	10% - 30% of available models pass	
	20	<10% of available models pass	
	Score for Endorsement Label Program Quality		

5.2.7 Comparison Label Program Context

The final two tabs of the ranking tool cover Comparison Label Programs Context and Quality. As with endorsement labels, the Program Context tab addresses program design and implementation. Program scope was weighted most heavily by the expert reviewers, followed by frequency of updates, consequences of non-compliance, and program communication. Experts also believe that categorical label programs should be rated more highly than continuous-type comparison. Table 26 provides a detailed look at the Comparison Label Program Context tab with associated category weights and points for each response.

Table 26: Comparison Label Program Context Worksheet with Assigned Weightings for Each Program Element

Comparison Label Program Context			
Ranking Criteria			
20	Comparison Label Program Scope		
	0	No comparison label program	
	1	Program covers < 30% of product sales	
	3	Program covers 30% - 50% of product sales	
	5	Program covers >50% of product sales	
	10	Mandatory program, excludes product classes with large sales volume	
	20	Mandatory program, covers all product classes with large sales volume	
10	Type of comparison		
	0	Continuous	
	10	Categorical	
5	Program Maturity		
	0	No program	
	1	≤ 2 years (just starting)	
	3	2 - 10 years	
	5	>10 years	
15	Update cycles		
	0	None	
	10	≥ 5 years	
	15	< 5 years	
10	Who is responsible for compliance?		
	0	No one (e.g., no budget)	
	3	Manufacturer organization	
	6	Third party	
	10	Govt. agency	
15	Consequences of non-compliance to manufacturer/importer		
	0	Almost no penalty	
	7.5	Shaming of violators, public disclosure	
	7.5	Low financial penalty	
	15	High financial penalty and/or product recalls	
10	Are Label Program resources adequate?		
	0	Essentially zero time, funds or staffing available	
	5	Some resources, but quite inadequate	
	10	Adequate staff and/or funding to do program well	
15	Label Program communication		
	6	Labeling program was designed and/or redesigned with consumer research	
	6	Communications and outreach program included	Check all that apply
	3	Brand management campaign included	
	Score for Comparison Label Program Context		

5.2.8 Comparison Label Program Quality

This tab ranks Program Quality from a user's perspective. The initial section applies to all comparison label programs and relies largely on information collected through research with program participants. This section closely resembles the Endorsement Label Program Quality tab. Two subsequent sections differentiate between categorical comparison labels and continuous comparison labels with questions tailored to specific characteristics of each type of label that research has demonstrated are indicative of program effectiveness. Table 27 shows the Comparison Label Program Quality tab and provides the weights and points assigned to each category and response, respectively.

Table 27: Comparison Label Program Quality with Assigned Weightings for Each Factor of Program Quality

Comparison Label Program Quality			
Ranking Criteria			
All Comparison Label Programs			Respondents Complete this Section
20	**How widely is the label recognized by potential purchasers?**		
	0	Data not collected by program	
	5	<25% recognize label	
	10	25% - 50% recognize label	
	15	50% - 75% recognize label	
	20	>75% recognize label	
15	**Perceived value of label**		
	0	No participant research conducted	Value of label to consumers and industry as indicated by reported use
	5	Little value reported	
	10	Modest value reported	
	15	High value reported	
20	**Ease of use by consumers**		
	0	No consumer research conducted	Ease of use as reported by consumers and/or as demonstrated through tests of consumer comprehension
	5	Difficult to use/comprehend	
	10	Moderate ease of use/comprehension	
	20	High level of use and/or comprehension	
5	**Does label include actual rating value or predicted energy use?**		
	5	Yes	e.g., EER, SEER or COP
Categorical Label Programs			Complete this section only if ranking a program using Categorical comparison (e.g., stars, letters, etc.)
15	**Stringency of highest (most efficient) category**		
	0	>20% of available models	
	5	10% - 20% of available models	
	10	<10% of available models	
	15	Small number, "aspirational," anticipates new approaches	
10	**Stringency of lowest (least efficient) category**		
	0	Lower than any frequently sold product	
	5	Lowest frequently sold product, or legal minimum	
	10	Bottom excludes some products marketed	
15	**Appropriate number of categories, if categorical**		
	0	Too few (2 or fewer)	
	0	Too many to absorb (>7)	
	15	3 - 7 categories	

