

Improving Global Comparability of Appliance Energy Efficiency Standards and Labels

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The Policy Partners



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Executive Summary

This report presents the largest and most comprehensive comparison of energy standards and labels¹ ever compiled, covering nine major economies and more than 100 products across eight different product areas. Data collected includes over 400 minimum energy performance standards (MEPS) and energy label regulations including their performance requirements, label thresholds, and the test procedures and energy efficiency metrics these are based on. Test procedures and efficiency metrics have been compared and conversion factors developed for approximately half the MEPS and labels identified, allowing for the detailed comparison of performance requirements between economies. This study is intended to provide policymakers with useful tools to assist them in analyzing country data at a macro-level, to enable more informed decisions about the most appropriate policies for their own economies.

The global landscape of test procedures and energy efficiency metrics can seem complex and impenetrable. Comparing energy performance requirements for appliances across economies is difficult because of variations in product definitions, misaligned energy test procedures, and divergent efficiency metrics. Different economies have sometimes selected slightly different versions of the same test procedure and energy efficiency metric, and have sometimes taken completely divergent approaches. Policymakers can use international comparisons of energy performance requirements and product coverage to better inform decisions about the technical or economic performance of products that are able to achieve higher efficiency levels, thereby enabling more stringent energy performance standards and energy labels (S&L) policy. However, the current lack of comparability of energy performance requirements among economies can lead regulators to set more conservative efficiency requirements than they might if they could easily translate or adapt other economies' more stringent policies in their own policy terms.

This report

This report attempts to shed light on the global landscape and enable meaningful comparisons at a macro-level which are helpful and necessary to policymakers in the development of sound and optimized energy efficiency policies. The ease or difficulty with which test procedures can be converted varies greatly depending on a wide variety of factors, as does the reliability of the conversion factors developed. In some cases there is only one test procedure in use (e.g., machine tools) while at the other end of the spectrum, for some products (e.g., walk-in cold rooms), differences are so large that estimating a conversion factor is virtually impossible.

The study builds on the 2011 CLASP study “Opportunities for Success and CO₂ Savings from Appliance Energy Efficiency Harmonization”, aiming to provide more documentation, a broader scope of economies and products, and more comprehensive and actionable information to policymakers about conversion between and ambition levels of MEPS and energy labels. Additional countries were selected based on their potential for global impact and, in particular, CO₂ emissions mitigation. Through a multi-criteria analysis, Australia, Indonesia, Mexico, the Russian Federation and South Africa were added to the countries already included in the 2011 study: China, the European Union, India and the United States.

The main results of the analysis of comparability of test procedures, energy efficiency metrics, MEPS and energy labels between economies are presented in section 6. Results are described per product area, including: an overview of the products covered; to what extent test procedures and efficiency metrics are aligned in that product area; how comparable MEPS and energy label

¹ Standards and labels, or S&L, is used as a collective term for minimum energy performance standards (“MEPS”) and energy efficiency labels (“labels”).



requirements are between economies; typical issues in the comparison of test procedures, efficiency metrics and S&L; where possible, how S&L compare between economies; and what the potential for and issues with further alignment of test procedures, efficiency metrics and S&L for that product area could be.

Standards and labels around the world

This report covers MEPS and energy labels in 9 economies and for over 100 products, of which 72 are presented in the comparative analysis (see section 6). In total, 425 regulations were identified, consisting of 228 MEPS and 197 energy labels. The EU and the US are clearly ahead in MEPS and labels for energy-using products with 67 and 70 products regulated, respectively. Perhaps surprisingly, the EU leads in MEPS, with regulations for 62 products, whereas the US has more energy labels than the EU. This is a reversal of earlier years in which the EU relied more on energy labels and the US more on MEPS. It should be noted that most US labels are ENERGY STAR endorsement labels, whereas most EU labels are categorical energy labels, which are often considered to be more effective in informing the consumer about energy performance and in transforming the market.

Internationally, the most regulated product areas are consumer electronics (CE) and information and communications technology (ICT), household appliances, and space and water heating. Lighting products, motors, fans and pumps, and commercial refrigeration products follow closely. The number of regulations is lower for cooking products, air conditioning products and transformers.

There is substantially more alignment of test procedures and efficiency metrics in the household appliances, lighting, CE/ICT, motors, fans and pumps, and transformers product areas, and less alignment for air conditioning and commercial refrigeration equipment. There is virtually no alignment for space and water heating products or cooking products. Partly, this reflects the level to which products themselves are internationally comparable:

- Many CE/ICT, lighting, motors and transformer products, for example, are the same globally.
- Household appliances have larger regional differences; however, these products have been regulated for energy performance for decades and the impact of different regulations on their performance is by now better known.
- Air conditioning product regulations use the same international test procedure for packaged products, though not for components, and vary greatly in the efficiency metrics used, leading to less alignment overall.
- Cooking and space and water heating products show large regional differences in their design, usage and characteristics, and regulations are typically built on regional test procedures and efficiency metrics, leading to virtually incomparable MEPS and labels for these products.

Test procedure and efficiency metrics alignment

In all economies, less than half of all regulations are fully aligned internationally. Full alignment requires that, first, test procedures are aligned and, second, that local usage characteristics are comparable enough for a globally aligned efficiency metric to define a globally acceptable way of describing what constitutes energy performance for a product. Australia, with its policy of international alignment, shows fully aligned test procedures and efficiency metrics for 14 out of its 36 regulated products (included in this analysis) and Mexico, with its policy of aligning with the US, for 9 out of 22 analyzed regulations. The EU shows a level of alignment on par with Australia and Mexico and the US follows closely behind. Both regulate substantially more products than other economies, yet show levels of alignment not much below Australia. This may partly be explained by



these two economies typically tackling products that have not been regulated elsewhere, and thus setting an international benchmark for testing and evaluating efficiency for those products.

Efficiency metrics in general appear to be much harder to align than test procedures. Whereas international test procedures often seem to provide a suitable way of measuring energy consumption under standardized conditions, efficiency metrics are more often adapted, usually to reflect different national circumstances such as climatic conditions or usage patterns. In fact, where there seems to be a movement towards using internationally aligned test procedures in all economies, efficiency metrics seem to be drifting further apart. A good example of this is in air conditioning, where virtually all economies have aligned to the same international test procedure for testing product performance, but then use quite different efficiency metrics to assess energy performance. In a way, this negates the progress being made in aligning test procedures for the purpose of product comparability but also, and more importantly, it creates a barrier for the transfer of energy efficient technologies between economies.

Potential for further alignment

Based on the information collected, the analysis of comparability and expert opinion, the potential for (further) alignment of test procedures and efficiency metrics has been assessed. In all cases, there is some potential for alignment, although that seems limited to components of test procedures in some cases. For many heating products, for example, basic product designs and operating conditions vary considerable globally, and it will be difficult to define common test procedures that provide adequate testing for all regions.

Of the 72 products analyzed:

- Only 17 (23%) have aligned test procedures, of which 4 (5%) also have aligned efficiency metrics.
- The remaining 56 products (77%) have no test procedure alignment.
- Full test procedure alignment appears possible for 27 more products, and
- Alignment of efficiency metrics for 24 more products.

This would bring the total potential for aligned test procedures to 44 products (61%) and for aligned efficiency metrics to 28 products (39%), including the ones already aligned. The best potential for alignment of test procedures and efficiency metrics appears to be in the lighting products, CE/ICT, motors, and pumps and fans, and the best potential for alignment of test procedures only is in the household appliances and cooking products areas.

S&L ambition levels

The number of products covered by S&L has grown substantially in recent years. The main driver for this has been the extension of scope and ambition level of several S&L programs, primarily in the EU and China. The EU Ecodesign program is now covering more products and often has more ambitious performance requirements, for MEPS and labels, than any other program.

The ambition level of MEPS and labels could only be compared with some reliability for 25% (18 out of 72) of the products covered in the analysis, across household appliances, lighting products, some CE/ICT products, air conditioning and motors. Caution is therefore required when interpreting the results of a comparative analysis of S&L requirements. Across these comparable products, the EU has the most ambitious MEPS for 9 out of 18 comparable MEPS, and the most ambitious energy labels for 9 out of 15 comparable labels. Australia follows the EU with 3 most ambitious MEPS and 5 labels. Next is the US with 5 most ambitious MEPS, all uniquely most ambitious, and 1 most ambitious label, shared with others. China and Mexico follow, trailed by India. Among the countries included in this study, Indonesia, Russia and South Africa have no most ambitious S&L.



01 Introduction: Background

Global landscape

"Twas brillig, and the slithy toves

Did gyre and gimble in the wabe:

All mimsy were the borogoves,

And the mome raths outgrabe."

Lewis Carroll, JABBERWOCKY

The global landscape of test procedures and energy efficiency metrics can seem complex and impenetrable. Comparing energy performance requirements for appliances across economies is difficult because of variations in product definitions, misaligned energy test procedures, and divergent efficiency metrics. Different economies have sometimes selected slightly different versions of the same test procedure and energy efficiency metric, and have sometimes taken completely divergent approaches. Policymakers can use comparisons of energy performance requirements and product coverage to better inform decisions about the technical or economic performance of products that are able to achieve higher efficiency levels, thereby enabling more stringent energy performance standards and energy labels (S&L) policy. However, the current lack of comparability of energy performance requirements among economies can lead regulators to set more conservative efficiency requirements than they might if they could easily translate or adapt other economies' more stringent policies in their own policy terms.

Comparing energy performance data from one economy to another requires finding a way to convert energy performance measurements or declarations from one set of test procedures and energy efficiency metrics to the next. How easy or difficult this is varies from product to product, depending on the choices made by the economies which have adopted a test procedure and set efficiency standards. The range is wide: at one end of the spectrum, for a few products there only exists one test procedure (e.g., machine tools), so a conversion is not really necessary; at the other extreme, for some products (e.g., walk-in cold rooms), differences are so large that estimating a conversion factor is virtually impossible.

Many national test procedures are based on a limited set of international ones, sometimes with modification. In those cases an understanding of the impact of any modifications on the test procedure is required. Though it would be nice if there were always a simple and neat way of precisely converting between these, the reality is that the use of different factors and components, country-specific allowances and test conditions, voltage differences, non-linear behaviors, and different usage requirements (among others) mean that these conversions are often far from straightforward.

This report attempts to shed light on the international landscape and enable meaningful comparisons at a macro-level which are helpful and necessary to policymakers in the development of sound and optimized policies. In order to do this, our experts have gotten into the trenches with these metrics, test procedures and regulations and made their best attempts at finding the factors that determine differences between economies and ways to correct for them. Sometimes this has been straightforward and sometimes incredibly complex. The landscape bears some resemblance to Lewis Carroll's poem, Jabberwocky: at first glance it may seem opaque, but if you look closely, clarity emerges which can guide decisions.



Research context for this study

The study provides a foundation for further work, for example: to compare the energy demand of product groups between economies and assess the potential for (further) energy savings by introducing S&L for products currently not covered in an economy (although covered in another economy); or revising existing S&L if other economies demonstrate that this can be done in a cost-effective way. The study also provides information to assess which product areas offer the best promise for international alignment of S&L and the metrics and test methods that S&L are built on, and can thus help direct international efforts to that end.

The study should be read with this frame of reference in mind: it is intended to support comparisons between countries, assess the order of magnitude of cost-effective energy savings available through the adoption of new or revised S&L, provide information to policymakers developing S&L about those already in place in other economies, and provide direction to international efforts to align test procedures and energy efficiency metrics.

It is not, however, intended to provide a precise conversion for energy performance values between economies on a detailed model by model or even sub-type of product level. In many cases, this requires much more robust technical analyses, often including extensive research and product tests, which is beyond the scope of this study. The CLASP Benchmarking reports, currently available for room air conditioners, reach-in coolers and vending machines, are intended for that purpose and provide a more detailed assessment of the comparability of product test and performance requirements.

Links to previous studies

The 2011 CLASP study “Opportunities for Success and CO₂ Savings from Appliance Energy Efficiency Harmonization”² (or “The Harmonization Study”) discussed benefits and barriers for alignment of appliance energy test procedures in five economies. It also provided rough estimates of the energy and CO₂ savings potential from adoption of standards at levels equivalent to the “World’s Best” standards and “World’s Best” technology. This study provided an important overall view of untapped potential for energy savings through more ambitious standards.

This study aims to build upon this earlier work, by reanalyzing a more complete group of standards in nine economies with high energy consumption and CO₂ emissions, providing more robust background needed to provide actionable information for policymakers. It further includes information about energy labeling thresholds, a policy tool of equal importance as standards. In addition, this study prepares the ground for a comprehensive analysis of the coverage of S&L and the untapped savings potential by allowing for cross-country comparisons of the energy demand and indicative energy savings potentials for nearly all major energy-using products in households, business and industry.

² Available at <http://www.clasponline.org/Harmonization>



02 Scope: Economies

The 2011 CLASP Harmonization study covered the US, the EU, China and India (and, in less detail, Japan). This study adds the following additional five economies: Australia, Indonesia, Mexico, the Russian Federation, and South Africa. Accordingly, nine economies are covered in this report, to the extent possible within the constraints of information availability and the scope of this study:

- | | | |
|------------------------|--------------|-----------------------|
| 1. Australia | 4. India | 7. Russian Federation |
| 2. China | 5. Indonesia | 8. South Africa |
| 3. European Union (EU) | 6. Mexico | 9. United States (US) |

Selection of Economies

This study provides a full revision of the first part of CLASP's previous 'Harmonization Study', making it more policy-relevant and covering more economies and a more detailed product assessment. A first step in the extension of the study was to expand the scope by selecting additional economies to cover. This was done on the basis of the potential for impact in the additional economies and, in particular, for CO₂ mitigation. The idea was to add 3 or 4 economies out of a potential 6 economies which were likely to be of interest, to the 4 economies pre-selected by CLASP for renewed inclusion (China, EU, India, US). A multi-criteria analysis was undertaken which resulted in a decision to add 5 economies with the understanding that there would be little information available for some of them but it would nonetheless be valuable to draw that information together.

Overview and results

Potential additional countries to be covered beyond the US, EU, China and India were analyzed. For this study, a multi-criteria analysis was undertaken for six potential additional economies, to provide a preliminary assessment of which policies to prioritize for analysis. Each of these criteria were scored 3, 2, or 1, generally representing high (3), medium (2), or low (1), and weighted based on relative importance. Overall, the criteria can be divided into three broad categories: 1) CO₂ savings potential; 2) Political potential; and 3) Executability.

Methodology

A list of potential countries was developed in coordination with CLASP. The list is as follows:

- | | | |
|-----------|-----------------|--------------------------------|
| 1. Brazil | 3. Indonesia | 5. Australia |
| 2. Mexico | 4. South Africa | 6. Russian Federation (Russia) |

Next, a list of criteria for evaluating each country's potential was developed to inform the decision as to which countries to select for analysis and addition to those already in the 2011 CLASP Harmonization study. Weightings for each factor were also developed based on its importance. Overall, the criteria can be divided into 3 broad categories: (1) CO₂ savings potential; (2) Political potential; and (3) Executability. These broad categories were broken down further in order to be able to use them to evaluate the potential of the countries based on available data. The list of criteria is as follows:

- **CO₂ emissions of electricity sector.** The electricity sector was specifically selected because the focus is on electrical products. This was considered the most important factor and allocated a weighting of 35%.
- **Executability** was based on data availability and complexity of evaluation. This factor took into account the availability of data and information to analyze from each country and how much time

and effort (resources) would be required to evaluate a country. This factor was allocated a weighting of 20%.

- **Population** was considered a relevant factor in terms of the influence and importance of a country's market but less important than other factors, and therefore allocated a weighting of 5%.
- **Economic growth** is correlated with increased use of appliances and consumption of energy. It was therefore considered an important factor and allocated a weighting of 15%.
- Whether countries could usefully benefit from international assistance and would be open to such assistance was called "**relevance for international cooperation**" and allocated a weighting of 10%.
- The **preliminary effectiveness potential** of each country was evaluated, considering the probability that assistance could result in energy savings in the country. It was allocated a weighting of 10%.

Relevant country characteristics against which to apply the evaluation criteria were researched. These are set out in summary below.

Country characteristics are set out in Annex 1. Table 1 below sets out CO₂ emissions and populations for each country.

Table 1. CO₂ electricity emissions and population by country under consideration

| | Australia | Brazil | Indonesia | Mexico | Russia | South Africa |
|---|-----------|--------|-----------|--------|--------|--------------|
| CO ₂ electricity emissions (Mt CO ₂) | 241 | 43 | 112 | 155 | 348 | 227 |
| Population (million people) | 22 | 190 | 250 | 115 | 143 | 50 |

Results

The results of the multi-criteria analysis are set out in Table 2 below.

