A global assessment of appliance energy consumption and coverage gaps in energy efficiency standards and labels

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Abstract

Appliance energy efficiency standards and labels (S&L) are proven effective policies to reduce energy consumption of appliances, equipment, and lighting in the residential, commercial, and industrial sectors. Worldwide, these products were estimated to consume over 21,000 TWh of electricity, oil, and gas in 2012, projected to grow to over 27,500 TWh in 2030. All economies have some gaps in S&L policy coverage for appliances. As such, there are opportunities for increased energy savings via additional product coverage through S&L, most notably in the commercial and industrial sectors.

This paper provides summaries, by sector, of existing global S&L policies and identifies opportunities for saving energy through increased coverage. By combining current information about S&L policies by product from the Collaborative Labeling and Appliance Standards Program's (CLASP) Global S&L Database with energy use by product category and economy for 2012 and 2030, we visually demonstrate the magnitude of the remaining energy savings opportunity via additional S&L coverage today and in the medium term. End-use energy consumption by product and economy provides a framework for prioritizing gaps. We examine how these opportunities vary between the EU, US, China, India, and approximately forty other economies. Finally, using the opportunity analyses, we provide conclusions for how best to achieve additional energy savings from S&L programs.

This high-level gap analysis provides a snapshot for appliance S&L stakeholders to understand the opportunities for broadening the reach of S&L policies. The broad nature of this analysis provides an initial framework for policymakers and stakeholders to better understand the magnitude of the opportunity in this important policy area, and provides a platform for additional research which should take into account economy-specific political and technical considerations.

Introduction

Appliance energy efficiency standards and labels (S&L) are proven, effective policies to reduce energy consumption of appliances, equipment, and lighting in the residential, commercial, and industrial sectors. Worldwide, these products are estimated to consume over 21,000 TWh of electricity, oil, and gas in 2012, and are projected to consume over 27,500 TWh in 2030.[1] All economies have some gaps in S&L policy coverage for appliances. As such, there are opportunities for increased energy savings via additional product coverage through S&L.

This high-level analysis provides a snapshot for appliance S&L stakeholders to understand the opportunities for broadening the reach of S&L policies. The broad nature of this analysis provides an initial framework to better understand the magnitude of the opportunity in this important policy area and provides a platform for additional research which should take into account economy-specific political and technical considerations.

This paper analyses policy coverage by product energy consumption, which we assume to be an indicator of potential

1. Global energy consumption estimates are extrapolated from outputs of the Bottom-up Energy Analysis System (BUENAS), a policy analysis tool created by the Lawrence Berkeley National Laboratory (LBNL) with support from CLASP.

energy savings. This is a simplification, as products have varying ranges of technical potential, and actual savings depend on the stringency of the minimum energy performance standards (MEPS) and the effectiveness of labelling program implementation. However, this approach allows for more straightforward analysis and provides a first pass at identifying possible priorities for increased coverage.

This analysis brings together two global resources on appliance efficiency S&L: the Collaborative Labeling and Appliance Standards Program's (CLASP) Global S&L Database,[2] an online resource detailing S&L policies and regulations around the world; and the Bottom-up Energy Analysis System (BUENAS), a policy analysis tool created by the Lawrence Berkeley National Laboratory (LBNL) with support from CLASP. The analysis identifies areas with potential for energy savings through the implementation of additional policies. However, because it focuses on the energy *consumption* of products and economies and does not examine energy *savings* per se, any identified opportunities to cover additional energy demand should be assessed to determine whether savings potentials are commensurate.

Methodology

POLICY COVERAGE

To perform this analysis, a copy of the Global S&L Database – which catalogues S&L policies that economies have developed for various products – was downloaded from the CLASP website to provide policy coverage information for products and product categories across 43 economies (see Table 1). Individual economies were removed that follow the S&L policies of the European Union – France, Germany, Poland, Sweden, and the United Kingdom. Although some of these economies have policies or regulations in addition to those put in place by the European Commission (EC), most of the S&L policy coverage for these countries is represented through the policies of the EC.

Some product categories included in the database were eliminated either because they were considered to be beyond the scope of this analysis – such as building materials and photovoltaic products – while other product types were grouped when appropriate.