Continuous Label Programs			Complete this section only if ranking a program using Continuous comparison (e.g., graphical scale)
25	**How many products at the most efficient end point?**		
	5	>20% of available models	
	10	10% - 20% of available models	
	15	<10% of available models	
	25	Small number, "aspirational," anticipates emerging technologies	
15	**Does scale beginning correspond to MEPS minimum or equivalent?**		
	0	Scale extends below "legal minimum" product or equivalent	
	15	Lowest level of scale is "legal minimum" or equivalent	
	Score for Comparison Label Program Quality		

5.3 Discussion

This project allowed for the development of a tool for ranking the effectiveness of S&L programs to inform policymakers and other interested stakeholders about best practices and to identify opportunities for improvement. As often occurs, the project design evolved during the investigation in response to challenges that emerged and opportunities that opened for more effective analysis.

Despite the fact that some economies with a long experience with S&L programs (notably the EU and Australia) were not covered by the ranking component because of time constraints on the part of external experts, the project team is confident that this component of the project succeeded in developing a robust Version 1.0 ranking tool (or, perhaps more appropriately, Beta) with input from the responses received and the judgment of the S&L experts represented by CLASP and the project team. The final ranking tool incorporates responses from experts from China, India, Japan, Canada, and the US, in addition to recommendations from CLASP staff and the various experts on the project team. Four of the seven experts providing feedback on the relative weighting of each program element/characteristic were from North America. However, the diversity of their viewpoints as evidenced by the variation in their responses suggests that this has not resulted in a North American bias or adherence to any single “North American” perspective.

This Version 1.0 tool can serve as a framework for ranking residential AC S&L programs and may be modified to rank S&L programs targeting other product classes. As the tool is further refined, input from a broader range of S&L experts can be incorporated. Experts have already suggested additional topics for consideration in future improvements of the ranking tool. Following final completion of the project, the survey instrument and its instruction package will be made available to CLASP and stakeholders on the global scene for use in any country where it might be deemed helpful.

CONCLUSION

In conclusion, the Cooling Benchmarking Study provided an analysis and comparison of the RAC markets and test procedures in place in selected economies. In addition, it allowed for the development of formulas and coefficients for the conversion of EE metrics for full load and seasonal efficiency of RAC products under different test procedures in use in major economies. These formulas were also used to compare the stringency of various S&L schemes implemented in the selected economies.

Laboratory testing of products representing significant market segments were conducted under different test procedures to identify the practical limitations of each testing standard and validate the conversion formulas and coefficients proposed for the various efficiency metrics used around the world. Finally, a ranking tool developed within the project will benefit policy makers and EE program managers by allowing a comparison of the stringency and efficiency of different S&L initiatives proposed or implemented in the economies targeted under the study.

Mapping

The mapping component confirmed that the sales-weighted average EER of single and multi-split AC products has been improving in the selected economies over the past decades. This corresponds to a large portion of the market as the study confirmed that split units dominate the RAC market in most economies.

The EER of unitary RACs (window types), which have a decreasing market share, has remained constant or even decreased as was observed in the EU from 2006 to 2011. This suggests a lack of effort on the part of manufacturers to improve these units, which are in less demand.

Despite variation in the economies considered under this study, the RAC market is undergoing significant growth, except in Japan where the market has been relatively constant over the last few years.

In some of the economies analyzed, such as China and Australia, the RAC MEPS level established and implemented has become more stringent over the years after one or several rounds of updates. India and Taiwan are considering implementing more stringent requirements in the near future.

Benchmarking

The benchmarking component has successfully produced robust EER and SEER conversion functions and coefficients that can be applied to convert between the RAC EE requirements in place in the major economies of the world. These allow comparisons of metrics addressing full and part load performance and thus can be used to compare the impact of policy requirements on peak power demand (EER metrics) and on annual energy use and CO_2 emissions (SEER metrics). The conversion metrics are applicable to non-ducted split-type RACs of either fixed-speed or variable-speed/frequency type and also to ducted split AC units.