Table 2. Scores and results of multi-criteria analysis

| | CO ₂ electricity emissions (per kWh generated) (1=low, 3=high) | Data availability and ease of evaluation (1=low, 3=high) | Population (1=small, 3=high) | Economic growth (1=low, 3=high) | Relevance for International cooperation (1=low, 3=high) | Preliminary effectiveness potential (1=low, 3=high) | Weighted value (1=low, 3=high) | Rank (1=high, 6=low) |
|---------------------|---|--|------------------------------|---------------------------------|---|---|--------------------------------|----------------------|
| Weight | 35% | 20% | 5% | 15% | 10% | 10% | | |
| Australia | 3 | 3 | 1 | 1 | 3 | 2 | 2.35 | 2 |
| Brazil | 1 | 1 | 2 | 2 | 1 | 1 | 1.15 | 6 |
| Indonesia | 2 | 1 | 3 | 3 | 3 | 3 | 2.1 | 4 |
| Mexico | 2 | 2 | 2 | 2 | 2 | 2 | 1.9 | 5 |
| Russia | 3 | 2 | 2 | 2 | 2 | 2 | 2.25 | 3 |
| South Africa | 3 | 2 | 1 | 2 | 3 | 3 | 2.4 | 1 |

Ranked from the country with the highest potential to that with the lowest potential, the results of the analysis are as follows:

- | | | |
|-----------------|-----------------------|-----------|
| 1. South Africa | 3. Russian Federation | 5. Mexico |
| 2. Australia | 4. Indonesia | 6. Brazil |

On the basis of this analysis and ranking, in addition to the original four economies covered (China, India, Europe and the US), as far as feasible given informational constraints and within the scope of this study, five of the six additional economies were added to the analysis: Australia, Indonesia, Mexico, the Russian Federation, and South Africa. Accordingly, the following 9 economies are covered in this report, to the extent possible within the constraints of information availability and the scope of this study:

- | | | |
|--------------|--------------|-----------------------|
| 1. Australia | 4. India | 7. Russian Federation |
| 2. China | 5. Indonesia | 8. South Africa |
| 3. Europe | 6. Mexico | 9. USA |



03 Purpose and Limitations

Using policies from other economies in policymaking

In developing national policies for S&L, policymakers often sensibly look to their counterparts in other economies to evaluate what is possible in global marketplaces for given products. If a product is manufactured globally, it should generally be able to meet the standards currently in place in any given economy, providing certainty that more efficient products can be required through S&L also where these are not yet commonly marketed. Of course, policymakers will take many other factors into consideration in determining appropriate levels for standards in their own economy, including differences in marketplaces and manufacturing costs for various levels of efficiency that exist in many product areas, as well as energy prices and the impact on local industries. Policymakers can then use the information on standards currently in place elsewhere to evaluate the strength of their own policies and ambitions, and assist them in developing and/or updating standards.

There is generally no perfect one-size-fits-all policy which can be applied across all economies. Different economies have different starting points and different local conditions. However, many constructive lessons and much inspiration can be drawn from the policies which are already in place in other economies. Taking those into account can save significant resources and can result in the development of sounder and more effective policies.

It can be difficult to make such comparisons between S&L policies in different economies if test procedures and energy efficiency metrics are not aligned. Not fully understanding how closely related results in one economy are to those in another increases the uncertainty in reaching out and considering policies from differing economies. It also renders comparisons between other economies' policies difficult, since it is hard to know how accurate those comparisons are.

This study is intended to provide policymakers with useful tools to assist them in analyzing country data at a macro-level. It is intended to give policymakers tools, where possible, to compare S&L policies between different economies and, where that is not possible, to know that and show which factors prevent comparison. We hope that this will result in policymakers being able to make more informed decisions, and therefore assist them in developing the most appropriate policies for their own economies and markets.

Macro-level conversions

Given the potential complexity, in most cases, of developing precise conversion factors, this study is not intended to be used for conversions on a model-by-model basis but rather for conversions between product types at a national level. The purpose is to provide an aggregate comparison of efficiency levels across a product type, not a detailed comparison for specific sub-types.

All products are different from each other, as are the markets in which they operate and often also the legislation of different economies which have implemented S&L policies concerning those products. In some cases, the MEPS or labeling policies are incredibly complex and contain numerous levels and sub-product categories. All of the products in regulated product ranges are not always highly relevant in terms of policy development due to the volumes of product in each category. For example, MEPS for US refrigerators designate 42 product categories, but most (estimated at over 90 percent) fall within 7 of those classes. It is beyond the scope of this report to analyze and develop conversion factors for sub-product categories that are rarely used or to develop complex equations for products with MEPS and labeling policies which are based on curves or difficult to express mathematically. Accordingly, where that is the case, we have selected representative products and developed conversion factors for those.



04 Methodology

This report and the conversion factors contained in it were developed through four main tasks described in this section:

- Developing an inventory of MEPS and labels and the underlying test procedures and efficiency metrics in the 9 economies selected
- Assessing the energy performance levels across different economies
- Developing conversion factors
- Assessing the robustness of the conversion factors

Summary descriptions of conversion factors and considerations for their development are included in this report, in particular in Annex 2: Product Fact Sheets. More detailed information is available upon request from CLASP for interested experts.

Task 1: Inventory of MEPS and labels in 9 economies

As a starting point, a complete overview of existing MEPS and energy labels in all selected economies (Australia, China, EU, India, Indonesia, Mexico, Russian Federation, South Africa, and US) was compiled. This included the energy performance levels required by those regulations and the test procedures and efficiency metrics on which performance levels are based. The existing CLASP Global S&L Database had recently been updated for all relevant economies except for the US. The US section of that database was updated and the overall database ordered by product groups.

Task 2: Assessment of energy performance levels across different economies

The aim of this task was to compare product energy performance data across economies, even though that data is based on different test procedures and energy efficiency metrics. In order to do this, research was undertaken to determine which, if any, international test procedure was used as the basis for national energy performance data and which modifications to that test procedure, if any, had been made, as well as whether these are likely to have a significant effect on reported energy performance.

Product experts, working with country experts where interpretation or translation was needed, determined which international test procedures³ were used in an economy for energy performance data, which modifications had been made to that test procedure and how significant these are. They also determined the energy performance levels required by a specific standard, and the highest and lowest energy performance level on the scale of energy labels (single level for endorsement labels or marks), and described these levels in a standardized way. This information was added to the information from the CLASP Global S&L Database, and an overview table for use in impact calculations was developed. The steps were as follows:

- **Determine international test procedure relevant for each country-specific performance level.** We assessed standards and labels regulations, in place or in preparation, for the test procedure required for energy performance measurements or declarations. This national test procedure was compared with international test procedures (primarily ISO/IEC; EN; US DOE; US ENERGY STAR; US ASHRAE; or JIS test procedures) to determine which international procedures

³ An international test procedure, for this study, is a test procedure used in multiple countries. It is not necessarily a test procedure established by an international test standards organization such as IEC or ISO; it can, for example, also be a test procedure established by ENERGY STAR and used in many countries.

formed the basis for the national procedure. This study built on the work done for the previous Harmonization Study, which determined this relationship for 26 product groups, with some products further broken down into sub-types. We checked if this information was still valid and added information for 5 new economies and new product groups.

- **Record performance level & reference test procedure in database.** Information was recorded from the CLASP Global S&L Database for this study, updating and adding to existing information where needed.
- **Record performance level & reference test procedure in overview table.** An overview table of energy performance requirements for MEPS and energy labels was developed for all product groups and economies. The requirements were listed in a generic format, so that requirements were made comparable for further analysis. The underlying international test procedure for performance requirements was clearly indicated, as were any substantial differences between the national test procedure and the underlying international one.
- **Determine “High Label” value.** Requirements for the highest label class of categorical energy labels as well as for endorsement labels or marks (the best known of which is ENERGY STAR) were compared for each country, and the most demanding requirements recorded as the “High Label” value. Continuous (non-categorical) energy labels were not included, as these offer no specific threshold or requirement that can be compared to other economies⁴.
- **Review of performance level assessment, adjust if needed.** A technical review of the overview of energy performance requirements was undertaken, to make sure that this analysis was transparent, well documented and as robust as possible within the confines of this study. Adjustments were made based on reviewer comments.

Task 3: Conversions between test procedures

In order to be able to compare energy performance data from one economy to another, it was necessary to be able to convert energy performance measurements or declarations from one set of test procedure and efficiency metrics to another one. Most national test procedures are based on a limited set of international ones, sometimes with modifications, and it was necessary to develop conversions between those international test procedures (and work out the impact of modifications, where relevant) for all product groups.

Available existing research was reviewed, including the work of the IEA 4E Mapping & Benchmarking (M&B) Annex, CLASP’s Benchmarking analyses and scoping studies, the analysis done for the previous Harmonization Study and various product-specific studies to determine for which product groups suitable conversion factors were already in place. For other product groups, the international test procedures in use were determined. Those procedures were then analyzed focusing on how differences between procedures can affect measured energy performance and estimated conversion factors between procedures. All work for this task was subjected to a technical review.

For some products (e.g., machine tools), only one test procedure is operational and conversions are not needed, while for other products (e.g., walk-in cold rooms), differences are so large that estimating conversion factors was not feasible within the scope of this study. For those cases, the main option is working with the reported energy performance as is, setting aside the unknown impact of test procedure differences for the moment. For the majority of products, however,

⁴ This, in practice, means that US FTC energy labels could not be included, but US ENERGY STAR labels are. Since the latter cover far more products, and there is no product covered in this report that is covered by an FTC label but not by ENERGY STAR, this has virtually no impact on the report and its conclusions.

reasonably accurate conversion, if not precise at a single product level, were available or could be estimated for this study. Task 3 was carried out in the following steps:

- **Retrieve & summarize available research into test procedure comparisons.** A team of experts which has been involved in a large number of product analyses and comparisons used their expertise, along with publicly available research and the internal documentation of assumptions underpinning the 2011 Harmonization Study. They determined the conversion factors available from those sources, reviewed these and amended where needed. The conversion formulae were then documented.
- **Expert assessment of product comparisons for other products.** The expert team assessed, for product groups for which conversion factors were unavailable, what the differences were between key test procedures and how these were likely to affect measured energy performance. Where comparative test data exist, we used this data to validate our analysis. We documented the conversion formulae to be used in this study, as well as the assumptions underpinning the conversions.
- **Review of performance level assessment, adjust if needed.** The analysis of conversion factors was reviewed. The review critically checked the documentation and validity of assumptions, documentation of sources, and internal consistency of the analysis. Where needed, conversion factors were reviewed to reflect reviewer concerns.
- **Index country performance levels to selected test procedures.** Once conversion factors had been determined, economy-specific (and test procedure-specific) energy performance levels were indexed to a selected test procedure for each product. Product experts selected, for each product, the most appropriate international test procedure to align performance levels with. In general, this would be the test procedure most widely used (directly or indirectly) in the economies concerned, to limit the number of conversions needed for comparisons and models. Where country-specific test procedures deviate significantly from the underlying international test procedure, the conversion was adjusted to take account of these differences. Performance levels were converted to the level based on the selected aligned test procedure and energy efficiency metrics were added to the overview table.

Task 4: Assessing the robustness of the conversion factors

Two types of conversion factors were developed for this study: test procedure conversion factors, and energy performance metric conversion factors. The former (test procedure conversion factors) are the numbers by which the result from the test procedure (the regional test procedure) should be multiplied in order to convert it to the reference test procedure (which is often an international standard but not always). The latter (energy performance metric conversion factors) is the number by which the result from the national energy performance metric should be multiplied in order to convert it to the metric produced by the reference test procedure. It is often the same multiplier as is used to convert from the regional test procedure to the reference test procedure.

As previously mentioned, these conversion factors are not intended to be used for conversions on an individual product (model by model) basis but rather for comparative conversions between product types at a national level. Some product types have significantly different requirements for sub-types, in which conversions need to be derived for representative sub-types. Although this approach is a fair approximation of an average conversion for the product type overall, as intended with this study, it does not necessarily mean that this also provides an accurate conversion for individual models or all sub-types of products.

Conversion factors and reliability

Given the possibility of widely diverging levels of reliability for conversion factors, the expert team then evaluated the reliability of the conversion factors developed. As well as documenting potential

issues with conversion factors, a traffic light system was used to clearly indicate how reliable the factors were for high-level comparisons of high volumes of products (not for individual products). Conversion factors were coded as follows:

- Green indicates a high level of confidence in the conversion factor. Converted results would be in the right ballpark, with expert assumption that results are within 10% from the indicated value.
- Amber indicates a medium level of confidence in the conversion factor. Converted results would broadly be in the right ballpark, with the potential for substantial outliers and the margin of error is larger. Expert assumption is that results are within 25% from the indicated value.
- Red indicates unreliable conversion factors. Converted results would be better than nothing, but may be substantially off. Expert assumption is that results could be more than 25% from the indicated value.
- In several cases, conversion factors are listed as not applicable (N/A), indicating there is insufficient information even for unreliable conversion factors.

Information about product MEPS, energy labels and conversion factors is included in section 6 of this report (and, in more detailed descriptions, in Annex 2: Product Fact Sheets). Please note that the overviews in this report only present values where there are identified MEPS and energy labels in place, and therefore show empty cells for countries that have not introduced regulations for a product type.

Overview: Product definitions, Test procedures, efficiency metrics, performance levels and S&L

Energy performance regulations are built on a series of interconnected parts, each defining one building block for energy performance requirements and energy labels. The table reads from the bottom up, reflecting that the regulations that are most visible build on underlying, less visible parts.

| | |
|---------------------------|--|
| MEPS & Labels | Minimum Energy Performance Standards and Energy Labels (together: S&L) regulations are the tip of the S&L iceberg. S&L regulations describe the performance levels that a product needs to meet in order to qualify for a MEPS level or an energy label category. S&L regulations typically also set the legal framework for S&L, as well as, sometimes, product registration and compliance checking requirements and information requirements for the suppliers of products. |
| Performance levels | Energy performance levels are thresholds that a product needs to meet in order to qualify for a certain performance level, as defined by an efficiency metric, measured by a test procedure and applicable for products meeting a product definition. Recently, some international test procedures, such as the one for electric motors, started defining energy performance levels alongside test procedure and efficiency metrics characteristics, greatly enhancing international comparability of energy performance requirements. |
| Efficiency metrics | Efficiency metrics define how an energy consumption measurement is translated into an energy performance indicator. Efficiency metrics can be straightforward or highly complex, and anything in between. An example of a fairly straightforward efficiency metric is the calculation that is necessary in Australia to determine the expected annual energy demand of a television based on the on-mode power demand and the standby power demand of that television, multiplied by on- and standby-mode usage periods. |

| | |
|----------------------------|---|
| Test procedures | Test procedures describe how the energy consumption of a product should be determined. A test procedure is usually a simplified reflection of how products are used in reality, defining elements such as the ambient conditions in which a product is tested, which duty cycle is applied for a test, which measurement instruments are to be used, how product characteristics such as volume or size are to be measured and many more aspects. |
| Product definitions | Product definitions define what is included in regulations for a specific product. This seems trivial, but isn't. Different economies, for example, use different size and capacity limits to define a product category, and sometimes group sub-types of products differently. Different size limits and categories greatly reduce comparability between economies. |



05 Products and Product Categories

Table 3 provides an overview of the product areas and product groups selected for this report.

Table 3. Products areas and product groups

| Product area | Product group |
|--|--|
| Household appliances | Household refrigeration appliances |
| | Household clothes washing machines |
| | Household clothes dryers |
| | Household dishwashers |
| Lighting products | Lighting - General purpose lighting (incandescent, CFLs halogen, LEDs) |
| | Lighting - Directional lighting (Halogen, reflector lamps, LEDs) |
| | Lighting - Street lighting (HID lamps, LEDs) |
| | Lighting - Commercial / office lighting (Linear Fluorescent Lamps and related systems, including ballasts) |
| | Lighting - Other lighting applications |
| Consumer electronics & ICT equipment, standby and power supplies | Televisions |
| | Displays |
| | Digital television decoders (set top boxes) |
| | External power supplies and battery chargers |
| | Audio equipment |
| | PCs and servers |
| | Imaging equipment |
| Air conditioning | Room air conditioners (non-ducted air conditioners) |
| | Central air conditioners (ducted air conditioners) |
| | Chillers |
| Space and water heating | Central heating boiler |
| | Central heating furnaces |
| | Other space heating products |
| | Water heating appliances |
| | Industrial boilers |
| Commercial refrigeration equipment | Reach-in coolers |
| | Refrigerated vending machines |
| | Walk-in cold rooms |

| Product area | Product group |
|------------------------|-------------------------------|
| Cooking products | Residential cooking equipment |
| | Commercial cooking equipment |
| | Coffee machines |
| Motors, pumps and fans | Electric motors |
| | Pumps and Circulators |
| | Fans |
| Transformers | Distribution transformers |
| Miscellaneous products | Commercial laundry products* |
| | Medical imaging equipment* |

* Not covered in section 6 as there is no comparable information to report for these products.