PRODUCT ENERGY CONSUMPTION

To determine the global energy consumption of appliances, this analysis used energy consumption results from the most recent business-as-usual (BAU) scenario from BUENAS. The BUENAS methodology is outlined in detail in a previous study.[3]

The BAU scenario in BUENAS covers major energy-consuming end uses in 13 major economies (see Table 2) which make up 77 % of global energy demand. To determine the energy consumption for remaining economies of major end-uses (lighting, refrigerators/freezers, televisions, space cooling, clothes washers, and fans), LBNL extrapolated energy use through ten regional groupings (the nine listed in Table 2, with Western and Eastern Europe treated as two different groups). This analysis uses the energy consumption data generated by BUENAS or extrapolated from those results.

To determine the energy consumption for remaining end-uses in economies not included in the BUENAS BAU scenario, this analysis produces a rough extrapolation by applying the global average percentage of energy use for each product category to the total energy use in each economy. The top-down total energy use in each economy was determined by compiling final energy consumption data from the International Energy Agency (IEA)[4] for electricity use, natural gas use, and oil use (liquefied petroleum gases, other kerosene, gas/diesel, and fuel oil) for each economy by sector (Residential, Commercial and Public Services, Industry).

COMBINING THE DATA SOURCES

To perform this analysis using policy coverage data from CLASP's Global S&L Database and energy consumption data from the BUENAS BAU scenario, it was necessary to reconcile the product categories used by each resource. The database and BUENAS use different taxonomies, and each resource uses varying levels of detail for different products or product categories.

The database uses four sector designations – residential, commercial, industrial, and multi-sector. For products with the multi-sector designation, judgment was used to determine which of the three sectors (residential, commercial, or industrial) was applicable to each product or product group. This decision was made using the information provided in the database rather than by going back to the original policies and regulations published by economies.

Additionally, certain product categories in the database are not currently covered in BUENAS. For this analysis, a case-by-case decision was made about how to treat these. Given the breadth of this analysis, many product categories were excluded. Selected products for which energy data was not available are presented separately (e.g., computers), as are appliance systems (e.g., ballasts and lighting systems), since it is outside the scope of this analysis to separate the energy use of systems from the energy use of the component parts.

Because we have sometimes grouped products from the database into one product category (e.g., policies for griddles and microwaves are both classified as cooking appliances), some product groups will be represented in this analysis as covered by S&L policies when in fact only some products types are covered within that product group.

Using the methodology described above, we graphed the total energy use – in 2012 and 2030 – for each product category that is covered by both MEPS and labels, covered by MEPS only, covered by a label only, or not covered at all. The graphs showing coverage of projected energy consumption in 2030 still use current S&L policy coverage; there are no assumptions made about future S&L policy coverage.

SCOPE OF ANALYSIS

Figure 1 shows the portion of world economies covered by this analysis. The graph on the left shows the percentage of economies included in the CLASP database (and therefore in this analysis) by number, while the graph on the right shows the

2. http://www.clasponline.org/en/ResourcesTools/Tools/SL_Search

3. McNeil, Michael, 2012. Bottom-Up Energy Analysis System – Methodology and Results.

4. IEA, 2009. Statistics and Balances. http://www.iea.org/stats/index.asp

Table 1. Economies covered in CLASP's Global S&L Database.

OECD Pacific	North America	Western and Eastern Europe	Former USSR	Latin America & Caribbean	Sub-Saharan Africa	North Africa and Middle East	China	Other Asia
Australia	Canada	European Union	Russia	Argentina	Ghana	Egypt	China	Brunei Darussalam*
Japan	United States	France*		Brazil	Kenya	Iran	Hong Kong	Chinese Taipei (Taiwan)
Korea		Germany*		Chile	Nigeria	Israel		India
New Zealand		Poland*		Jamaica	South Africa	Jordan		Indonesia
		Sweden*		Mexico		Tunisia		Malaysia
		Switzerland		Peru		United Arab Emirates		Pakistan
		Turkey						Philippines
		United Kingdom*						Singapore
								Thailand
								Vietnam
*Countries not considered individually in this analysis.								

Table 2. Economies covered in the BUENAS Business as Usual (BAU) scenario.

OECD Pacific	North America	Western and Eastern Europe	Former USSR	Latin America	Sub-Saharan Africa	North Africa and Middle East	China	Other Asia
Australia	Canada	European Union	Russia	Brazil	South Africa		China	India
Japan	United States			Mexico				Indonesia
Korea								

percentage of included economies' contribution to global energy consumption by sector.