In addition, the impact of differences in the permitted tolerances have been identified and addressed. The uncertainty from applying these measures has been assessed and documented by comparison with detailed test results. While the error margins are sometimes too large for the conversion metrics to be practically applied for the purpose of rating individual products, they are sufficiently small to permit the meaningful comparison of the broad ambition of regulatory policy settings, which was the primary purpose of this exercise.

The conversion functions and coefficients developed have been applied to compare the minimum energy performance requirements for the most common types of split RACs in the world's major economies. The results show that the Japanese Top Runner requirements are comfortably the most stringent existing requirements for split AC units and that these are between 17% (for more than 6 kW units) and 68% (for less than 3.2 kW units) more demanding than any current or proposed requirements in other economies. The resulting analysis shows that despite the limitations in accuracy of the conversion methods, there are still substantial differences in the efficiency of the AC products sold in different markets. Furthermore, there are major discrepancies among the stringencies of current policy settings.

Testing

The testing component found that testing variable-capacity ACs (inverters) can be a problem for third-party testing or market surveillance when contact with the manufacturer may not be allowed or communication might be difficult. For variable-capacity ACs, the testing laboratory has to obtain information from the manufacturer to set the unit in the correct mode, both for full load and part load rating conditions. In the absence of such information, testing is impossible to conduct in some cases. Nevertheless, the study has demonstrated that it is possible to test these units if the testing laboratory has a test facility where it is possible to set the load which the tested unit has to overcome, the speed of the fan is known, and the part load ratio is defined in the test procedure. It is recommended that an alternative approach to setting the part load capacity on the indoor side of the test sample be standardized to allow uniformity across testing standards and laboratories.

Differences identified among the test procedures used in different economies led to different measurement uncertainties. For most of those differences, there is not a systematic difference for the EER result itself. However, some differences between test procedures were found to have a systematic effect on the EER measurement, including:

- testing temperature conditions;
- the length of the refrigerant piping; and
- the fan correction factor applied to ducted units.

The effects of variation in testing temperature conditions and fan correction were included as part of the conversion coefficient developed under the benchmarking component. Recommendations were made to harmonize the refrigerant piping length and fan correction procedures for ducted units among the different economies.

The study also found that the parasitic power can have an effect on the calculation of the seasonal efficiency. As of today, most test procedures do not include parasitic power in seasonal calculations. It is thus recommended to consider parasitic power (thermostat off, standby, crankcase heater) and input power in all SEER calculations, as incorporated in the recent revision of EU SEER calculation procedures.

Additionally, we recommend that manufacturers pay more attention to the improvement of power inputs in thermostat off and standby modes. In many cases, it is possible to achieve significant improvements without large incremental costs. This would need to be incorporated in basic designs and would therefore benefit EE worldwide, not only in regions where an improvement of this kind can improve the EE classification of ACs. Some strategies that could be considered include:

- Using fans with better efficiency.
- Stopping the fans when there is no load (non-ducted units). If the air temperature sensor is in the indoor unit, this may result in a loss of signal reading. A possibility to overcome this problem could be to start the fan from time to time to check the temperature condition.
- Reducing the speed of the fan when there is no load (ducted units). This can be done if the ventilation and filtration needs can still be fulfilled at lower flow rate.
- Reducing the power input in standby mode. This is, or soon will be, a requirement in many economies.
- Controlling the crankcase heater so that it will function only when required.

Furthermore, the testing component of the study found that inverter units have poor latent heat removal characteristics at low load. There is also anecdotal evidence that a small share of the units on the market do not have any latent heat removal characteristic even at high loading. However, the study has not addressed the question as to whether and how humidity removal should be incorporated as part of requirements for energy efficiency testing procedures and metrics because this is beyond the study scope. Therefore, it is recommended that further research be conducted on this topic to determine the technical implications, the manufacturing cost, the deviation from indoor comfort conditions for buildings in different climates, and the market requirements in dry or humid climates before deciding if this should be included in RAC testing procedures and in EER and SEER calculations.