06 Overview of each product category and associated test procedure

This section presents the main results of the analysis of comparability of test procedures, energy efficiency metrics, minimum energy performance standards and energy labels between economies. Results are described per product area, including an overview of the products covered; to what extent test procedures and efficiency metrics are aligned in that product area; how comparable MEPS and energy label requirements are between economies; typical issues in that comparison of test procedures, efficiency metrics and S&L; where possible how S&L compare between economies; and what the potential for and issues with further alignment of test procedures, efficiency metrics and S&L for that product area could be. Descriptions of test procedures, efficiency metrics and S&L in place are included in Annex 2; summary information is presented here.

Household Appliances

Products covered

Products included within household appliances in the analysis are:

- Small refrigerator
- Small refrigerator-freezer
- Medium refrigerator-freezer
- Chest freezer
- Clothes washer
- Combination clothes washer/dryer
- Clothes dryer
- Dishwasher

In most countries a significant proportion of household refrigerators, refrigerator-freezers and freezers are used in offices and workplaces. Typical products range in storage capacity from 50 to 750 liters. Household washing machines (clothes washers) are generally broken down into horizontal axis (drum) and vertical axis (agitator and impeller) with most products being in the range of 3kg to 10kg capacity. A number of product types exist for electric clothes dryers with air vented versus condensing dryers available. The heat source for drying can be resistance – with a low capital cost – and more recently heat pumps with double efficiency but higher capital cost. The majority of dishwashers are a standard size (usually 600mm width) but smaller models do exist, as well as larger models. Dryers and dishwashers are predominantly used in developed countries.

Test procedure and efficiency metrics alignment

For **refrigerators, refrigerator-freezers and freezers**, all of the test procedures covered measure the energy consumption of the product at a single and elevated ambient temperature. However, each of the test procedures sets different internal temperatures for energy measurements and does not provide information at other operating conditions, nor the energy consumption that is likely during normal use. The new IEC62552-3-2014 test procedure measures energy at two ambient temperatures (16°C and 32°C), as well as processing efficiency, thus providing much more information on likely field performance. While most countries appear to use energy consumption



per adjusted volume as the raw efficiency metric for refrigerators, refrigerator-freezers and freezers, the concept of adjusted volume has many flaws, and comparisons are currently very difficult due to the historically poor alignment of test procedures.

For this analysis, conversion factors were developed based on defining four representative sample products and calculating the energy threshold for each set of local test conditions and efficiency metrics. Test conditions were compared to the new IEC62552-3-2014 test procedure, and corrections made to address differences in ambient conditions. Efficiency metrics were calculated taking into account local factors for adjusted volume and other aspects, and resulting energy consumption values were then compared to determine conversion factors.

Test procedures for **clothes washers**, which define a load and place this into a machine, are poorly aligned. Efficiency metrics are also highly variable. While most regions use rated capacity, many regional specifications now include part loads and a range of wash temperatures rendering local energy values completely incomparable across regions.

Conversion factors were developed by defining representative horizontal and vertical axis machines and calculating local energy metric and efficiency threshold requirements. These were then corrected for known issues regarding test procedure and wash temperature settings. For the US, implied drying energy use was removed from the energy calculation, and for all countries calculated energy values were adjusted to reflect those of a warm wash at rated capacity as defined in IEC60456 for comparison. No corrections are available for many other confounding factors. Because of this, and given the high level of variability in how performance is controlled, meaningful international comparisons are almost impossible.

Test procedures for electric **dryers** include parameters that vary substantially among different regions and between individual machines. The only feasible approach to developing conversion factors for dryers was to define a representative dryer and calculate energy thresholds for each region, with corrections added for moisture content, composition of the test load, and specified usage (generally partial load). Those differences in load, initial and final moisture contents are significant. Final moisture content reflects what should be generally understood as “acceptably dry” with the US and Australia having drier specifications for final moisture content than IEC/Europe; small differences in this specification have large impacts on measured energy. Although the factors influencing dryer energy performance are generally known, the size of corrections needed makes comparisons between regions somewhat unreliable.

For **dishwashers**, most regions outside of North America are aligned, or close to being aligned, in terms of test procedures. A representative product was defined and energy thresholds calculated for each country, with corrections added for test condition differences (typically inlet water temperature). There are, however, still widely varying approaches to dealing with performance (washing and drying), making alignment of efficiency metrics virtually impossible.

Table 4 presents the conversion factors for household refrigerators and freezers, clothes washers, clothes dryers and dishwashers as determined for this analysis.



Table 4. Conversion factors for household refrigerators and freezers, clothes washers, clothes dryers and dishwashers

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|----------------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| | Test procedure | Efficiency metrics |
| Small refrigerator | 0.95 | | 1.63 | | 1.63 | | 0.95 | | | | 0.96 | | 0.99 | | N/A | | 1.63 | |
| Small refrigerator-freezer | 1.08 | | 1.26 | | 1.26 | | 1.08 | | | | 1.17 | | 1 | | 1.26 | | 1.26 | |
| Medium refrigerator-freezer | 1.08 | | 1.26 | | 1.26 | | 1.08 | | | | 1.17 | | 1 | | 1.26 | | 1.26 | |
| Chest freezer | 1.15 | | 1.12 | | 1.12 | | | | | | 1.01 | | 1.01 | | N/A | | 1.12 | |
| Clothes Washer | 1 | | 0.55 | | 0.68 | | N/A | | | | 1 | | 1 | | 0.55 | | 0.65 | |
| Combination Clothes Washer/Dryer | | | | | N/A | | | | | | | | N/A | | N/A | | N/A | |
| Clothes Dryer | 0.78 | | | | 1.3 | | | | | | | | 1.3 | | | | N/A | |
| Dishwasher | 1.05 | | | | 1 | | | | | | | | 0.93 | | 1 | | 1 | |

Comparability and alignment of MEPS and energy labels

MEPS for **refrigerators and freezers** are more stringent in the EU than in other economies. The data presented is based on conversions which have substantial limitations; nevertheless, it appears that US, Chinese and Mexican MEPS are considerably less stringent, and Australia's and India's MEPS stand out as being the least stringent. Sometimes, progress in US refrigerator energy demand is shown to demonstrate the effectiveness of S&L. Data presented here, combined with the fact that US refrigerators are typically larger and thus more energy demanding even at the same efficiency level, suggest that there may be better examples to show what can be achieved with S&L.

Label classes follow a somewhat similar pattern, with two notable exceptions in Australia and the US. Australia's energy labels include many classes for more efficient products which are not used until new products meeting the requirements of those classes come onto the market. The energy demand indicated represents the best energy efficiency currently presented through Australia's energy labels, not the highest level possible. The US uses a continuous energy label which cannot be compared to labels used in other economies and has not been included in this overview.

Direct comparisons of MEPS levels are much more complicated for other household appliances, due to performance requirements being in place in some economies but not in others.

For **clothes washers**, EU and US MEPS values appear virtually the same; however, they are not comparable. EU energy tests include a fairly stringent test of wash performance, whereas US tests do not. Wash performance requirements have a substantial impact on energy demand, and since it is not known how wash performance compares between regions, resulting energy performance data may not represent the same functionality.

A similar situation applies to **dishwashers**, where the EU MEPS is considerably more stringent than the US one. As for **washing machines/clothes washers**, the EU test procedure includes cleaning performance, which is not tested in the US. Australia's most efficient energy label class stands out as having a much lower energy demand than others.

The US MEPS for **clothes dryers** seems to be more ambitious than the EU one, whereas the EU high energy label indicates far greater efficiencies than the US one. This can be explained by the availability of heat pump dyers in the EU, which have a much better energy performance, but which are not commonly marketed in the US or other economies.

Table 5 provides an overview of MEPS and energy label thresholds for household refrigerators and freezers, clothes washers, clothes dryers and dishwashers (non-converted).

Table 5. Original (non-converted) MEPS and energy label thresholds for household appliances

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|----------------------------------|-----------|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Small refrigerator | 332 | 101 | 204 | 128 | 113 | 59 | | 248 | | | 311 | | 227 | | N/A | N/A | N/A | N/A |
| Small refrigerator-freezer | 414 | 163 | 313 | 179 | 205 | 107 | 482 | 198 | | | 349 | | 294 | | N/A | N/A | N/A | N/A |
| Medium refrigerator-freezer | 499 | 232 | 456 | 261 | 294 | 154 | 580 | 238 | | | 427 | | 360 | | N/A | N/A | N/A | N/A |
| Chest freezer | 334 | 161 | 360 | 200 | 188 | 99 | | | | | 344 | | 327 | | N/A | N/A | N/A | N/A |
| Clothes Washer | | 0.28 | 1.35 | 0.78 | 0.89 | 0.69 | | 0.08 | | | N/A | N/A | 0.93 | N/A | N/A | | N/A | N/A |
| Combination Clothes Washer/Dryer | | | | | N/A | N/A | | | | | | | | N/A | | N/A | | N/A |
| Clothes Dryer | | 2.65 | | | 2.69 | 0.76 | | | | | | | 2.34 | 2.26 | | | | N/A |
| Dishwasher | | 0.38 | | | 1.04 | 0.83 | | | | | | | 1.42 | 1.37 | N/A | N/A | | N/A |

Table 6 provides an overview of MEPS and energy label thresholds for household refrigerators and freezers, clothes washers, clothes dryers and dishwashers converted for test procedure and efficiency metrics differences where appropriate.

Table 6. Converted MEPS and energy label thresholds for household appliances

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|----------------------------|-----------|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Small refrigerator | 315 | 96 | 332 | 208 | 183 | 96 | | 236 | | | 298 | | 224 | | N/A | N/A | N/A | N/A |
| Small refrigerator-freezer | 448 | 177 | 394 | 225 | 258 | 135 | 522 | 214 | | | 408 | | 294 | | N/A | N/A | N/A | N/A |
| Medium | 540 | 251 | 575 | 329 | 370 | 194 | 628 | 257 | | | 499 | | 360 | | N/A | N/A | N/A | N/A |

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | | |
|----------------------------------|-----------|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|--|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | |
| refrigerator-freezer | | | | | | | | | | | | | | | | | | | |
| Chest freezer | 384 | 185 | 404 | 224 | 211 | 111 | | | | | 346 | | 329 | | N/A | N/A | N/A | N/A | |
| Clothes Washer | | 0.28 | 0.74 | 0.43 | 0.61 | 0.47 | | 0.08 | | | N/A | N/A | 0.93 | N/A | N/A | | N/A | N/A | |
| Combination Clothes Washer/Dryer | | | | | N/A | N/A | | | | | | | N/A | | N/A | | | N/A | |
| Clothes Dryer | | 2.07 | | | 3.49 | 0.99 | | | | | | | 3.05 | 2.94 | | | | N/A | |
| Dishwasher | | 0.40 | | | 1.04 | 0.83 | | | | | | | 1.32 | 1.28 | N/A | N/A | | N/A | |

Potential for alignment of test procedures, efficiency metrics and S&L

Alignment of **refrigerator** test procedures and efficiency metrics is complex. On the one hand, a new IEC test procedure (IEC62552-3-2014) has been developed which seems to offer technical benefits over existing test methods, by testing products over a representative range of ambient temperatures. On the other hand, refrigerator test procedures and metrics show substantial regional differences and product designs may in part be optimized for how products are tested. A switch to a radically different test procedure in an economy may thus result in substantial shifts in the energy efficiency rankings of existing products. Since all included economies already have refrigerator test procedures, it is difficult to assess how the technical advantages of a new IEC test procedure, with probably better representation of refrigerator energy demand in real life, compare to vested interests in existing regional test procedures and the market disturbance that a switch-over may entail. The situation is largely similar for other household appliances.

Clothes washers are assessed radically differently in different economies, with major differences in the testing of wash performance and whether spin performance is included in washing energy performance, both of which have considerable impacts on energy use. In addition, energy consumption can be rated per unit of load capacity or drum volume. Alignment of clothes washer testing would need to start with finding common approaches for these issues, more than resolving, for example, differences in actual test conditions.

The same broadly applies to **dishwashers**, for which the inclusion of cleaning and drying performance is a major difference between economies. Most regions outside of North America are aligned or are close to being aligned in terms of test procedures. The US uses a different test load (which could be addressed through an update of the relevant IEC60436 test procedure). This, however, does not address the differences in testing for cleaning and drying performance, or whether a hot water supply is specified (as is common in the US). Energy and water consumption are closely aligned with cleaning and drying performance, implying that introducing performance testing may require a change in the energy requirements in an economy. It further seems difficult to achieve global agreement on what constitutes acceptable dishwashing performance.

Clothes dryers are currently tested under quite different conditions, with the two largest differences being load composition and allowed residual moisture content. The basic approach, however, is the same in all economies, in that a moist load is placed in the machine and dried until it reaches the residual moisture content requirement. These differences are mainly historical and

could be addressed through the use of IEC61121 Edition 4 as the basis. International alignment of test procedures seems achievable if the IEC load composition and final moisture content specification can be generally accepted. The test procedure also has an option to allow a load to be tested at a low and high initial moisture content, which would allow dryer energy performance testing to be matched with clothes washer testing and/or assess the impact of partial loads.

Lighting

Products covered

Products covered within lighting are:

- Lamp - Compact fluorescent
- Lamp - Filament, non-directional
- Lamp - Filament, directional
- Lamp - HID high pressure sodium
- Lamp - HID metal halide
- Ballast - HID (all)
- Lamp - Linear fluorescent
- Ballast - Linear fluorescent

Compact fluorescent lamps (CFLs) or bulbs include the curly, screw-in versions of the long tube fluorescent lights for which the ballast is integrated into the lamp, in contrast to linear fluorescent lights consisting of fluorescent lamp tubes with external ballasts. **Filament lamps** may or may not contain gases influencing the process of incandescence. Some lamps contain halogens that are employed to maintain a clean bulb wall. The **directional element** of the filament lamps refers to a lamp having at least 80% light output within a solid angle of π sr (corresponding to a cone with angle of 120°). **High Intensity Discharge (HID)** lamps are lamps in which the light is produced, directly or indirectly, by an electric discharge through a gas, a metal vapor or a mixture of several gases and vapors; and in which the light producing arc is stabilized by wall temperature and the arc has a bulb wall loading in excess of 3 watts per square centimeter. **Ballasts** are lamp control gear, which serves to limit the current of lamps to the required value. It may also include means for transforming the supply voltage, dimming the lamp, correcting the power factor and, either alone or in combination with a starting device, providing the necessary conditions for starting the lamps. **Linear fluorescent lamps** are discharge lamps of the low pressure mercury type in which most of the light is emitted by one or several layers of phosphors excited by the ultraviolet radiation from the discharge. Fluorescent lamps are supplied either with or without integrated ballasts. The linear aspect refers to the shape of the bulbs which are straight.

Test procedure and efficiency metrics alignment

For **CFLs** test procedure IEC 60969 references globally-accepted CIE photometry methods, and only the US and Mexico do not base their CFL test procedure on this standard. However the test procedures, at least for efficacy, are well aligned between the IEC and North American standards bodies. As a result no conversion was necessary for CFL test procedures (efficacy) or metrics (efficacy). The same applies to **HID lamps** and **linear fluorescent lamps**.

All testing for **filament directional lamps** as well as **filament non-directional lamps** is based on CIE 84 and the test procedures, at least for efficacy, are well aligned so no conversion was necessary. Although the test method is the same in terms of measurement of light output, the EU MEPS for directional lamps only considers a certain amount of light – within a 90 or 120 degree “cone” depending on lamp type – whereas most other economies (e.g., the US and Australia) consider the light in a 180 degree “hemisphere”. Converting between the “cone” approach and the “hemisphere” approach would be very difficult because the relationship is likely to vary for various lamp types

and would require in-depth examination of light distribution data from many lamps. This is not an issue for non-directional lamps, which are all tested in the same way.

For **HID ballasts**, Mexico, the EU and China base their test procedure on IEC 60923; therefore no conversion was necessary for test procedures and metrics. Representative products were used in order to compare MEPS limits as those vary depending on product parameters such as lamp power. The reference test procedures for **HID lamps** are held in IEC standards (IEC 61167, IEC 60662 and IEC 60188), which rely on globally accepted CIE photometry methods.

For **linear fluorescent ballasts**, Australia, China, and the EU base their test procedure on EN 50294. The US is moving to a simplified test procedure, which does not involve photometric testing, and other countries might follow this example. For **linear fluorescent lamps**, most countries base their test procedure on IEC 60969, while the US and Mexico follow different standards. However, the test procedures, at least for efficacy, are well harmonized between the IEC and North American standards bodies. Mandatory MEPS are set by Australia, China, the EU and the US and cover efficacy as well as other performance parameters such as lumen maintenance and color rendering index. Label programs are in place in Mexico and India.

Table 7 presents the conversion factors for lighting as determined for this analysis.