Although this analysis only covers 31 % of all economies by count, those economies make up 91 % of energy consumption in the residential, commercial, and industrial sectors. Because the BUENAS energy analysis used does not include every end use within each sector, however, the actual energy demand covered is lower than 91 %.

Appliance Policy Coverage Results

Examination of end-use energy consumption by product and by economy provides a framework for identifying coverage gaps that represent the largest amounts of energy consumption. Below are the results of this analysis separated into the residential, commercial, and industrial sectors.

RESIDENTIAL APPLIANCES

Looking first to the residential sector, Figure 2 plots the total energy consumption of the major energy-using appliances. Each bar represents a product category, and economies' energy use for each product category is grouped based on the presence or absence of S&L coverage. Therefore, the total height of each bar represents the cumulative energy consumption for that product category across all included economies. The top section of each bar, denoted by diagonally-striped shading, represents the energy consumption from economies not covered by the CLASP S&L database (i.e., economies that comprise 9 % of global energy consumption). For this analysis, the energy consumption within these economies is assumed to be spread proportionally across all end use categories.

Information by product: trends and coverage gaps

In the residential sector, for the 43 economies covered by the CLASP S&L database, over two-thirds of appliance energy use is covered by either a MEPS or a label. Out of nearly 9,500 TWh of energy use from all product categories in 2012, 5,800 TWh is covered by both MEPS and labels, and an additional 700 TWh are covered by only one or the other. As MEPS and labels function in different ways to achieve energy savings, these partially covered appliances represent an opportunity for achieving additional savings. However, the greatest additional energy savings can be found via the product and economy combinations that have neither MEPS nor