Ranking

The ranking component developed a ranking tool that can be used to measure the stringency and effectiveness of various S&L initiatives implemented in different countries. It was built as a simple spreadsheet tool that can be used by stakeholders interested in S&L around the world.

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APPENDIX 1: TECHNICAL CHARACTERISTICS OF MEPS AND LABELING PROGRAM

	Australia	China	EU	India	Japan	Korea	Taiwan	US
Program Maturity	7 years	22 years	16 years	1 year	15 years	6 years	20 years	20 years
Update Cycle	Less than 5 years	More than 5 years	More than 5 years	Proposed update will be by 2012 then 2014	More than 5 years (revised in 2010)	The evolution of MEPS shows 4 stages from 1994 to 2004 (which means two revisions). No other revision at the best of our knowledge.	More than 5 years (first revision in 2001)	More than 5 years
Rating Method Establishment for the Country	The Department of Climate Change and Energy Efficiency in collaboration with Standards Australia	China National Institute of Standards (CNIS)	Trade association Eurovent	BEE in collaboration with the BIS	Energy Conservation Center of Japan in the framework of the Top Runner program	Korea Energy Management Corporation (KEMCO)	Bureau of Standards, Metrology and Inspection (BSMI)	Department of Energy in collaboration with the American National Standards Institute
MEPS Harmonization and Basis	Government adaptation of international standards	Government adaptation of international standards	EN which is directly equivalent to the ISO 5151 test procedure	Unique national standard. The adaptation of ISO standards is under consideration	Government adaptation of international standards	Government adaptation of international standards	Government adaptation of international standards	International standards such as ISO
New Product Rating	Certification required for sale	Certification required for sale	Certification required for sale	Certification required for sale	Certification required for sale	Certification required for sale	Certification required for sale	Certification
Testing for Certification	Accredited laboratories paid by manufacturers	Accredited laboratories paid by manufacturers	Accredited laboratories paid by manufacturers	Accredited laboratories paid by manufacturers	Honor-based declaration	Accredited laboratories paid by manufacturers	Accredited laboratories paid by manufacturers	Accredited laboratories paid by manufacturers
Check Testing for Compliance	Accredited laboratories paid by compliance agency	Accredited laboratories paid by compliance agency	Accredited laboratories paid by compliance agency	Accredited laboratories paid by compliance agency	Manufacturers	Accredited laboratories paid by compliance agency	Accredited laboratories paid by compliance agency	Accredited laboratories paid by compliance agency (DOE)
Consequences of Non-Compliance to Manufacturer/Importer	Registration cancellation and liability for costs for testing in case of non-compliance	High financial penalty and product recalls (if possible revoke the business license based on the seriousness of the situation)	Products removed from website of Eurovent certified list	Registration cancellation and product recalls	Public disclosure ("Name and Shame" approach). Approach consisting of four phases: (i) recommendation, (ii) publication of the name of the company, (iii) order and (iv) penalty up to one million yen	Products prohibited from being produced and sold. In case of non-observance of the rules, a fine up to US $18,000	High financial penalty	Certification cancellation

APPENDIX 2: WEIGHTING SCORES ASSIGNED BY EXPERT PANEL

Overall Program Ranking

FINAL	Ranking Criteria	Canada	China	India	Japan	USA 1	USA 2	USA 3
17	MEPS Stringency	10	10	16	20	30	10	20
20	MEPS Program Characteristics	15	20	20	20	20	40	15
20	MEPS Rating Method Technical Characteristics	20	15	18	20	30	5	25
7	Endorsement Label Program Context	10	5	10	10	0	5	7
11	Endorsement Label Program Quality	10	15	8	10	20	5	8
15	Comparison Label Program Context	15	20	15	10	0	25	15
10	Comparison Label Program Quality	20	15	13	10	0	10	10
100	Max. Possible Score for Overall Program Ranking							