Table 7. Conversion factors for lighting

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|----------------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| | Test procedure | Efficiency metrics |
| Lamp - Compact fluorescent | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | 1 | 1 | | | | |
| Lamp - Filament, non-directional | 1 | 1 | | | 1 | 1 | | | | | | | 1 | 1 | N/A | N/A | | |
| Lamp - Filament, directional | 1 | 1 | | | 1 | 1 | | | | | | | 1 | 1 | | | | |
| Lamp - HID high pressure sodium | | | 1 | 1 | 1 | 1 | | | | | 1 | 1 | | | | | | |
| Lamp - HID metal halide | | | 1 | 1 | 1 | 1 | | | | | 1 | 1 | | | | | | |
| Ballast - HID (all) | | | 1 | 1 | 1 | 1 | | | | | 1 | 1 | | | | | | |
| Lamp - Linear fluorescent | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | | | | |
| Ballast - Linear fluorescent | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | 1 | 1 | | | | |

Comparability and alignment of MEPS and energy labels

For lighting, representative products were used in order to compare MEPS limits, as the MEPS limit varies depending on product parameters such as lamp power and lumen maintenance.

Many countries – though not Indonesia, India, Russia and South Africa – have set mandatory MEPS for **CFLs**, typically covering efficacy, and in most cases many other performance parameters such as lifetime, start time, color rendering index, etc. The range of efficacy values (55-65 lm/W) is closely aligned amongst countries that have been regulating this product category for quite some years now.

Australia, the EU and the US have MEPS for **filament directional lamps** that typically cover efficacy and, in some cases, other performance parameters such as lifetime and lumen maintenance. This product is somewhat comparable across economies, except for the issue of the “cone” vs. “hemisphere” approach described above in relation to the EU MEPS. As a result of this and other complexities, there is no direct comparison possible between MEPS values in the EU and elsewhere.

Australia, the EU and the US also have MEPS for **filament non-directional lamps**, effectively banning traditional incandescent lamps (but allowing improved efficiency versions on the market). China has banned traditional incandescent lamps based on a technical description, not a performance requirement. The US MEPS requirement is considerably more demanding than Australia’s and the EU’s. The EU is the only economy with an energy label for non-directional filament lamps, as part of a label covering all non-directional lamp types. Highest label classes, however, are practically not achievable with filament lamps. The highest class available for a filament lamp is the B-class, which is an unusually wide class with a maximum threshold lamp being far more than twice as efficient as a minimum threshold lamp. The minimum B-class threshold is almost the same as (just below) the US MEPS requirement (for a 1000 lm lamp). This suggests that this label has limited use in differentiating between types of filament lamps, although it does provide for a direct comparison with, for example, CFL and LED lamps.

China, the EU and Mexico have S&L programs for **HID Ballasts** with MEPS covering ballast efficiency. This product type is relatively comparable due to the wide use of IEC60923. The same countries have S&L programs for **HID lamps** (metal halide, sodium and mercury vapor lamps) with MEPS all covering efficacy, and in some cases other performance parameters such as lumen maintenance. With the test procedures being globally consistent HID lamps are very comparable. The EU appears to have more stringent thresholds than China and Mexico.

Australia, China, the EU and the US set mandatory MEPS for **linear fluorescent ballasts**, and many countries have had MEPS for some time. This product type is relatively comparable except for the difference in US/EN test procedures limit, while **linear fluorescent lamps** are very comparable. China’s MEPS are substantially less demanding for these types of lamps than for the EU, Australia or Russia, while labeling is in place in China, EU, India and Mexico. The same countries have set MEPS and labels for ballasts; Australia’s, China’s and the EU’s MEPS and labels are set at similar thresholds, US values are not comparable due to different approaches in setting ballast standards.

Table 8 provides an overview of MEPS and energy label thresholds for lighting, converted for test procedure and efficiency metrics differences where appropriate.



Table 8. Converted MEPS and energy label thresholds for lighting

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | | |
|----------------------------------|---|------------|-------------|--------------|----------------|--------------|-------|------------|-----------|------------|--------|------------|------------|------------------|--------------|------------|--------------|------------|--|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | |
| Lamp - Compact fluorescent | 56 | | 56 | N/A | 56 | N/A | | | | | N/A | 60.5 | N/A | 60 | Form-ula [1] | | | | |
| Lamp - Filament, non-directional | 14.6 | | N/A | | 16.3 | 22 | | | | | | | | 23 | | N/A | | | |
| Lamp - Filament, directional | Form-ula [4] | | | | N/A | N/A | | | | | | | | N/A | N/A | | | | |
| Lamp - HID high pressure sodium | | | 75 | N/A | 100 | | | | | | | 75 | | | | | | | |
| Lamp - HID metal halide | | | 72 | N/A | 85 | | | | | | | 65 | | | | | | | |
| Ballast - HID (all) | | | 85% | N/A | 85% | | | | | | | | N/A | | | | | | |
| Lamp - Linear fluorescent | 80 | | 62 | 75-88 lm/W | 92 | | | 92 | | | | | 46-90 lm/W | 88 | | | | | |
| Ballast - Linear fluorescent | EEI = B2 | EEI = A2 | EEI = B2 | EEI = A2-BAT | EEI = B2 | EEI = A2-BAT | | | | | | | | Complex function | | | | | |
| Formulae | 1 - (US, CFL high label): 55 lm/W (lamps <15W), 65 (lamps >=15W) 2 - (AUS, non-directional filament lamps MEPS): Initial efficacy >= 0.95*(2.8 ln(flux) - 4.0) 3 - (EU, non-directional filament lamps MEPS): Initial efficacy >= flux / (0.8 * (0.88 * SQRT(flux) + 0.049*flux)) 4 - (AUS, directional filament lamps MEPS): Initial efficacy >= (2.8 ln(flux) - 4.0) | | | | | | | | | | | | | | | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

Lamp test procedures are largely harmonized through the use of IEC test procedures in all parts of the world except North America, and the US and Mexican test procedures are usually aligned with these IEC test procedures. Actual efficiency requirements are often complex formulae, however, and although an efficiency value for a single product can easily be converted between economies, this is often not the case for the range of products covered by MEPS or labeling regulations. Alignment efforts should therefore focus on finding common approaches to describing efficiency metrics and possibly defining aligned efficiency ranges that can be used across economies.

There are two notable exceptions to the level of alignment seen for lighting products: North America uses a different way of measuring and regulating the efficiency of linear fluorescent lamps and ballasts, which is not easily comparable to other economies,⁵ and the EU uses a different approach to testing the light output of filament directional lamps, making measured values difficult to compare. Alignment of tests for these products would require a switchover of test procedures and efficiency metrics in these economies for these products (or in all other economies).

⁵ A CLASP benchmarking study focusing on linear fluorescent lighting is forthcoming in late 2014. It will provide a more detailed description of the comparability of linear fluorescent lighting, including ballasts and lamps.

Consumer Electronics and ICT

Products covered

Products covered within consumer electronics and ICT are:

- Television
- Display
- Simple set top box (STB)
- Complex set top box (STB)
- Computer and server
- Imaging equipment
- External power supply
- Audio equipment

Televisions are commercially-available products with a display screen and associated electronics, often encased in a single housing, that display visual information from wired or wireless sources. **Display** as a category includes products displaying visual information and that is connected to the mains power source for its intended continuous use, either directly or via an external power supply. Common display technologies include liquid crystal display (LCD), light emitting diode (LED), cathode-ray tube (CRT), and plasma display panel (PDP). **Set top boxes (STB)** vary greatly across regions and platforms. A STB is a device combining hardware components with software programming designed to receive television and related services from terrestrial, cable, satellite, broadband, or local networks. They are categorized as ‘Simple set-top boxes’ (SSTB) and ‘Complex set top boxes’, the latter including additional features such as pay TV and network connectivity. **Computers** include both stationary and portable units (desktop computers, gaming consoles, integrated desktop computers, notebook computers, small-scale servers, thin clients, and workstations), as well as **servers**. The **Imaging equipment** category includes printers, copiers, facsimile (fax) Machines, multifunction devices (MFDs) and mailing machines. Also covered in this analysis are **External power supplies** AC and DC, battery chargers and uninterruptible power supplies. **Audio equipment** is described in Annex 2: Product Fact Sheets but not discussed here, as there is only one voluntary label in one economy for this product.

Test procedure and efficiency metrics alignment

All **television** test procedures reference the IEC 62086 Ed 3 Section 11 method for power measurement – using the IEC broadcast loop to determine power consumption – with all countries using a watts/area metric except China, which uses a luminance efficiency metric and does not adopt an “out of the box” condition for measurement. Australia converts the watts/area metric into a kWh/annum Total Energy Consumption (TEC)⁶. Australia uses an “on” period of 10 hours per day for TV use, on which the conversion factor for this study is based for the purpose of comparison with the US, EU, and India. For **displays** a similar approach was followed although specifications – ENERGY STAR in particular, on which the US and Australia base their standards – include very elaborate methods for determining factors for pixel density and include special equations for advanced technology. Many displays are excluded from this analysis for technological reasons as a result.

Set top boxes vary greatly between regions and across platforms. Two substantially different approaches to determining efficiency metrics exist amongst countries: a power on-mode requirement with a standby requirement, and a TEC approach. Because standby power varies so

⁶ A TEC value represents the total energy demand, typically over a year, of a duty cycle including various operational modes.

greatly across regions and platforms for STBs, no assumption can be made that allows for a conversion factor between the on-mode power approach and the TEC approach.

S&L programs for **computers** in the countries analyzed are based on ENERGY STAR 5.1, with Australia completely adopting ENERGY STAR 5.1 resulting in a conversion factor of 1. S&L for **servers** are limited to power supply efficiency requirements. The requirements for **imaging equipment** under ENERGY STAR are complicated and are referenced, rather than described, in this report. Only China has a separate program in place for this product group but information on test procedure and efficiency metrics was not available, thus no conversion factor could be determined for the Chinese requirements.

China and Australia follow the US ENERGY STAR specifications for **external power supplies** including power supplies, battery chargers and uninterruptible power supplies, and the conversion factor for these products in those countries is 1.

Table 9 presents the conversion factors for CE/ICT as determined for this analysis.

Table 9. Conversion factors for CE/ICT

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|---------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| | Test procedure | Efficiency metrics |
| Television | 1 | 0.27 | N/A | N/A | 1 | 1 | 1 | 1 | N/A | N/A | | | 1 | 1 | N/A | N/A | | |
| Display | 1 | 0.27 | N/A | N/A | 1 | 1 | | | | | | | 1 | 1 | N/A | N/A | | |
| Simple Set Top Box (STB) | 1 | 1 | N/A | N/A | 1 | 1 | N/A | N/A | | | N/A | N/A | 1 | 1 | | | | |
| Complex Set Top Box (STB) | N/A | N/A | N/A | N/A | | | | | | | | | 1 | 1 | | | | |
| Computer | 1 | 1 | | | 1 | 1 | N/A | N/A | | | | | 1 | 1 | | | | |
| Server | 1 | 1 | | | 1 | 1 | | | | | | | 1 | 1 | | | | |
| Imaging Machine | 1 | 1 | 1 | N/A | 1 | 1 | N/A | N/A | | | | | 1 | 1 | N/A | N/A | | |
| External Power Supply | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | 1 | 1 | | | | |

Comparability and alignment of MEPS and energy labels

For **televisions** and **displays**, China is alone in using a luminance efficiency approach and not testing televisions in their "out of the box" conditions. This makes comparisons between China and all other countries currently impossible. Only the EU and Australia (of the countries analyzed) have set MEPS and energy labels for televisions, and two more (US and India) have labels only. The Australian MEPS for TVs is currently 20-30% more demanding than the EU's MEPS. The highest EU energy label class is far more demanding than the US ENERGY STAR label, and both are far more demanding than India's highest energy label class. In fact, India's highest energy label class allows for 3-4 times more energy consumption than Australian and EU MEPS (and approximately 8 times more than US ENERGY STAR v6), and it seems likely that virtually any television can exceed India's highest energy label class.

The conversion factor comparing the EU, US, India and Australia – based on Australia’s usage assumptions as described above – is very reliable as measurements are all based on the same IEC test procedure and efficiency metrics all relate to watt per screen area requirements.

Because standby power varies so greatly across regions and platforms for **set top boxes**, no assumption can be made that allows for a conversion factor between the on-mode power approach and the TEC approach. Comparisons are only meaningful within each approach and not between them.

For **computers** and **servers**, ENERGY STAR 5.1 is the sole program referenced, although the EU regulation has defined a different duty cycle for computers (applicable for desktops and laptops), making TEC values not directly comparable to those obtained from ENERGY STAR. The situation for **imaging equipment** is straightforward, with ENERGY STAR being essentially the only program adopted by Australia, EU and the US. China has its own program for imaging equipment but it was not possible to access the details of the Chinese MEPS and energy labels for this category, nor establish a conversion factor. Finally, Australia, China, the EU and the US all have requirements for **external power supplies**, with the US MEPS (to be in effect in 2016) being somewhat more demanding than requirements in other economies (for power supplies of 50W to 250W). Interestingly, US MEPS (in effect in 2016) also seem to be more demanding than the current US ENERGY STAR label, which would make that label meaningless for power supplies.

Table 10 provides an overview of MEPS and energy label thresholds for CE/ICT (non-converted).

Table 10. Original (non-converted) MEPS and energy label thresholds for CE/ICT

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|---------------------------|----------------|------------|---------------------|---------------------|--|--|------------------------|------------|-----------|------------|--------|------------|--------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Television | Formula [1] | N/A | LCD: 0.6, PDP: 0.6 | 1.2 | TVs 16 W + A · 3,4579 W/dm ² | N/A | P = (0.613 x A) + 4.38 | N/A | N/A | | | | | N/A | | N/A | | |
| Display | Formula [2] | N/A | CRT: 0.14 LCD: 0.55 | CRT: 0.18 LCD: 1.05 | 12W + A* 3.4579 W/dm ² | 0,1* (15W + A 4,3224 W/dm ²) | | | | | | | | N/A | | N/A | | |
| Simple Set Top Box (STB) | Formula [3] | | N/A | N/A | Standby: 1W + adders Active: 5W + adders | | | | | | | N/A | | N/A | | | | |
| Complex Set Top Box (STB) | Formula [4] | | N/A | | | | | | | | | | N/A | N/A | | | | |
| Computer | Same as ES 5.1 | N/A | | | | | | N/A | | | | | | N/A | | | | |
| Server | | N/A | | | | | | | | | | | | N/A | | | | |
| Imaging Machine | | N/A | N/A | N/A | | N/A | | N/A | | | | | | N/A | | N/A | | |
| External Power Supply | >0.84 | | >0.84 | | >0.85 | | | | | | | | > 0.88 | >0.87 | | | | |

| | |
|----------|--|
| Formulae | <p>1 - $P = 65.3 + 0.0934 * A$ (cm²) kWh/a</p> <p>2 - PO(MEPS) = (6 for ≤1.1 Mp or 9 for > 1.1 Mp Screen resolution) + (0.007 75 Screen area in cm²) + 3</p> <p>3 - SD STBS (On Mode 7W Passive 2W) or (On Mode 8W Passive 1W) - HD (On mode 11W Passive 2W or (On mode 12W Passive 1W)</p> <p>4 - Satellite and Cable base allowance 60 kWh/a</p> |
|----------|--|

Table 11 provides an overview of MEPS and energy label thresholds for CE/ICT, converted for test procedure and efficiency metrics differences where appropriate (in this case televisions and displays only).

Table 11. Converted MEPS and energy label thresholds for CE/ICT

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|---------------------------|---|------------|----------------------|----------------------|---|--|-------|------------|-----------|------------|--------|------------|-------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Television [1] | 142W | N/A | LCD: 0.6 PDP:0.6 | 1.2 | 184W | 23W | 466 W | N/A | N/A | | | | | 66W | | N/A | | |
| Display | Formula [2] | N/A | CRT:0.14 LCD:0.55 | CRT:0.18 LCD:1.05 | 12W + A* 3.4579 W/dm ² | 0,1* (15W + A 4,3224 W/dm ²) | | | | | | | | N/A | | N/A | | |
| Simple Set Top Box (STB) | Formula [3] | | N/A | N/A | Standby: 1W + adders Active: 5W + adders | | | | | | | N/A | | N/A | | | | |
| Complex Set Top Box (STB) | Formula [4] | | N/A | | | | | | | | | | N/A | N/A | | | | |
| Computer | Same as ES 5.1 | N/A | | | | | N/A | | | | | | | N/A | | | | |
| Server | | N/A | | | | | | | | | | | | N/A | | | | |
| Imaging Machine | | N/A | N/A | N/A | | N/A | N/A | | | | | | | N/A | | N/A | | |
| External Power Supply | >0.84 | | >0.84 | | >0.85 | | | | | | | | >0.88 | >0.87 | | | | |
| Formulae | <p>1 - Indicative MEPS and Label thresholds (42" TV, no ABC, no other features)</p> <p>2 - PO(MEPS) = (6 for ≤1.1 Mp or 9 for > 1.1 Mp Screen resolution) + (0.007 75 Screen area in cm²) + 3</p> <p>3 - SD STBS (On Mode 7W Passive 2W) or (On Mode 8W Passive 1W) - HD (On mode 11W Passive 2W or (On mode 12W Passive 1W)</p> <p>4 - Satellite and Cable base allowance 60 kWh/a</p> | | | | | | | | | | | | | | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

Test procedures for CE & ICT products are, in general, well-aligned. For important products in this category, such as **TVs and displays**, all countries use the same IEC test procedure as a basis, although China then uses a different test set-up and different efficiency metric for its actual requirements. **Office equipment** is generally tested using ENERGY STAR test procedures and efficiency metrics, and although most products are regulated in only a few economies, these all are based on the same procedures.