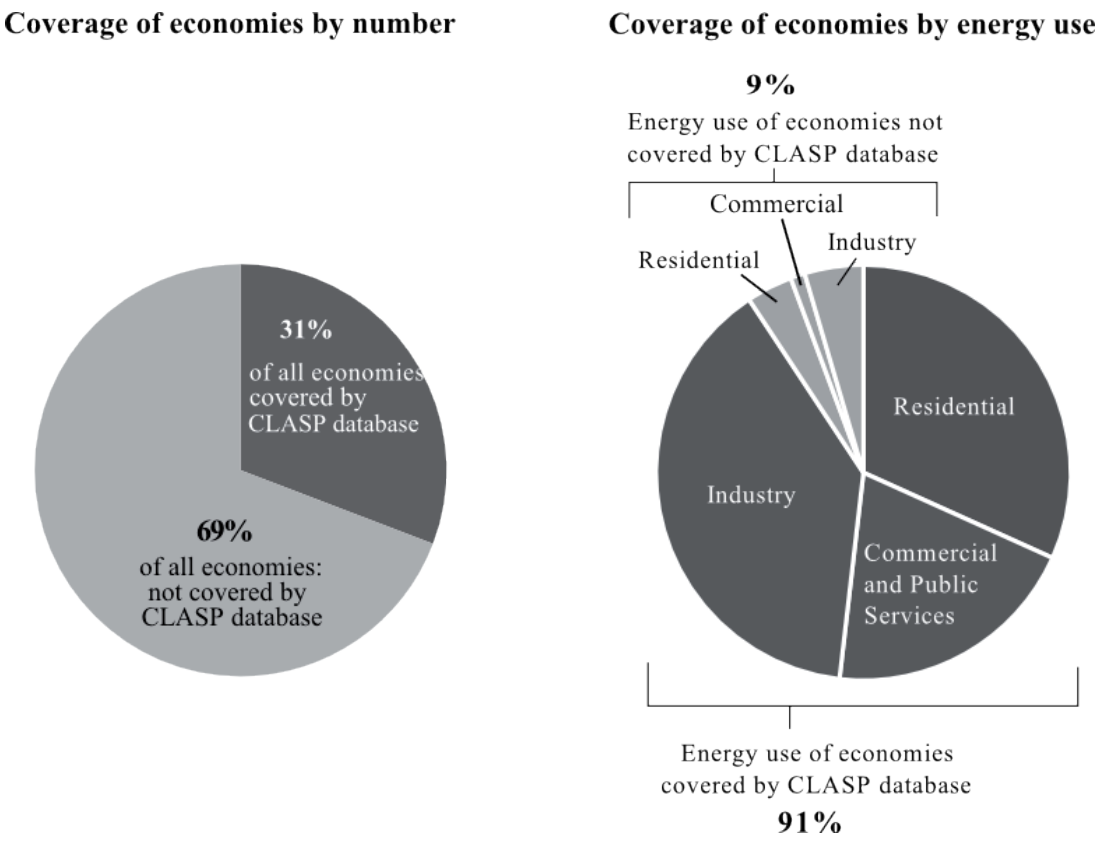

Figure 1. Coverage of economies by number and energy use.

labels. Of these, the biggest coverage gap from Figure 2 is in space heating.

Space Heating

Figure 2 shows space heating is the highest energy-using end use in the residential sector. This product category includes boilers and other space heating equipment such as furnaces.

The largest amount of uncovered energy consumption is represented by boilers in the EU which consumed an estimated 1,700 TWh in 2012; however, as of mid-February 2013, the European Commission had approved energy labels for this appliance class. A vote is planned for March 2013; if the vote passes the label, then official publication is expected in summer 2013 and implementation is expected in 2015.

The next largest amount of uncovered energy for space heating is in China, where energy consumption from space heating appliances grows substantially from 180 TWh in 2012 to 600 TWh in 2030. While China has a label for room heaters, it does not have S&L policies in place for boilers or other residential space heating equipment. Implementing MEPS or labels for space heating in China could therefore have significant impact, especially since the growth between 2012 and 2030 implies that much of this energy use comes from equipment that has yet to be purchased.

Standby

Though standby power consumes much less energy than space heating Figure 2 above also shows a large coverage gap for standby power. Though many economies have S&L policies in place on a product-by-product basis, there are very few economies with a policy for standby power across all products (also referred to as a "horizontal" policy"): there is a label in Argentina and MEPS in the EU, Canada, and Australia. However, this coverage gap only tells part of the story, as discussed in a previous study[5]:

> Most economies are currently regulating standby power levels on a product by product basis. The EU, however, has introduced horizontal standby power limits … By making these provisions horizontal it avoids regulatory gaps caused by delays in the regulatory process or because of the standby power consumption of the many small electrical end-uses that often do not consume enough power to justify having a dedicated rulemaking. They thus ensure that all relevant products are covered. The Commission project power savings of over 70 % from these measures (39 TWh annually in 2020) … The main reason why an economy may not choose to introduce horizontal requirements is that it may require a new legislative mandate as the requirements do not apply to any specific product class uniquely, thus the pace of regulatory development may depend on the primary legislative mandates in place.

Lighting

Aside from space heating and standby power, the energy use for most other residential product categories is covered by S&L programs. One additional area of interest is in lighting, partly because of coverage gaps but also due to the significant