MEPS Stringency										
FINAL	**Ranking Criteria**		**Canada**	**China**	**India**	**Japan**	**USA 1**	**USA 2**	**USA 3**
70	**Basis for Setting Stringency Level**		**70**	n/a	**70**	n/a	n/a	**70**	**30**
		Minimum market disruption							
		Statistical analysis of available products							
		Adopting best available international level							
		Techno-economic analysis of potential							
AND									
30	**Stringency of Rating Method**		**30**	n/a	**30**	n/a	n/a	**30**	**70**
	Stringency of Seasonal Rating Method								
		No MEPS program							
		Weak, <SEER 10 USA or SEER 3 metric							
		Between SEER 10 USA/3 Metric & 14 USA/4 metric							
		World-class, SEER 14 USA or EER 4+ metric							
OR									
	Stringency of Steady-State Rating Method								
		No MEPS program							
		Weak, <EER 11 USA or EER 3.2 metric							
		Between EER 11 USA/3.2 Metric & 13 USA/3.3 metric							
		World-class, at least EER 13 USA or EER 3.3 metric							
	Score for MEPS Stringency								

MEPS Program Characteristics									
	Ranking Criteria		Canada	China	India	Japan	USA 1	USA 2	USA 2
30	**MEPS Program Scope**		**30**	**35**	**36**	**50**	**60**	**15**	**35**
		No MEPS program							
		Program covers < 30% of unit sales							
		Program covers 30% - 50% of unit sales							
		Program covers >50% of unit sales							
		Mandatory program, but excludes product classes with large sales volume							
		Mandatory program, includes all product classes with large sales volume							
5	**Maturity of MEPS Program**		**10**	**10**	**7**	**10**	**0**	**5**	**5**
		No program							
		≤ 2 years (just starting)							
		2 - 10 years							
		10 - 20 years							
		> 20 years							
20	**How often is rating method reviewed for updating?**		**15**	**15**	**18**	**20**	**20**	**20**	**25**
		No regularly scheduled review and update							
		Scheduled updates on cycle longer than five years							
		Scheduled updates on cycle equal to or less than five years							

15	**What is the lag time between adoption of a standard and its implementation?**		**10**	N/A	**14**	N/A	N/A	**20**	**10**
		Not defined in program for this economy							
		> 5 years							
		3 - 5 years							
		<3 years							
10	**Is there a mandatory national database of products that comply with MEPS?**		**15**	**10**	**10**	**10**	**0**	**30**	**10**
		No							
		Yes							
20	**MEPS program enforcement in the market**		**20**	**30**	**15**	**10**	**20**	**10**	**15**
		None							
		Honor-based manufacturer declaration of compliance							
		Shaming of violators, public disclosure							
		Low financial penalty							
		High financial penalty and/or product recalls							
	Score for MEPS Program Characteristics								

MEPS Rating Method Technical Characteristics									
Ranking Criteria			Canada	China*	India	Japan*	USA 1*	USA 2	USA 3
20	**Who establishes the rating method for the country?**		**20**	**27**	**22**	**25**	**11**	**30**	**25**
		Manufacturers and/or trade association							
		Non-government third party, such as ANSI process							
		Government agency							
20	**How are new products rated?**		**20**	**20**	**18**	**12.5**	**22**	**30**	**5**
		Honor system without any oversight by manufacturer association							
		Honor system with weak oversight by manufacturer association							
		Honor system with strong oversight by manufacturer association							
		Certification required for sale							
15	**Who does the testing for certification?**		**20**	**13**	**8**	**12.5**	**11**	**20**	**10**
		Manufacturers, or non-accredited labs							
		Accredited labs paid by manufacturer							
		Accredited labs paid by rating agency							
		Government agency (internal)							
	Rating Method for Central Air Conditioners			**40**		**50**	**56**		
10	**Does rating method allow comparing different equipment types & sizes?**		**10**	N/A	**16**	N/A	N/A	**5**	**15**
		No							
		Yes, can compare the major types available in the economy							

10	**What is the basis for the rating method?**	**5**	N/A	**12**	N/A	N/A	**5**	**15**
	Derived from moderate temperature test, ~ 28°C = 82°F							
	Derived from high temperature test, at least 35°C = 95°F							
	Uses both high and moderate outdoor temperatures							
15	**Appropriate test temperature for national climate?**	**15**	N/A	**14**	N/A	N/A	**4**	**15**
	No, international standard used is based on much hotter/cooler climate							
	Yes, local or international conditions that match climate well							
10	**What is the basis for information reported to consumers?**	**10**	N/A	**10**	N/A	N/A	**2**	**15**
	Steady-state at moderate or high temperature							
	Seasonal integration instead of steady-state							
	Seasonal integration **and high-temperature** steady-state							
	Score for MEPS Rating Method Technical Characteristics							

* China, Japan and USA 1 responded to an earlier version of the weighting spreadsheet that included an additional question. Their responses have been normalized to the remaining questions. In addition, these respondents were not asked to weight the same series of questions about the specifics of the rating method. As a result, only the overall value they assigned to the rating method is included.