Set top box testing is different in every economy, and often within economies. This may reflect that set top boxes are, typically, custom-built products designed to work within a specific network and with functionality that reflects the need of the network operator. Set top box functionalities vary widely and develop at a fast pace, and there is yet no clear route to alignment of set top box requirements in view. **Power supply and battery charger** test procedures are different in theory, but in practice well-aligned.

Efficiency metrics in the CE & ICT area do vary, however, and although test procedures are typically well-aligned, comparisons of energy performance are not always possible due to this. Where countries follow ENERGY STAR efficiency metrics, comparisons are straightforward; however, where this is not the case, conversions are more difficult to make. There may be scope for defining a range of common efficiency thresholds, based on common test procedures and aligned, as much as possible, with ENERGY STAR and other efficiency metrics, as the basis for new regulations. It should also be recognized, however, that the CE & ICT area includes many of the fastest developing products and international alignment may not be able to keep up with the pace of new product functionality being introduced.

Set top boxes stand out as a product that has no common test procedure and virtually no comparability in efficiency metrics, sometimes even within economies. Although there may be scope for defining common test procedures for set top boxes, it should also be recognized that set top box functionality and performance is heavily influenced by the network in which these products operate, and full alignment of test procedures may not be feasible, and possibly not even desirable.

Air Conditioning

Products covered

Products covered within air conditioning are:

- Room ACs
- Central ACs
- Chillers

An air conditioner is an appliance designed to maintain the temperature of indoor air at a given temperature level for a given heat load to be extracted. There are different types of residential air conditioners. **Central air conditioners** are generally heat pumps or cooling units installed as part of a building's central heating and cooling system. They use ducts to distribute cooled or dehumidified air to more than one room. Residential **room air conditioners** are mounted in windows or through walls and deliver conditioned air to enclosed spaces. Room air conditioners typically extract heat from the room and vent it outdoors. Room ACs include the following: split-packaged units (also called mini-split or duct-free split on the US market; note that both split and multi-split units are regulated as central ACs in the US, but as room ACs in other markets); multi-split packaged units; single packaged units (typically window air conditioners in the EU, but also packaged terminal air conditioners on the US market); single duct units; double duct units; and residential chillers. **Chillers** produce water that is used by building space cooling equipment and many industrial processes.

Test procedure and efficiency metrics alignment

Most countries use the energy efficiency ratio (EER) testing procedure from ISO 5151 at least as the dominant procedure underlining their testing approach for **room ACs**. However, the annual/seasonal energy efficiency ratio (SEER) is beginning to be adopted by various economies

and is the focus of future development. This may actually increase differences between requirements, as different economies so far tend to adopt different SEER efficiency metrics. US test conditions are very similar to ISO 5151 except for a variation in the indoor wet bulb temperature, which is corrected for with a conversion factor of 1.0096.

SEER values are not easily comparable between economies, as the mix of values feeding into a single SEER value is different across economies. Most economies do not require disclosure of the contributing factors in a SEER calculation, making it likely that the comparability of air conditioner energy performance will become much harder in future.

For **central ACs** (ducted air conditioning systems), there are some similarities in the test procedures in China, the US, EU and Australia. However, significant differences do exist and have not been quantified. There is very limited information available to compare energy performance data for central (ducted) air conditioning units and no conversion factors could be developed.

Test procedures and efficiency metrics for **chillers**, in place in India, China and Australia and under development in the EU are all different and there are no signs of alignment or comparability between them. Extensive research and testing would be required to assess how test procedures and efficiency metrics relate to each other.

Table 12 presents the conversion factors for ACs as determined for this analysis.

Table 12. Conversion factors for ACs

| | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| PRODUCT | Test procedure | Efficiency metrics |
| Room AC | 1 | N/A | 1 | 1.01 | 1 | 1.13 | 1 | N/A | 1 | N/A | 1.01 | 1 | 1.01 | 1 | | | N/A | N/A |
| Central AC | N/A | N/A | N/A | N/A | N/A | N/A | | | | | N/A | N/A | N/A | N/A | | | | |
| Chiller | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | | | | | | | | | | |

Comparability and alignment of MEPS and energy labels

Room AC standards can be more accurately compared between the US and EU and more broadly compared with and between China, India, Indonesia and Australia. The thresholds for MEPS for variable speed room ACs are a little more demanding in China than in the EU and US, which have near-identical requirements. Note, however, that thresholds vary by product sub-type. The threshold for energy labels appears more demanding in the EU than in other countries; however, the picture is not fully complete, with missing detailed information from the US and China.

There are many differences in the test procedures and efficiency metrics for **central ACs** in Australia, China, the EU and the US. MEPS and label thresholds are therefore not comparable between economies.

India, China and Australia all describe **chiller** energy performance with a coefficient of performance (COP). However, these coefficients are all based on different non-comparable test

procedures. The EU is developing a seasonal energy performance ratio, based on a different test procedure.

Table 13 provides an overview of MEPS and energy label thresholds for AC (non-converted).

Table 13. Original (non-converted) MEPS and energy label thresholds for ACs

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|------------|-------------|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|--------|------------|------|--------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Room AC | | 5.25 | 3.2 | N/A | 3.24 | 8.5 | 2.3 | 3.3 | | 12.8 3 | N/A | N/A | 2.84 | N/A | | | | |
| Central AC | 2.75 | 5.25 | 2.8 | 3.6 | N/A | | | | | | | N/A | 3.8 | ≥14 (≥11) | | | | |
| Chiller | 2.7/ 3.7 | | | | 157% | | N/A | | N/A | | | | | | | | | |

Table 14 provides an overview of MEPS and energy label thresholds for ACs, converted for test procedure and efficiency metrics differences where appropriate.

Table 14. Converted MEPS and energy label thresholds for ACs

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|------------|---|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|--------|------------|-------------|------------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Room AC | | 5.25 | <u>3.2</u> | N/A | <u>2.9</u> | <u>7.5</u> | 2.3 | 3.3 | | 3.8* | N/A | N/A | <u>2.87</u> | N/A | | | | |
| Central AC | 2.75 | 5.25 | 2.8 | 3.6 | N/A | | | | | | | N/A | 4.18 | ≥4.1/ (≥ 3.2) | | | | |
| Chiller | 2.7/ 3.7 | | | | 157% | | N/A | | N/A | | | | | | | | | |
| Notes | Underlined values are converted * values are converted from Btu/kWh to kWh/kWh | | | | | | | | | | | | | | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

Test procedures for room and central air conditioning products are closely aligned, with all based on the same ISO 5151 test procedure. There are minor differences in test conditions between North America and the rest of the world, which can be corrected for. Efficiency metrics used to be highly comparable for air conditioners (energy efficiency ratio (EER) based on full load performance) but are being changed to seasonal ratios based on a mix of full and partial load performances. These are different for each economy, reflecting that climatic conditions are different. Comparability, however, is lost in the transition to SEER metrics. While it is probably desirable that each economy defines SEERs in the way that best matches their climatic conditions and needs, it would be helpful if economies required the disclosure of the measured full and partial load efficiency ratios that

feed into SEER calculations. That would not help in blanket economy-to-economy comparisons, which are probably losing relevance since requirements are being tailored to the needs of a specific set of climatic conditions. It would, however, allow for comparisons on a product-by-product basis.

Test procedures and efficiency metrics for **chillers** vary widely and there is no obvious candidate for a global procedure or metric towards which economies could align. Given that S&L in this area are in their infancy, it might be possible to define a global test procedure, efficiency metrics and energy performance bands. The many uses chillers have and their different efficiencies under different climatic conditions might make this a demanding task with uncertain outcomes.

Space & Water Heating

Products covered

Products included within space and water heating are:

- Space heater - Electric
- Space heater - Residential boiler gas
- Space heater - Residential boiler oil
- Space heater - Commercial boiler gas
- Space heater - Commercial boiler oil
- Space heater - Commercial furnace gas
- Space heater - Commercial furnace oil
- Space heater - Combined heat and power
- Space heater - Heat pump
- Space heater - Furnace oil
- Space heater - Furnace gas
- Water heater - Instantaneous gas
- Water heater - Instantaneous electric
- Water heater - Heat pump
- Water heater - Storage electric
- Water heater - Storage gas
- Water heater - Solar
- Water heater - Commercial boiler oil
- Water heater - Commercial boiler gas

Central heating boilers provide heat to a water-based central heating system in order to reach and maintain at a desired level the indoor temperature of an enclosed space such as a building, a dwelling or a room. Boilers generate heat – either hot water or steam – using the combustion of fossil fuels and/or biomass fuels, and/or using electric resistance heating elements. Central heating boilers include boiler combination heaters which are boiler space heaters also designed to provide hot drinking or sanitary water and are connected to an external supply of drinking or sanitary water. **Residential and commercial furnaces** include gas, electric, and oil-fired furnaces. Furnaces heat air and distribute the heated air through the house or building using ducts. **Industrial boilers** are used to generate steam and hot water for use in industrial processes.

Water heaters are products that utilize oil, gas, or electricity to heat potable water for use upon demand for activities such as washing dishes or clothes or bathing. Water heaters include storage type units that store heated water in an insulated tank and instantaneous type units that heat water on demand.

Test procedure and efficiency metrics alignment

Test procedures, and often also the products themselves, vary so substantially between countries that no meaningful assumptions on potential alignment can be made for **central heating boilers**. A similar situation applies to central heating furnaces. For **other space heaters** and **industrial boilers** (the latter being only regulated in India), conversions of test procedures are not possible because test procedures are sometimes unknown, are largely not aligned with international procedures, and there is no comparative information available on which to base a comparison.

Overall, space and water heating equipment is often tailored to the needs and/or traditions of a specific region, and international comparisons are difficult, not in the least because the actual products are often different in design and usage pattern.

No test procedure or efficiency metric conversion factors are presented for space and water heaters, as none could be derived for this analysis.

Comparability and alignment of MEPS and energy labels

MEPS for **central heating boilers** are based on different seasonal efficiency metrics in the EU and the US, and on steady state operation in India. Steady state efficiency was traditionally the way to test boiler performance; however, economies are gradually moving away from this to better reflect actual operation of boilers. Test conditions for boilers vary significantly between economies and test results are not comparable.

Minimum energy performance standards are in place in the EU and the US for **central heating furnaces**; they both use seasonal efficiency metrics, albeit different ones – rendering meaningful comparisons impossible.

Only India has implemented energy labels for **industrial boilers**. These seem to include various aspects of product performance, possibly including energy performance (the actual requirements being unavailable). MEPS were considered in Australia but were not adopted.

Water heater MEPS and energy labels are in place in most economies for various products. Product definitions and the scope of regulations vary significantly between regions. The US, for example, has established MEPS for commercial water heaters separate from MEPS for residential water heaters, where these are covered by one regulation in the EU. There are large differences in test conditions such as tapping or draw off patterns (or the lack thereof), as well as substantial differences in efficiency metrics.

Given the significant differences in test procedures and efficiency metrics for all space and water heating products, as well as the differences in product design, meaningful comparisons between economies are not possible in this product area.

Table 15 provides an overview of MEPS and energy label thresholds for space & water heating.

Table 15. MEPS and energy label thresholds for space & water heating

| HIGHER VALUE = MORE EFFICIENT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|---------------------------------------|-----------|------------|-------------|------------|----------------|-------------------|-------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Space heater - Electric | | | | | 30% | $\eta_s \geq 150$ | | | | | | | N/A | | | | | |
| Space heater - Residential boiler gas | N/A | | 84% | 94% | Formula [1] | $\eta_s \geq 150$ | | | | | | | 82% | 85% | | | | |

| HIGHER VALUE = MORE EFFICIENT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|---------------------------------------|----------------------------------|------------|---------------------------|------------|----------------|----------------------|-------|------------|-----------|------------|--------|-------------------------|-------------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Space heater - Residential boiler oil | | | | | Formula [1] | $\eta_s \geq 150$ | | | | | | | 84% | 85% | | | | |
| Space heater - Commercial boiler gas | | | | | 86% | | | | | | | | 80% | | | | | |
| Space heater - Commercial boiler oil | | | | | | 86% | | | | | | | 82% | | | | | |
| Space heater - Commercial furnace gas | | | | | | | | | | | | | 80% | | | | | |
| Space heater - Commercial furnace oil | | | | | | | | | | | | | 81% | | | | | |
| Space heater - CHP | | | | | 86% | $\eta_s \geq 175$ | | | | | | | | | | | | |
| Space heater - Heat pump | | | | | 115% | $\eta_s \geq 175$ | | | | | | | | | | | | |
| Space heater - Furnace oil | | | | | 72% | | | | | | | | 83% | 85% | | | | |
| Space heater - Furnace gas | 70% | N/A | | | 72% | | | | | | | | 80% | 95% (90%) | | | | |
| Water heater - Instantaneous gas | N/A | N/A | 84% | 96% | 30% (27%) | $\eta_{wh} \geq 163$ | | | | | N/A | N/A | Formula [2] | N/A | | | | |
| Water heater - Instantaneous electric | | | | | 30% (27%) | $\eta_{wh} \geq 163$ | | | | | 84% | N/A | Formula [3] | N/A | | | | |
| Water heater - Heat pump | N/A | N/A | 3.7 | N/A | 30% (27%) | $\eta_{wh} \geq 163$ | | | | | | | | | | | | |
| Water heater - Storage electric | Max heat loss per day (kWh): 98% | N/A | ≤ 1 (@ $\geq 50\%$) | ≤ 0.6 | 23% (20%) | 62% | N/A | N/A | | | | | Formula [4] | N/A | N/A | N/A | | |
| Water heater - Storage gas | N/A | N/A | | | 23% (20%) | 62% | | | | | N/A | 76%-77%-79%-82% dep. on | Formula [5] | N/A | | | | |

| HIGHER VALUE = MORE EFFICIENT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | | | |
|--------------------------------------|---|------------|-------------|------------|----------------|----------------------|-------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|--|------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | | |
| | | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | | type |
| Water heater - Solar | | | N/A | N/A | 30% (27%) | $\eta_{wh} \geq 163$ | | | | | | | | | | | | | | |
| Water heater - Commercial boiler oil | | | | | | | | | | | | | 78% | N/A | | | | | | |
| Water heater - Commercial boiler gas | | | | | | | | | | | | | 80% | N/A | | | | | | |
| Formulae | 1 - 75% (86% for boilers other than B11 boilers) 2 - $EF = 0.82 - (0.0019 \times \text{Rated Storage Volume in gallons})$ 3 - $EF = 0.93 - (0.00132 \times \text{Rated Storage Volume in gallons})$ 4 - $EF = 0.960 - 0.0003 \times \text{Volume} (<=55 \text{ gallon}); EF = 2.057 - 0.00113 \times \text{Volume} (>55 \text{ gallon})$. 5 - $EF = 0.675 - (0.0015 \times \text{Volume} (<=55 \text{ gallon}); EF = 0.8012 - 0.00078 \times \text{Volume} (>55 \text{ gallon})$ | | | | | | | | | | | | | | | | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

Overall, space and water heating equipment is often tailored to the needs and/or traditions of a specific region, and international comparisons are difficult, not in the least because the actual products are often different in design and usage pattern. This may change in the future, as the boiler industry is starting to collaborate and integrate more globally and new technologies are transferred between countries. Space and water heating equipment, however, often operates within a heating and hot water distribution system in buildings and is usually tailored to meet the specifications of those existing systems. Test procedures need to reflect local usage conditions, and it seems unlikely that global test procedures and efficiency metrics can be developed that cover the needs of all economies, even though it may be possible to develop global test procedures that uniformly test specific modes of operation, such as full and partial load steady state efficiency, heating up and cooling down efficiency for space heaters.

In theory, electric storage water heaters would allow for an easier international alignment of test procedures, as these products are largely similar around the world and their operation is relatively uncomplicated. Differences between local test procedures are still substantial, however, in particular around the use of tapping or draw-off patterns (some countries use these, some do not, and the ones that do use different patterns). The efficiency rankings of these products are sensitive to the type of tapping pattern used. Similarly, there could be scope for globally aligned test procedures for relatively new products such as solar and heat pump water heaters, even though there are significant differences in local climatic conditions and heating system layout.

Major economies so far seem to be developing their own routes towards regulating the performance of space and water heater products, focusing more on comparability of different technologies within their economy than on comparability of different products between economies. It seems likely that global alignment of test procedures for space and water heating products is far away. Global alignment might even be counterproductive, unless it can also address the comparability of different space and water heating technologies and products.