5. Paul Waide, 2011. Opportunities for Success and CO2 Savings from Appliance Energy Efficiency Harmonization.

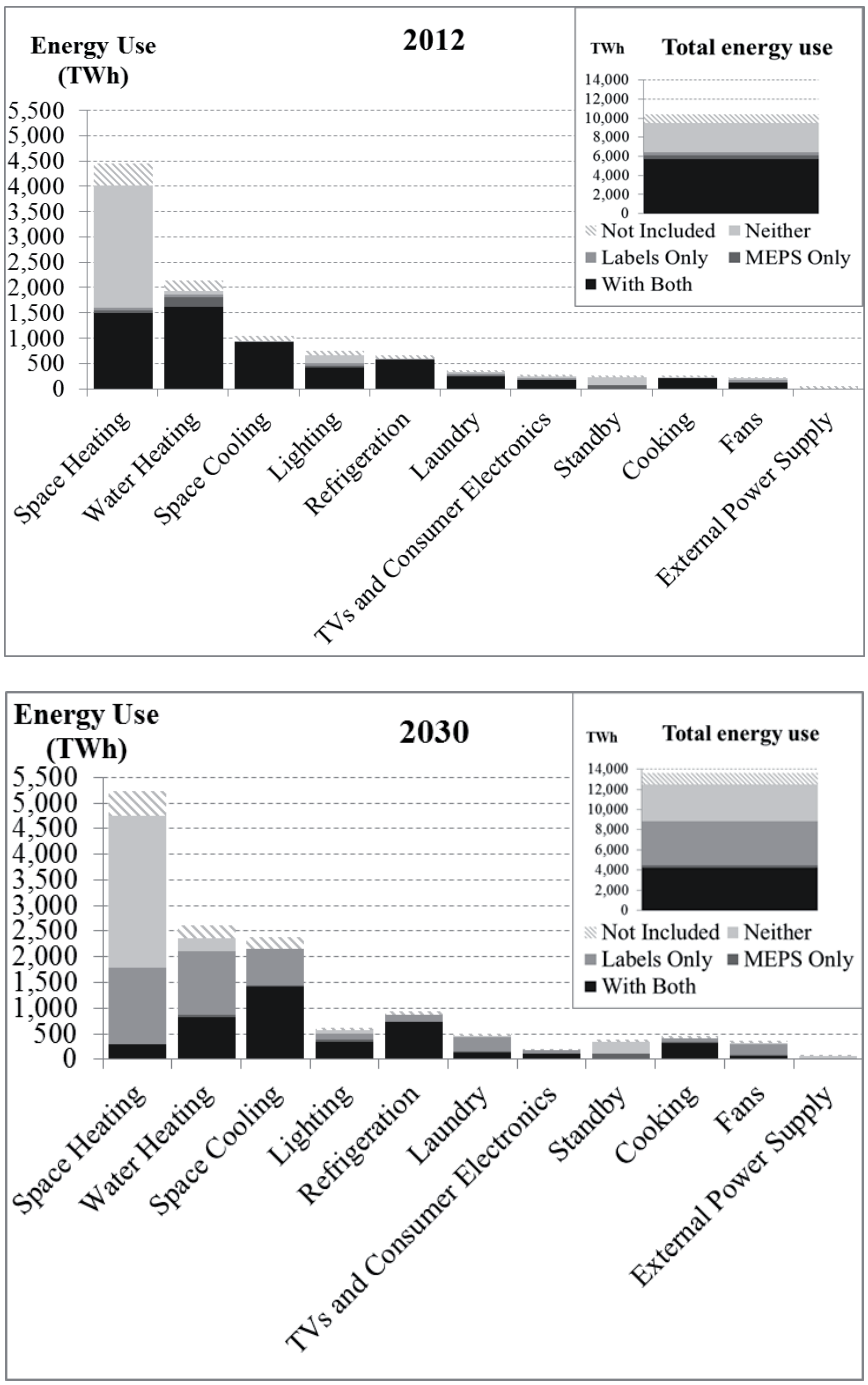

Figure 2. Energy use of residential products in 2012 and 2030.

changes expected in the technologies used. Figure 3 shows the lighting product category split into the three most common current technology types in the residential sector – incandescent, conventional fluorescent, and compact fluorescent lighting (CFL).

Numerous countries have implemented phase-outs of incandescent lighting, and CFLs have gained wider consumer acceptance in recent years. BUENAS energy estimates for these three categories clearly show this trend, with CFLs replacing much of incandescent energy use, and with the total energy consumption of residential lighting decreasing from 2012 to 2030 due to the higher efficiency of fluorescent products. This shift is being driven predominantly by policies already in place to phase out incandescent bulbs (often through MEPS), rather than by changing consumer preferences. As Figure 3 shows, MEPS and labels for incandescent bulbs continue to offer significant energy reductions between 2012 and 2030.

Many economies are also beginning to implement standards for LED performance, quality, and safety. While LEDs may offer significant additional savings as their market share increases, current costs and efficiencies do not make them cost effective for most lighting applications. LEDs are not assumed to be a substantial portion of the Business as Usual case in BUENAS, and as such, they have not been included here.