Endorsement Label Program Context									
Ranking Criteria			Canada	China	India	Japan	USA 1	USA 2	USA 3
25	**Program scope**		**20**	**20**	**20**	**20**	**30**	**25**	**20**
		No program							
		Program covers product types accounting for < 30% of sales							
		Program covers product types accounting for 30% - 50% of sales							
		Program covers product types accounting for >50% of sales							
5	**Label program maturity**		**10**	**15**	**9**	**10**	**0**	**10**	**5**
		No program							
		≤ 2 years (just starting)							
		2 - 10 years							
		>10 years							
20	**Update cycles**		**15**	**15**	**16**	**20**	**20**	**25**	**15**
		None							
		≥ 5 years							
		< 5 years							
15	**Who is responsible for compliance?**		**15**	**15**	**12**	**20**	**10**	**10**	**10**
		No one (e.g., no budget)							
		Manufacturer organization							
		Third party							
		Govt. agency							

10	**Consequences of non-compliance to manufacturer/importer**	**20**	**15**	**14**	**10**	**10**	**10**	**10**
	Almost no penalty							
	Shaming of violators, public disclosure							
	Low financial penalty							
	High financial penalty and/or product recalls							
10	**Are Label Program resources adequate?**	**10**	**10**	**18**	**10**	**10**	**10**	**15**
	Essentially zero time, funds or staffing available							
	Some resources, but quite inadequate							
	Adequate staff and/or funding to do program well							
15	**Label Program communication**	**10**	**10**	**11**	**10**	**20**	**10**	**25**
	Communications and outreach program included							
	Brand management campaign included							
	Score for Endorsement Label Program Context							

Endorsement Label Program Quality								
Ranking Criteria		Canada	China	India	Japan	USA 1	USA 2	USA 3
35	**How widely is the label recognized?**	**30**	**50**	**35**	**70**	**30**	**30**	**20**
	Data not collected by program							
	<25% of potential purchasers recognize label							
	25% - 50% of potential purchasers recognize label							
	50% - 75% of potential purchasers recognize label							
	>75% of potential purchasers recognize label							
20	**Perceived value of endorsement**	**20**	**10**	**25**	**10**	**30**	**20**	**30**
	No consumer research has been done							
	Little value reported							
	Modest value reported							
	High value reported							
25	**Ease of use by consumers**	**20**	**30**	**30**	**10**	**25**	**10**	**30**
	No consumer research has been done							
	Difficult to understand and use							
	Moderate ease of use/understanding							
	High level of use and understanding							
20	**Endorsement level stringency**	**30**	**10**	**10**	**10**	**15**	**40**	**20**
	>60% of available models pass							
	30% - 60% of available models pass							
	10% - 30% of available models pass							
	<10% of available models pass							
	Score for Endorsement Label Program Quality							

Comparison Label Program Context								
	Ranking Criteria	Canada	China*	India	Japan*	USA 1*	USA 2	USA 3
20	**Comparison Label Program Scope**	**25**	**17**	**30**	**20**	**31**	**20**	**25**
	No comparison label program							
	Voluntary program covers < 30% of product sales							
	Voluntary program covers 30% - 50% of product sales							
	Voluntary program covers >50% of product sales							
	Mandatory program, but excludes product classes with large sales volume							
	Mandatory program, includes all product classes with large sales volume							
10	**Type of comparison**	**5**	**11**	**9**	**10**	**12.5**	**30**	**10**
	Continuous							
	Categorical							
5	**Program maturity**	**10**	**16.5**	**7**	**10**	**0**	**0**	**5**
	No program							
	≤ 2 years (just starting)							
	2 - 10 years							
	>10 years							
15	**Update cycles**	**10**	**16.5**	**8**	**20**	**25**	**10**	**10**
	None							
	≥ 5 years							
	< 5 years							
10	**Who is responsible for compliance?**	**10**	**5.5**	**13**	**10**	**12.5**	**10**	**10**
	No one (e.g., no budget)							
	Manufacturer organization							
	Third party							
	Govt. agency							