Commercial Refrigeration Equipment

Products covered

Products covered within commercial refrigeration equipment are:

- Reach-in cooler: refrigerated display cabinets
- Reach-in cooler: freezers
- Reach-in cooler: refrigerated cabinets
- Refrigerated vending machines
- Walk-in cold rooms
- Ice machines

The **reach-in coolers** category covers a very wide range of commercial cooling products, which can vary according to ambient, storage and processing (e.g., blast cooling, pass through) conditions, use (retail or catering), enclosure shape and volume, and refrigeration system (e.g., integral or remote condenser). The sub-types **refrigerated display cabinets**, **commercial freezers** and **refrigerated cabinets** are included in this analysis. **Refrigerated vending machines** are commercial refrigerated cabinets designed to accept consumer payments or tokens to dispense chilled or frozen products without on-site labor intervention. Vending machines are most often plug-in appliances, and there are three main types: can, drum and spiral. The prevalence and functionality of these types varies by economy. **Walk-in cold rooms** temporarily store refrigerated or frozen food or other perishable goods and are used primarily in the food service and food sales industry. They are commercial enclosed storage spaces that can be walked into, and generally do not include products designed and marketed exclusively for medical, scientific, or research purposes. **Ice machines** are dedicated products for the production of ice (frozen water), with a wide range of capacities.

Note: The “CLASP Commercial refrigeration equipment: mapping and benchmarking” study was published after research for this report was completed. It provides a more detailed description of the comparability of reach in coolers and vending machines.

Test procedure and efficiency metrics alignment

Over 10 separate standards are identified for **retail display cabinets / cases** and **commercial refrigerators/freezers**. However, most of the market within the scope of this study is covered by ASHRAE 72 or ISO 23953. Whilst both test procedures have very similar parameters, most parameters are dealt with differently, rendering a simple conversion of one standard into another highly unlikely.

Walk-in cold rooms vary greatly in size, level of customization and on-site assembly, and operating conditions (including ambient and cooling temperatures, humidity, and frequency of use). Efficiency gains cannot easily be captured in a single metric, and so tend to be dealt with elementally: levels of insulation, thermal bridging and air tightness; lighting and control; refrigeration plant (which comes in various configurations) – all of which render comparison and alignment of test standards more challenging.

Table 16 presents the conversion factors for commercial refrigeration as determined for this analysis.



Table 16. Conversion factors for commercial refrigeration

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|------------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| | Test procedure | Efficiency metrics |
| Refrigerated Display Cabinet | 1 | N/A | 1 | N/A | 1 | N/A | | | N/A | N/A | N/A | N/A | | | | | | |
| Refrigerated Cabinet | | | N/A | N/A | | | | | | | N/A | N/A | N/A | N/A | | | | |
| Refrigerated Vending Machine | 1 | N/A | | | N/A | N/A | | | | | | | 1 | N/A | | | | |
| Walk-In Cooler & Freezer | N/A | N/A | | | N/A | N/A | | | | | | | | | | | | |
| Freezer | | | | | | | | | | | N/A | N/A | N/A | N/A | | | | |
| Ice Machine | N/A | N/A | | | N/A | N/A | | | | | | | N/A | N/A | | | | |

Comparability and alignment of MEPS and energy labels

Although test procedures for commercial refrigeration products show some similarities and some conversions are possible, as described above, efficiency metrics vary greatly in scope and way of describing product energy efficiency and no directly comparable efficiency metrics were found. As a result, a comparison of MEPS and energy label requirements is not possible for these products.

For **refrigerated vending machines**, MEPS and mandatory labeling is currently under consideration in the EU, while in the US and Australia, the voluntary ENERGY STAR label is available. The US has MEPS in place, and Australia is considering MEPS.

The US is the only economy with MEPS in place for walk-in cold rooms. EU requirements are under development and Australia has initial proposals. There are significant challenges associated with applying MEPS and/or labeling to these products.

Table 17 provides an overview of MEPS and energy label thresholds for commercial refrigeration, converted for test procedure and efficiency metrics differences where appropriate.

Table 17. Converted MEPS and energy label thresholds for commercial refrigeration

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|------------------------------|-----------|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Refrigerated Display Cabinet | Note [1] | | N/A | N/A | <125 | | | | N/A | | | | | | | | | |

$$C = 0,1555 * (V) - 0,2915$$

| | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|------------------------------|---|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|------------------|------------|----------|---------------------------|--------|------------|--------------|------------|
| PRODUCT | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Refrigerated Cabinet | | | N/A | | | | | | | | Various formulae | N/A | N/A | N/A | | | | |
| Refrigerated Vending Machine | N/A | | | | N/A | | | | | | | | Note [2] | 0.45 [8.66 + (0.009 x C)] | | | | |
| Walk-In Cooler & Freezer | 0.22 / 1.67 | | | | Note [3] | | | | | | | | Note [4] | | | | | |
| Freezer | | | | | | | | | | | N/A | N/A | N/A | Various formulae | | | | |
| Ice Machine | N/A | | | | N/A | | | | | | | | N/A | N/A | | | | |
| Note | 1 - Remote and self-contained must be purchased 2 - Type A: $0.055 \times V + 2.56$; Type B: $0.073 \times V + 3.16$ 3 - 0.35 medium temp ; 0.2 low temp 4 - Various U-value and component requirements | | | | | | | | | | | | | | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

S&L for commercial refrigeration equipment (CRE) are fairly new. Only a few MEPS and labels exist in only a handful of countries. Test procedures and efficiency metrics are also relatively new; for some CRE equipment, such as walk-in cold rooms, these look somewhat primitive. Reasons for this probably include: the large variety in products; that many of these products, such as supermarket refrigerators and walk-in cold rooms, are effectively assemblies of standardized components more than standardized products; and perhaps also that regulator attention for these products is fairly recent and data availability low.

The high variety in and customization of products complicates test procedure development and it seems unlikely that globally aligned test procedures could be developed that adequately cover the rich variety in products and usage around the world. On the other hand, some approaches in regulating CRE products focus on the efficiency of the constituting components, which might be much easier to align globally. If several economies were to decide that the way forward in regulating some CRE equipment is through performance requirements of their constituting components, test procedure alignment might be possible in a relatively easy and straightforward way, building on existing test procedures for items such as heat losses, linear thermal bridges, and refrigeration plant efficiency.

Cooking Products

Products covered

Products covered within cooking products are:

- Conventional ranges (commercial and residential)
- Conventional cooking tops (commercial and residential)
- Conventional ovens (commercial and residential)
- Microwave ovens (commercial and residential)

| | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | | |
|--------------|---------------------|------------|-------------|------------|----------------|------------|-------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|--|
| PRODUCT | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | |
| Coffee maker | standby requirement | | | | 1W standby | | | | | | | | | | | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

Cooking products may be a difficult area in which to align test procedures and efficiency metrics. Some products are quite region-specific, and product use varies greatly by region, making globally aligned efficiency metrics difficult to establish. There may be more scope to develop and agree on common test procedures for some products which are more standardized across regions, such as microwave ovens. There is no clear route towards global test procedures for any cooking product, however, beyond test procedures for standby power, which are similar to other standby power consumption measurements.

Motors, Pumps and Fans

Products covered

Products covered within motors, pumps and fans are:

- Medium size 3-phase induction motors
- Small size 3-phase induction motors
- Generic pumps
- Building circulators
- Pool pumps
- Dirty water pumps
- Agricultural pumps
- Ceiling fans
- Portable fans
- Industrial blowers
- Fume or cooktop hoods
- Furnace and duct fans
- Integrated fans

Electric motors convert electrical energy to rotating mechanical energy to drive devices such as fans, pumps, blowers, compressors, and conveyors. **Pumps** transport fluids, for example in agriculture, oil and gas production, water and wastewater systems, manufacturing, mining, and commercial building systems. Pumps contain motors and the system boundaries depend on whether the pump and motor are integrated: where the motor can be removed and tested separately, the pump and motor are considered separate products; otherwise, the pump and motor are considered an integral product. **Fans** have rotating blades that create a current of air for cooling or ventilation.

Test procedure and efficiency metrics alignment

For **motors**, all test methods give results that at a macro-level are very similar and any differences can be neglected. There have been great efforts by the IEC to harmonize global motor test methods, culminating in the 2007 revision of the key standard IEC 60034-2-1. This was long

overdue, as different global regions have, in the past, used significantly different test methods, not allowing comparison between motors tested to different standards. Currently only North America is not fully aligned with the IEC standard, instead using the direct torque method for some sizes. This, however, introduces only a minor correlation factor difference.

Since motors are essentially all tested with the same test procedure and use the same efficiency metric calculation (with the small exception of some US motor types), efficiency results are comparable between economies. All economies also use the IEC-defined “IE” ranking for motors, in which higher numbers, such as IE3 and IE4, represent more efficient motors. Comparing efficiencies is therefore possible simply by comparing the efficiency ranking referred to in MEPS or energy labels.

Pumps are all tested to ISO9906, and only the Best Efficiency Point performance is included. Where pumps are tested with their driving motor, the efficiency values will be shaped by the combination of pump efficiency and motor efficiency, both of which vary with size but in different ways. The results of pumps tested with and without their motors cannot be compared.

Given that pumps are all tested using the same ISO test procedure, and S&L use the same efficiency metric, energy performance requirements are fairly comparable between economies. Except for generic pumps, however, this is not always helpful, as many countries have dedicated regulations for specific types of pumps, and these product categories are not aligned between economies. So, even though test results are comparable in theory, this is not always the case in practice due to specific pumps being subject to different requirements in different economies.

For commercial **fans**, ISO5801 is the universally accepted global test standard, and ISO12759 has been developed to provide the technical basis for efficiency metrics of a MEPS scheme. No country regulates the fan (blades and hub) alone because fans invariably come attached to a motor. Test procedures for small fans (e.g., ceiling, fume/cooker hood, small domestic bathroom/kitchen extractor fans) vary substantially between economies.

Fan energy performance levels are somewhat comparable between economies. Many economies have just started to regulate fans, and there are only a few regulations in place for fans. Commercial fans are all tested using the same ISO procedure, but efficiency metrics vary substantially, limiting the comparability of energy performance requirements. Small fan regulations are all different and there is no universally accepted way of testing small fan performance. Ceiling fan energy performance is somewhat comparable between economies, but such a comparison is not available for other small fans such as portable and cooktop or fume hood fans.

Table 19 presents the conversion factors for motors, pumps and fans as determined for this analysis.

Table 19. Conversion factors for motors, pumps and fans

| | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|--------------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| PRODUCT | Test procedure | Efficiency metrics |
| Medium 3-Phase General Purpose | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | 1 | | | | |

| | | | | | | | | | | | | | | | | | | |
|-------------------------------|---|---|-----|-----|-----|-----|-----|-----|-----|-----|---|---|-----|-----|--|--|--|--|
| Small 3-phase General Purpose | | | 1 | 1 | | | | | | | 1 | 1 | 1 | 1 | | | | |
| Generic pumps | | | 1 | 1 | 1 | 1 | | | | | 1 | 1 | 1 | 1 | | | | |
| Heat Pump Systems | | | N/A | N/A | | | | | | | | | | | | | | |
| Building Circulator | | | | | N/A | N/A | | | | | | | | | | | | |
| Pool | 1 | 1 | | | 1 | 1 | | | | | | | | | | | | |
| Dirty water | | | | | N/A | N/A | | | | | | | | | | | | |
| Agricultural | | | | | | | N/A | N/A | | | | | | | | | | |
| Cooktop/Fume Hood | | | N/A | N/A | | | | | | | | | N/A | N/A | | | | |
| Portable Fan | | | N/A | N/A | | | | | N/A | N/A | | | | | | | | |
| Industrial Blower | | | 1 | N/A | | | | | | | | | 1 | N/A | | | | |
| Ceiling Fan | | | 1 | 1 | | | 1 | 1 | | | | | 1 | N/A | | | | |
| Furnace/Duct Fan | | | | | | | | | | | | | N/A | N/A | | | | |
| Integrated Fan | | | | | N/A | N/A | | | | | | | N/A | N/A | | | | |

Comparability and alignment of MEPS and energy labels

Motor efficiency rankings are easily comparable between countries, since all use IEC “IE” rankings. However, all economies use different size classes to set requirements for motors, complicating an otherwise straightforward comparison. Most large economies now require IE2 as the minimum energy performance, and the US requires IE3 for some motor sizes. The international tendency appears to be to move MEPS levels up to IE3, which is happening, for example, in the EU at the start of 2015. Highest label classes are harmonized at the IE4 level internationally. The analysis suggests that India and Mexico have aimed highest so far, with MEPS at the IE3 level already in place for medium size motors in both countries. However, it is unclear whether this efficiency requirement is actually enforced in Mexico, and it is not enforced in India.

An interesting development is the EU’s decision to allow IE2 motors on the market after IE3 becomes the new MEPS level, if these are equipped with a variable speed drive (VSD, also known as ASD). This recognizes that motor energy losses are to a large extent the result of motors operating at higher outputs than needed, which can be prevented by using a VSD.

MEPS and energy labels for **pumps** are difficult to compare between countries. Even though all countries use the same test procedure, efficiency requirements are defined in different terms, complicating comparisons. There are various “acceptance grades” (tolerances) specified in the test procedures and used in regulations and, more importantly, different approaches to regulating pumps, e.g., requirements for the pump part only, or for the motor-pump combination. The current situation is therefore that these metrics do not allow for simple conversion between them, but can sometimes be “unpicked”.

The EU and China use comparable approaches for regulating pump energy performance, focusing on pump hydraulics as opposed to the efficiency of a motor and pump combined. This approach allows for more accurate setting of MEPS values, as it can separate the motor MEPS and pump MEPS. This is important because the same kW rating of pump will have different MEPS rating according to the duty (head and flow). Note that the same pump will have a different MEPS value according to the speed, as specific speed considerations will mean that it is inherently better at some speeds than others. In comparison, the Chinese MEPS requires efficiency levels typically >5% higher efficiency than for the EU MEPS for the same pump. Both the EU and the US are developing new approaches to regulating pump energy performance, to include pump + motor + controls in one metric. EU and US

approaches are different and it is not yet clear which one will come up with more comprehensive ways of describing pump efficiency.

Fans can only be compared with others in the same category or sub-product. For each category, the underpinning measurement standard refers to an international test procedure. However, actual requirements for fans vary between economies and are complicated, making a direct comparison of S&L virtually impossible. All fan types are regulated in one or a few economies only, further limiting the use of a direct comparison of S&L.

Ceiling fans, for example, are a common product regulated in three economies included in this analysis – China, India, and the US. The energy performance measurement has similarities in that all three measure the energy consumption at rated flow only, and differences in separate requirements for standby (China, US) or for the speed regulator (India).

Table 20 provides an overview of MEPS and energy label thresholds for motors, pumps and fans, converted for test procedure and efficiency metrics differences where appropriate.

Table 20. Converted MEPS and energy label thresholds for motors, pumps and fans

| HIGHER VALUE = MORE EFFICIENT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|--------------------------------|-----------|------------|-------------|------------|----------------|------------|--------|------------|-----------|------------|--------|------------|------------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Medium 3-Phase General Purpose | MEPS 2 | IE4 | IE2 | IE4 | IE2 | | IE3 | IE4 | N/A | N/A | IE3 | IE4 | IE2 IE3 | | | | | |
| Small 3-phase General Purpose | | | IE2 | IE4 | | | | | | N/A | | IE4 | MEPS 1 | | | | | |
| Generic pumps | | | MEPS 2 | N/A | MEI = 0.1 | | | | | | MEPS 1 | N/A | N/A | | | | | |
| Heat Pump Systems | | | | N/A | | | | | | | | | | | | | | |
| Building Circulator | | | | | 0.27 | | | | | | | | | | | | | |
| Pool pump | MEPS 1 | | | | N/A | | | | | | | | | | | | | |
| Dirty water pump | | | | | N/A | | | | | | | | | | | | | |
| Agricultural pump | | | | | | | MEPS 1 | | | | | | | | | | | |
| Cooktop/Fume Hood | | | | N/A | | | | | | | | | MEPS | | | | | |
| Portable Fan | | | | N/A | | | | | MEPS | N/A | | | | | | | | |
| Industrial Blower | | | N/A | N/A | | | | | | | | | MEPS | | | | | |
| Ceiling Fan | | | N/A | N/A | | | | N/A | | | | | MEPS 1 | N/A | | | | |
| Furnace/Duct Fan | | | | | | | | | | | | | MEPS | | | | | |
| Integrated Fan | | | | | Eff. Grade 1 | | | | | | | | MEPS | N/A | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

Test procedures and efficiency metrics for **motors** are already well aligned between economies. From a regulatory perspective, major differences are in the size categories used to set MEPS levels; however, these are all defined using the same IEC-defined “IE” levels, and all countries seem to be moving to a MEPS level of IE3. Less well defined is the use of VSDs: the EU has included VSDs in its MEPS regulation, and others may follow suit at some point given the major benefits of using VSDs, where appropriate, to reduce overall energy consumption. There is currently no test procedure for VSDs, making it impossible to define efficiency or performance requirements for them. Developing common approaches to regulating VSDs, both in terms of efficiency or performance requirements and in their inclusion in motors MEPS regulations, appears to be a priority for international collaboration.