15	**Consequences of non-compliance to manufacturer/importer**	**20**	**11**	**12**	**10**	**0**	**10**	**10**
	Almost no penalty							
	Shaming of violators, public disclosure							
	Low financial penalty							
	High financial penalty and/or product recalls							
10	**Are Label Program resources adequate?**	**10**	**5.5**	**11**	**10**	**6**	**10**	**15**
	Essentially zero time, funds or staffing available							
	Some resources, but quite inadequate							
	Adequate staff and/or funding to do program well							
15	**Label Program communication**	**10**	**16.5**	**10**	**10**	**12.5**	**10**	**15**
	Labeling program was designed and/or redesigned with consumer research							
	Communications and outreach program included							
	Brand management campaign included							
	Score for Comparison Label Program Context							

* China, Japan and USA 1 responded to an earlier version of the weighting spreadsheet that included an additional question. Their responses have been normalized to the remaining questions.

Comparison Label Program Quality								
	Ranking Criteria	Canada	China*	India	Japan*	USA 1*	USA 2	USA 3
For all Comparison Label Programs:					**30**			
20	**How widely is the label recognized by potential purchasers?**	**25**	**15**	**17**	**N/A**	**15**	**10**	**10**
	Data not collected by program							
	<25% of potential purchasers recognize label							
	25% - 50% of potential purchasers recognize label							
	50% - 75% of potential purchasers recognize label							
	>75% of potential purchasers recognize label							
15	**Perceived value of label**	**15**	**10**	**15**	**N/A**	**15**	**10**	**10**
	No consumer research has been done							
	Generally ignored by consumers and industry							
	Carries modest weight among consumers & industry							
	Carries great weight among consumers & industry							
20	**Ease of use by consumers**	**15**	**20**	**16**	**N/A**	**15**	**10**	**20**
	No consumer research has been done							
	Research indicates it has little value to consumers							
	Modest value to consumers and industry							
	Research shows great value to consumers & industry							
5	**Does label include actual rating value or predicted energy use?**	**15**	**5**	**6**	**N/A**	**5**	**0**	
	Yes							
Points for Categorical Label					**40**			
15	**Stringency of highest category**	**10**	**5**	**9**	**N/A**	**10**	**20**	**15**
	>20% of available models							
	10% - 20% of available models							
	<10% of available models							
	Small number, "aspirational," anticipates new approaches							

10	**Stringency of lowest category**	**20**	**10**	**8**	**N/A**	**10**	**0**	**5**
	Lower than any frequently sold product in the economy							
	Bottom is lowest frequently sold product, or legal minimum							
	Bottom excludes some products marketed							
15	**Appropriate number of categories, if categorical**	**0**	**10**	**5**	**N/A**	**5**	**20**	**10**
	Too few (2 or fewer)							
	Too many to absorb (>7)							
	3 - 7 categories							
Points for Continuous Label					**30**			
25	**How many products at the most efficient end point?**	**20**	**15**	**13**	**N/A**	**20**	**20**	**20**
	>20% of available models							
	10% - 20% of available models							
	<10% of available models							
	Small number, "aspirational," anticipates new approaches							
15	**Does lowest legal efficiency of common product correspond to scale beginning?**	**10**	**10**	**11**	**N/A**	**5**	**10**	**10**
	Scale extends below "legal minimum" product or equivalent							
	Lowest level of scale is "legal minimum" or equivalent							
	Score for Comparison Label Program Quality							

* China, Japan and USA 1 responded to an earlier version of the weighting spreadsheet. Their responses have been normalized as possible to the revised questions. In the case of Japan, the respondent did not provide more detailed weighting to subcategories.