Test procedures for **pumps** are also well aligned; however, there are significant differences in the efficiency metrics used to regulate pumps. Some economies focus on the hydraulic performance of the pump alone, while others focus on the pump-motor combination. These approaches are fundamentally different and can give very different energy performance results for the same pump in different economies. Latest developments are towards including pump, motor and controls in one metric. Both the EU and the US are working on this, using different approaches. It is yet unclear which approach is the most comprehensive, and too soon for harmonization. However, it would be prudent to ensure that, when these economies adopt a new pump-motor-controls approach, they use the same one. A small but significant market segment includes swimming pool pumps, for which Australia and the EU have standards, and there is a clear opportunity to align EU and Australian test procedures and efficiency metrics for this product.

Test procedures for commercial **fans** are well aligned, even though only a few countries so far regulate the energy performance of commercial fans. In addition, IEC is developing a common energy performance metric. The alignment challenge is probably more in making sure that, when new countries start regulating fan energy performance, established IEC test procedures and efficiency metrics are used rather than aligning what is currently in place.

For small fans, there are no universally accepted test procedures or efficiency metrics available. Many countries seem to have an interest in regulating the energy performance of small fans, and there may be scope to develop rigorous international test procedures and efficiency metrics for small fans, analogous to those for commercial fans (though possibly of a lesser complexity).

Transformers

Products covered

Products covered within transformers are:

- Distribution transformers

Distribution transformers provide the final voltage transformation in the electric power distribution system, stepping down the voltage used in the distribution lines to the level used by the customer.

Test procedure and efficiency metrics alignment

All countries analyzed use the same IEC60076 standard as the basis of the standard. The energy performance metrics used in different countries are very similar, but subtle differences mean that there is still the need for alignment. For example, there are differences in the load point at which



efficiency is measured (100%, 50%, 40%, or a combination) and the normalized operating temperature used in tests. Achievable efficiency levels are also impacted by factors such as the frequency of operation, where 60Hz transformers have approximately 10% higher losses compared to 50Hz transformers. Adding 10% to the allowable losses of a 60Hz transformer gives an acceptable technical equivalent to the same 50Hz transformer, allowing comparison of both 50Hz and 60Hz transformers.

Table 21 presents the conversion factors for transformers as determined for this analysis.

Table 21. Conversion factors for transformers

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|--------------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|----------------|--------------------|
| | Test procedure | Efficiency metrics |
| Distribution transformer | 1.1 | 1 | 1.1 | N/A | 1.1 | 1 | 1.1 | N/A | | | 1 | 1 | 1.1 | N/A | | | | |

Comparability and alignment of MEPS and energy labels

Efficiency requirements for distribution transformers vary greatly with product sub-type, making a global comparison between economies almost impossible without breaking down this product into many different sub-types.

Table 22 provides an overview of MEPS and energy label thresholds for transformers. Conversions were not possible as performance requirements vary substantially with product sub-type, making a generic comparison for this product type almost impossible.

Table 22. MEPS and energy label thresholds for transformers

| PRODUCT | Australia | | China (PRC) | | European Union | | India | | Indonesia | | Mexico | | US | | Russia | | South Africa | |
|--------------------------|-----------|------------|-------------|------------|----------------|------------|--------|------------|-----------|------------|--------|------------|------|------------|--------|------------|--------------|------------|
| | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label | MEPS | High Label |
| Distribution transformer | N/A | N/A | N/A | N/A | N/A | | 3 star | 5 star | | | N/A | N/A | N/A | | | | | |

Potential for alignment of test procedures, efficiency metrics and S&L

Test procedures for distribution transformers are already based on the same IEC test procedure (or the similar IEEE test procedure). There are differences in load points and ambient temperature for tests, which could be aligned. The impact of the current variation in load points and temperature is difficult to assess. In addition, transformers have short circuit current requirements, defined by network requirements, which will also impact transformer design. For this product type, even small differences can have large impacts given the relatively small losses due to inefficiencies (which turn into large absolute losses given the large amounts of energy involved). Given the wide variety of product sub-types, there may be scope to develop a unified breakdown of sub-types which could be applied across economies.

07 Summary of Findings and Implications

Introduction

This report presents the largest and most comprehensive comparison of energy standards and labels ever compiled, covering nine major economies and more than 100 products across eight different product areas. Data collected includes over 400 MEPS and label regulations, with their performance requirements, label thresholds, and the test procedures and energy efficiency metrics these are based on. Test procedures and efficiency metrics have been compared and conversion factors developed for approximately half the MEPS and labels identified, allowing for the detailed comparison of performance requirements between economies.

Further information about product requirements, test procedures, efficiency metrics and their comparability is presented in summary in section 6, above, and in detail in Annex 2: Product Fact Sheets. This section provides a crosscutting analysis of this wealth of data, looking beyond individual products and focusing on wider trends and developments. Sub-sections address the level of alignment within product areas as well as a comparison of the level of alignment between economies; a comparison of product coverage with MEPS and labels between economies, as well as which economies have the most ambitious performance requirements; an overview of the status of and potential for further harmonization of test procedures, efficiency metrics and performance levels per product; and overall conclusions from this analysis.

Areas of Most Alignment

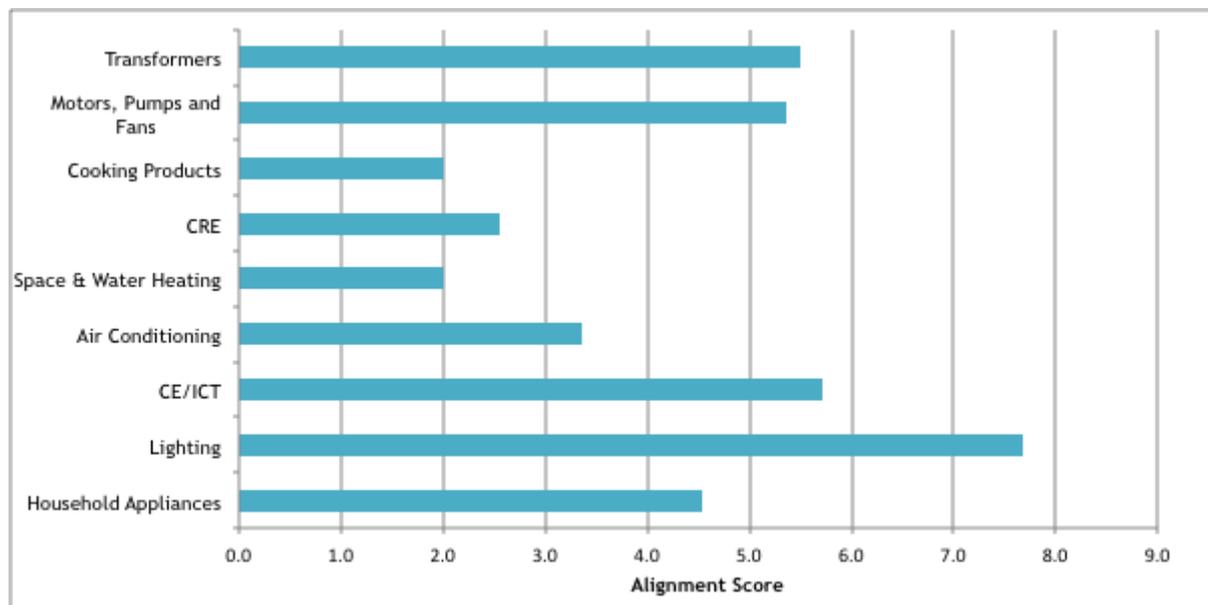
International efforts, over the past years, have focused largely on two courses: better alignment of test procedures for product energy performance, and the development of new international test procedures – for example, via the SEAD initiative and IEC and ISO work – on developing new energy performance test procedures. There has been comparatively little work on the development of common energy efficiency metrics, although regulators have sometimes aligned these without specific international efforts. An interesting development is that some test procedures, such as the one for electric motors, include efficiency metrics and a scale of product energy efficiency levels or tiers in the international test procedure. More commonly, however, efficiency metrics are developed separately within each economy, even if the test procedure is aligned internationally.

The level of alignment in each product area is analyzed by comparing the number of aligned procedures with the total number of products in each area, as well as with the total number of regulated products. This is presented in Figure 1. The analysis underpinning the graphs include:

- Scoring the alignment of conversion for each product type and each country on a 5 point scale, from 0 for no MEPS or Label to 4 for reliable conversion factors;
- Weighing the results by the number of MEPS and label regulations in place within each product area to test to which level internationally comparable test procedures and efficiency metrics are used within that product area.



Figure 1: Alignment of test procedures and efficiency metrics by product area



The chart clearly illustrates differences in the level of alignment between product areas. There is substantially more alignment in the household appliances, lighting, CE/ICT, motors, fans and pumps, and transformers product areas, and less alignment for air conditioning and commercial refrigeration equipment. There is virtually no alignment for space and water heating products or cooking products. Partly, this reflects the level to which products themselves are internationally comparable. Many CE/ICT, lighting, motors and transformer products, for example, are globally traded and the same all over the world. Household appliances have larger regional differences; however, these products have been regulated for energy performance for decades and the impact of different regulations on their performance is by now better known. This enables the development of conversion factors for (known) differences. The motors, pumps and fans area scores lower on alignment than might have been expected based on the product area description, which reflects that energy performance regulations are new to these products and that there are many products currently only regulated in one economy. Where that is the case, international alignment with other economies is impossible. However, where regulations exist, these are usually built on internationally agreed test procedures.

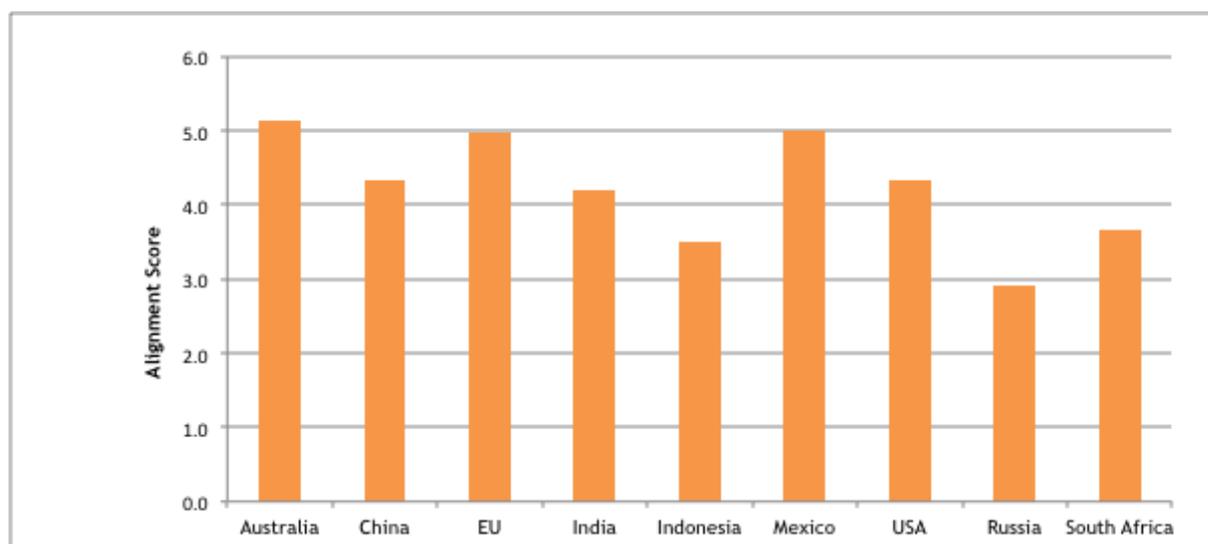
Air conditioning product regulations use the same international test procedure for packaged products, though not for components, and vary greatly in the efficiency metrics used, leading to less alignment overall. Cooking and space and water heating products show large regional differences in their design, usage and characteristics, and regulations are typically built on regional test procedures and efficiency metrics, leading to virtually incomparable MEPS and labels for these products. It is even doubtful to what extent elaborate research or the development of new, internationally aligned test procedures could improve comparability in these areas, given the substantial differences in product definitions and the overall approaches to regulating energy performance in the space and water heating product area.

Amongst the 72 product sub-types selected for this report, there are relatively few products that are more regulated than transformers. Small and medium-sized refrigerator-freezers, chest freezers, clothes washers, televisions and room ACs are all subject to 7 or 8 S&L programs among the nine economies covered in this analysis, whereas medium 3-phase general purpose motors, electric storage water heaters, imaging equipment, simple set-top boxes, linear fluorescent lamps

and CFLs are each covered by 6 S&L measures. There are many other products that are substantially less regulated in each category.

International alignment of test procedures and efficiency metrics has also been analyzed per economy, to assess to which extent economies have aligned their regulations. This is presented in Figure 2, which sets out the level of alignment for MEPS and labels by economy, weighted again by the number of products and by the number of regulations in each product area. These graphs are based on the same methodology as those depicted in Figure 1.

Figure 2: Alignment of test procedures and efficiency metrics by economy



Alignment of test procedures and efficiency metrics varies between countries. When looking solely at the number of aligned test procedures and efficiency metrics per product area, the EU scores highest; however, this number is influenced by the large number of S&L implemented by the EU. Weighted by the number of regulations in place, China, India and the US all show a similar level of international alignment within the economies included in this study, whereas Australia, the EU and Mexico score somewhat higher. For Australia and Mexico, this seems to be the result of a deliberate policy choice: in Australia's case, to align with the most appropriate international standard for its economy; in Mexico's case, to mainly copy (sometimes older) US regulations. The explanation for the EU is probably somewhat different: The EU regulates substantially more products than other economies, typically tackling products that have not previously been regulated elsewhere, and thus setting an international benchmark for testing and evaluating efficiency for those products. This is demonstrated, for example, by pump and fan systems, where ISO test procedure development seems to closely follow the EU Ecodesign process. A similar process applies to the US, although probably more limited to ICT products, where US ENERGY STAR regulations seem to set the example of how to measure and rank energy performance. Other economies seldom tackle novel products and thus typically can choose to adopt an already established test procedure and efficiency metric, or not.

Russia's low ranking is largely explained by the confusing state of its test procedures and S&L, with many outdated Soviet-era standards in place with unclear legal status, and many new regulations possibly, but not certainly, in the process of being aligned with primarily EU requirements. Indonesia's and South Africa's scores are influenced by most of their S&L being under development and uncertainty about which test procedures and efficiency metrics will be applied.

In all economies, less than half of all regulations are fully aligned internationally. Australia, with its policy of international alignment, shows fully aligned test procedures and efficiency metrics for 14 out of its 36 regulated products (included in this analysis), and Mexico, with its policy to align with the US, for 9 out of 22 analyzed regulations.

All economies, with the exception of Mexico, show more alignment in test procedures than in efficiency metrics. Whereas international test procedures often seem to provide a suitable way of measuring energy consumption under standardized conditions, efficiency metrics are more often adapted, probably to reflect different national circumstances such as climatic conditions or usage patterns. In fact, where there seems to be a movement towards using internationally aligned test procedures in all economies, efficiency metrics seem to be drifting further apart. A good example of this is in air conditioning, where virtually all economies have aligned to the same international test procedure for testing product performance, but then use quite different efficiency metrics to assess energy performance. This, in a way, negates the progress being made in aligning test procedures for the purpose of product comparability but also, and more importantly, it creates a barrier for the transfer of energy efficient technologies between economies. It is important to recognize, however, that locally tailored efficiency metrics can be important to ensure that MEPS and energy labels are representative of actual usage in an economy.

Who's ahead in S&L development?

This report covers MEPS and energy labels in 9 economies and for over 100 products, of which 72 are presented in the comparative analysis (see section 6)⁷. In total, 425 regulations were identified, consisting of 228 MEPS and 197 energy labels⁸. The EU and the US are clearly ahead in regulating energy-using products with 67 and 70 products regulated, respectively. Perhaps surprisingly, the EU leads in MEPS, with regulations for 62 products, whereas the US has more energy labels than the EU⁹, which is a reversal of earlier years in which the EU relied more on energy labels and the US more on MEPS. It should be noted that most US labels are ENERGY STAR endorsement labels, whereas most EU labels are categorical energy labels, which are often considered to be more effective in informing the consumer about energy performance and in transforming the market.

China leads in the number of energy labels in place, with 42 products labeled out of a total of 51 regulated. Australia has MEPS and/or energy labels for 41 products, followed by Mexico with regulations for 33 products. India, Russia, Indonesia, and South Africa trail the list, with regulations in place for 16, 14, 10, and 9 products, respectively. Of the 425 S&L regulations identified, 91% (387 regulations) are included in comparisons between countries, and information about performance requirements is available for 52% (219 regulations). Table 23 presents an overview of S&L identified per economy.

⁷ Several product types were grouped for this summary analysis, and some were left out, usually because there was insufficient data for an analysis and/or because only one economy regulates the product

⁸ This analysis groups all types of energy labels and focuses on the performance level of the highest class of a categorical level and the threshold for a benchmark. Labels without energy performance thresholds, such as US EnergyGuide, are not included as there are no performance levels that can be compared.

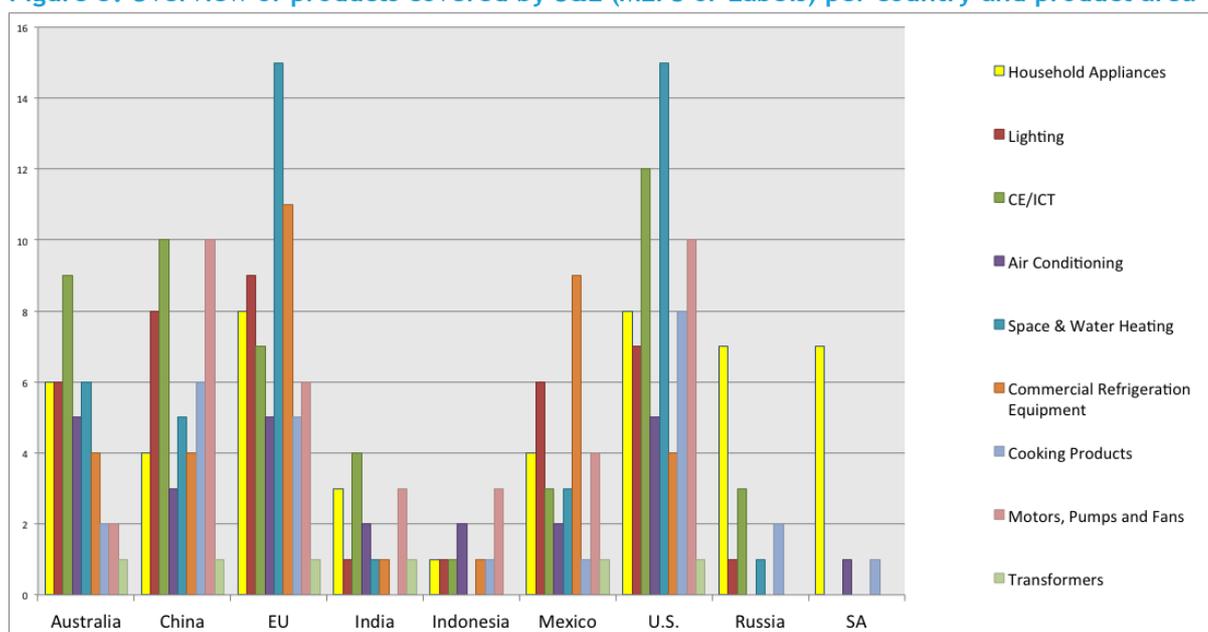
⁹ Situation by mid-2013; since, several countries have adopted new regulations

Table 23. Products covered by S&L (MEPS and/or Labels) by economy for all products analyzed

| Country | MEPS | Labels | MEPS or Labels |
|----------------|------------|------------|----------------|
| Australia | 35 | 18 | 41 |
| China (PRC) | 39 | 42 | 51 |
| European Union | 62 | 35 | 67 |
| India | 5 | 14 | 16 |
| Indonesia | 7 | 8 | 10 |
| Mexico | 23 | 23 | 33 |
| US | 47 | 40 | 70 |
| Russia | 8 | 9 | 14 |
| South Africa | 2 | 8 | 9 |
| Total: | 228 | 197 | 311 |

Internationally, CE/ICT, household appliances and space and water heating are the most regulated product areas, with 49, 48 and 46 S&L regulations, respectively. These are closely followed by lighting products, with 39 regulations; motors, fans and pumps, with 38 regulations; and commercial refrigeration products, with 34 regulations. The number of regulations is lower for cooking products, with 26 regulations, and air conditioning products, with 25 regulations. Transformers, a small and distinct product area, are covered by 6 regulations.

Figure 3 provides a breakdown of S&L regulations per economy and product area. It shows that the EU and US consistently have wider S&L coverage across all product areas, with China and Australia following closely. Mexico seems to focus its efforts to date mainly on lighting and commercial refrigeration products, and South Africa primarily on household appliances. Household appliances are still the only product area with S&L regulations in every economy in our analysis; this is perhaps unsurprising, given that these have been the starting point of product energy efficiency regulation globally and in every economy.

Figure 3: Overview of products covered by S&L (MEPS or Labels) per country and product area

The ambition level of MEPS and labels could only be compared with some reliability for 25% (18 out of 72) of the products covered in the analysis, across household appliances, lighting products, some CE/ICT products, air conditioning and motors. Caution is therefore required when interpreting the results of a comparative analysis of S&L requirements.

Across these comparable products, however, the European Union stands out as the clear leader in S&L development, having by far the largest number of MEPS as well as the most ambitious MEPS and energy labels for more than half the S&L. The EU has the most ambitious MEPS for 9 out of 18 comparable MEPS, and the most ambitious energy labels for 9 out of 15 comparable labels. Of these, 8 MEPS and 8 labels are unique leading positions, and 1 MEPS and label each are shared most ambitious levels with other economies. Australia follows the EU with 3 most ambitious MEPS and 5 labels, of which Australia is uniquely most ambitious for 2 MEPS and 3 labels. Next is the US with 5 most ambitious MEPS, all uniquely most ambitious, and 1 label, shared with others. Following is China, with 2 most ambitious MEPS and 3 most ambitious labels (of which 1 MEPS and 1 label uniquely), followed by Mexico, with 2 most ambitious MEPS and 2 labels (of which only 1 MEPS uniquely). India has one most ambitious label (shared with other economies), and among the countries included in this study, Indonesia, Russia and South Africa close the ranks with no most ambitious S&L.

Table 24. Most ambitious S&L identified by economy for all products analyzed

| Country | Most ambitious | | Unique most ambitious | |
|----------------|----------------|------------|-----------------------|------------|
| | MEPS | High Label | MEPS | High Label |
| Australia | 3 | 5 | 2 | 3 |
| China (PRC) | 2 | 3 | 1 | 1 |
| European Union | 9 | 9 | 8 | 8 |
| India | - | 1 | - | - |
| Indonesia | - | - | - | - |
| Mexico | 2 | 2 | 1 | - |
| US | 5 | 1 | 5 | - |
| Russia | - | - | - | - |
| South Africa | - | - | - | - |

Note: In some instances, more countries share a “most ambitious” MEPS or High Label. As a result, the sum of MEPS and High Labels across countries is not identical to the total number of MEPS and High Labels that can be compared: those totals are 18 comparable MEPS and 15 comparable High Labels.

It should be repeated that comparisons like these need to be treated with caution. There are, for example, several instances of products only labeled (with an ENERGY STAR label) in the US or only subject to Ecodesign requirements in the EU, and those will not show up in a comparison between economies. The tendency shown in the data presented here is clear, however, and there is no reason to assume that this picture would be very different for other product areas.

Potential for test procedure and efficiency metrics alignment

The analysis shows a wide range of alignment for test procedures and efficiency metrics in place: a few products have fully aligned test procedures and efficiency metrics, even including aligned

efficiency levels (such as electric motors) or aligned labels (such as labels for some ICT products). Most products, however, have virtually no alignment of test procedures at all, such as all space and water heating products.

Based on the information collected, the analysis of comparability and expert opinion, the potential for (further) harmonization of test procedures and efficiency metrics has been assessed. In all cases, there is some potential for harmonization, although that seems limited to components of test procedures in some cases. For many heating products, for example, basic product designs and operating conditions vary considerably globally, and it will be difficult to define common test procedures that provide adequate testing for all regions. A similar situation probably applies to many cooling products, beyond integrated room air conditioners. It may be possible, however, to define common tests of product components or modes of operation, such as full and partial load steady state efficiency as well as heating up and cooling down efficiency for space heaters, and chiller energy performance under several load conditions. Similar approaches have recently been used successfully for ISO standards for pump systems. In other cases, fully aligned test procedures seem to be achievable, for example for household refrigerators; however, efficiency metrics may not be so easy to align.

Efficiency metrics in general appear to be much harder to align than test procedures, as alignment requires that, first, test procedures are aligned and, second, that local usage characteristics are comparable enough for a globally aligned efficiency metric to define a globally acceptable way of describing what constitutes energy performance for a product. Some international initiatives have started work on defining or aligning global test procedures, and it seems that economies more and more aim to align their test procedures internationally. However, efficiency metrics, which define how a test result is converted into an energy performance rating, are much less aligned, with some notable exceptions such as international initiatives to define efficiency metrics and energy performance levels in international standards (e.g., for motors and fans). Globally, alignment of efficiency rankings may even be decreasing, for example for air conditioning systems, where the switch from energy efficiency ratios (EERs) to seasonal energy efficiency ratios (SEERs) seems to lead to divergence in S&L, despite convergence to a single internationally agreed test procedure.

Test procedures and efficiency metrics alignment can be complicated by existing national procedures and metrics. Many product designs are tailored to specific test and efficiency requirements, in which case a switch to a different test procedure in an economy may result in substantial shifts in the energy efficiency rankings of existing products. Further, local test procedures and metrics may better represent product usage conditions in an economy. It is not necessarily the case, however, that products regulated only in one or two economies are good candidates for international harmonization. Product designs may differ substantially between economies, as is the case for many heating products, or existing test procedures and efficiency metrics may be representative of specific local usage patterns or climatic conditions not found elsewhere (as, for example, for many cooking products). A case-by-case assessment is needed to determine the expected benefits and the potential for the development of internationally aligned test procedures and efficiency metrics.

Table 25 presents the assessment of alignment potential per product, for the 8 product areas covered in this analysis.



Table 25. Alignment potential per product

| PRODUCT | | Possible for test procedure components | Possible for full test procedure | Possible for test procedure & efficiency metrics | Test procedure already aligned, possible for efficiency metrics | Test procedure & efficiency metrics already aligned | Test procedure, efficiency metrics & ranking already aligned | Test procedure, efficiency metrics, ranking & label already aligned |
|-----------------------|---------------------------------------|--|----------------------------------|--|---|---|--|---|
| Household appliances | Small refrigerator | | | | | | | |
| | Small refrigerator-freezer | | | | | | | |
| | Medium refrigerator-freezer | | | | | | | |
| | Chest freezer | | | | | | | |
| | Clothes Washer | | | | | | | |
| | Combination Clothes Washer/Dryer | | | | | | | |
| | Clothes Dryer | | | | | | | |
| | Dishwasher | | | | | | | |
| Lamps | Lamp - Compact fluorescent | | | | | | | |
| | Lamp - Filament, non-directional | | | | | | | |
| | Lamp - Filament, directional | | | | | | | |
| | Lamp - HID high pressure sodium | | | | | | | |
| | Lamp - HID metal halide | | | | | | | |
| | Ballast - HID (all) | | | | | | | |
| | Lamp - Linear fluorescent | | | | | | | |
| | Ballast - Fluorescent | | | | | | | |
| CE/ICT | Television | | | | | | | |
| | Display | | | | | | | |
| | Simple Set Top Box (STB) | | | | | | | |
| | Complex Set Top Box (STB) | | | | | | | |
| | Computer | | | | | | | |
| | Server | | | | | | | |
| | Imaging Machine | | | | | | | |
| External Power Supply | | | | | | | | |
| AC | Room AC | | | | | | | |
| | Chiller | | | | | | | |
| | Central AC | | | | | | | |
| Space & Water heaters | Space heater - Electric | | | | | | | |
| | Space heater - Residential boiler gas | | | | | | | |
| | Space heater - Residential boiler oil | | | | | | | |
| | Space heater - Commercial boiler gas | | | | | | | |
| | Space heater - Commercial boiler oil | | | | | | | |
| | Space heater - Commercial furnace gas | | | | | | | |
| | Space heater - Commercial furnace oil | | | | | | | |
| | Space heater - CHP | | | | | | | |
| | Space heater - Heat pump | | | | | | | |
| | Space heater - Furnace oil | | | | | | | |
| | Space heater - Furnace gas | | | | | | | |
| | Water heater - Instantaneous gas | | | | | | | |
| | Water heater - Instantaneous electric | | | | | | | |
| | Water heater - Heat pump | | | | | | | |

| PRODUCT | Possible for test procedure components | Possible for full test procedure | Possible for test procedure & efficiency metrics | Test procedure already aligned, possible for efficiency metrics | Test procedure & efficiency metrics already aligned | Test procedure, efficiency metrics & ranking already aligned | Test procedure, efficiency metrics, ranking & label already aligned |
|--------------------------------------|--|----------------------------------|--|---|---|--|---|
| Water heater - Storage electric | | | | | | | |
| Water heater - Storage gas | | | | | | | |
| Water heater - Solar | | | | | | | |
| Water heater - Commercial boiler oil | | | | | | | |
| Water heater - Commercial boiler gas | | | | | | | |
| CRE | | | | | | | |
| Refrigerated Display Cabinet | | | | | | | |
| Refrigerated Cabinet | | | | | | | |
| Refrigerated Vending Machine | | | | | | | |
| Walk-In Cooler & Freezer | | | | | | | |
| Freezer | | | | | | | |
| Ice Machine | | | | | | | |
| Cooking | | | | | | | |
| Oven | | | | | | | |
| Cook top/hob | | | | | | | |
| Microwave oven | | | | | | | |
| Rice cooker | | | | | | | |
| Coffee maker | | | | | | | |
| Motors, Pumps & Fans | | | | | | | |
| Medium 3-Phase General Purpose | | | | | | | |
| Small 3-phase General Purpose | | | | | | | |
| Generic pumps | | | | | | | |
| Heat Pump Systems | | | | | | | |
| Building Circulator | | | | | | | |
| Pool | | | | | | | |
| Dirty water | | | | | | | |
| Agricultural | | | | | | | |
| Cooktop/Fume Hood | | | | | | | |
| Portable Fan | | | | | | | |
| Industrial Blower | | | | | | | |
| Ceiling Fan | | | | | | | |
| Furnace/Duct Fan | | | | | | | |
| Integrated Fan | | | | | | | |
| Distribution transformer | | | | | | | |
| Total | 28 | 16 | 11 | 13 | 0 | 2 | 2 |

Of the 72 products analyzed:

- Only 17 (23%) have aligned test procedures, of which 4 (5%) also have aligned efficiency metrics.
- The remaining 56 products (77%) have no test procedure alignment.
- Full test procedure alignment appears possible for 27 more products, and
- Alignment of efficiency metrics for 24 more products.

This would bring the total potential for aligned test procedures to 44 products (61%) and for aligned efficiency metrics to 28 products (39%), including the ones already aligned. The best potential for



alignment of test procedures and efficiency metrics appears to be in the lighting products, CE/ICT, and motors, pumps and fans areas, and the best potential for test procedure only alignment is in the household appliances and cooking products areas.

Key observations from this analysis

This analysis was conducted to compare MEPS and energy labels among nine economies. During the analysis, data was collected about S&L energy performance requirements and the test procedures that are used to determine those performance levels.

Test procedures were compared and, where possible, linked to reference test procedures (international ones, such as ISO and IEC test procedures, or in some cases, national ones that are internationally accepted such as ENERGY STAR test protocols). Where comparisons were possible, conversion factors were determined to translate energy measures obtained with one test procedure into those that would have been obtained when using the reference test procedure. In most cases, that test procedure conversion factor is either 1, implying that the national test procedure literally or practically aligns with those in other economies, or it is not determinable because the differences are too extensive or there simply is no international reference test procedure.

Efficiency metrics were also compared between economies to assess whether energy performance requirements stated in one economy have the same meaning as those in another. Efficiency metrics turned out to show much greater differences than test procedures. Where test procedures are starting to be more aligned between economies, efficiency metrics are not and differences may even be increasing globally. This partly reflects that an efficiency metric needs to represent the usage of a product in a given region, which differs due to climatic and other factors, and partly probably lack of attention for the importance of efficiency metrics among regulators and international bodies. When efficiency metrics do not align, S&L are typically not comparable, even when the test procedures themselves are comparable.

Findings about individual products have been described in section 6 of this report, and cross-cutting observations in this section. This analysis concludes with a few key observations, relevant for those active in S&L though not directly linked to an individual economy or product:

- Data about S&L performance levels and the test procedures and efficiency metrics underpinning these is not always accessible, even to professionals active in the field.
- Efficiency metrics are as important as test procedures, yet receive virtually no international attention. There is some value in aligning test procedures without also addressing efficiency metrics to reduce testing costs; however, the full benefit is not captured without also addressing efficiency metrics.
- Equally important are product definitions and the scope of regulations and requirements, also overlooked aspects of S&L. For many products, scope and definitions differ considerably between economies, in particular for novel regulations of commercial and industrial products.
- Alignment is greatest at the earlier stages of S&L development, namely test procedures, and is less so for efficiency metrics, and least for MEPS and highest label threshold levels.
- The leading role for the US in S&L development is much smaller than it used to be. In terms of MEPS coverage and ambition level, the US is falling behind other countries.
- The number of products covered by S&L has grown substantially in recent years. The main driver for this has been the extension of scope and ambition level of several S&L programs, primarily in the EU and China. The EU Ecodesign program is now covering more products and has more ambitious performance requirements, for MEPS and energy labels, than any other program.