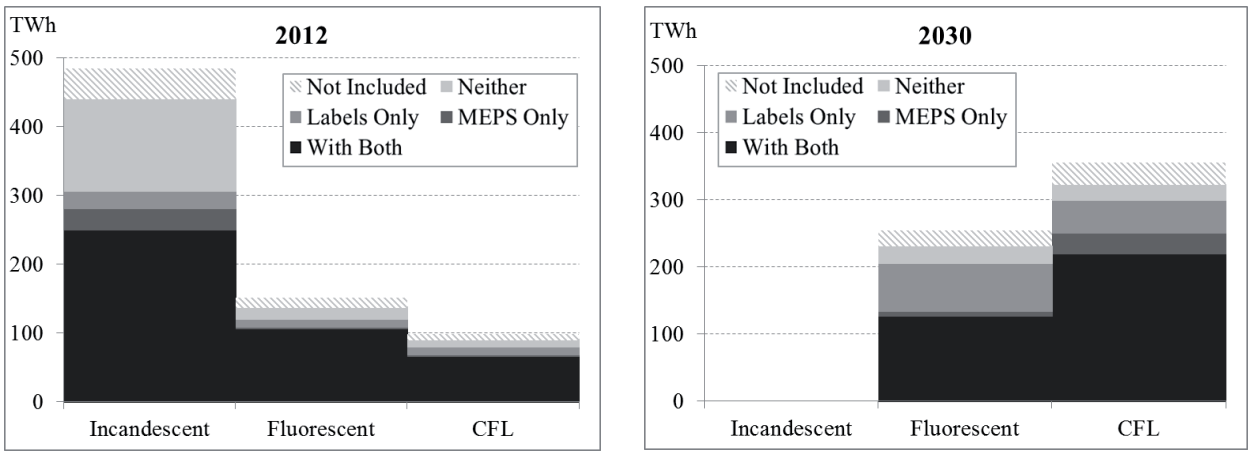

Figure 3. Energy use of residential lighting in 2012 and 2030.

Laundry

Energy use of laundry products is divided into two main categories: clothes washers and clothes dryers. Figure 4 shows that clothes washers use more energy than clothes dryers; the biggest opportunity for this product is in increasing coverage by MEPS, as a substantial portion of clothes washer energy use is covered only by labels.

Most of the energy consumed by clothes dryers occurs in seven economies, all of which have both MEPS and labels in effect. There are substantial cultural differences in the use of clothes dryers, and many economies without policy coverage do not have significant energy use in this category. With growing affluence, this may change; however, significant growth in clothes dryer energy consumption in countries such as China, Brazil, and India currently is not assumed in the BUENAS Business as Usual case. This will be a shift to watch in coming years to determine whether energy demand in this appliance category grows more than expected.

Televisions and consumer electronics

Televisions and consumer electronics are split into two television types – flat screen and cathode ray tube (CRT) – and set top boxes. The current BUENAS results do not include energy use from residential computers; computer S&L policies are shown in the matrix in Figure 6 to display policy coverage in the absence of energy consumption information.

The biggest current opportunity to increase S&L policy coverage of energy consumption in televisions and consumer electronics is for CRT televisions; however, Figure 5 shows that all energy consumption from CRT televisions is expected to be replaced by flat screen televisions by 2030. Unlike the transition from incandescent bulbs to more efficient lighting technologies, this transition is driven by a technology shift based on consumer preferences; flat screen televisions provide improved viewing quality and require less space. Most energy use of flat screen televisions is covered; therefore, energy savings in this product category will come from the addition of a MEPS in economies that only have a label, and from increased stringency in economies that already have both a MEPS and a label.

Economy-specific opportunities for increasing coverage

The matrix in Figure 6 visually displays how S&L coverage of residential appliances varies by economy. Economies are sorted top to bottom by most to least comprehensive coverage in the residential sector, and products are sorted left to right by most to least comprehensive coverage. Unlike the graphs above, which use energy demand per economy per end use, this matrix uses average energy use for each product or product group across all economies. The width of each column is scaled in proportion to the global energy use of that product or product group. For economies, the height of each row is scaled in proportion to the energy use of that economy in the residential sector.[6]

From Figure 6, it is clear that S&L policy coverage in the residential sector is fairly comprehensive. With the exception of boilers (discussed above in the space heating section), there are very few opportunities for large increases in energy use covered by S&L policy through a single policy action (i.e., a single end use in a single economy). Therefore, it is important to focus on increasing the stringency of existing regulations while also complementing labels with MEPS (e.g., refrigeration, space cooling, and water heating in Argentina), complementing MEPS with labels (e.g., water heaters in Japan), and complementing both with market transformation policies such as incentive programs.

A final strategy for increasing energy savings in the residential sector is to create S&L programs in those economies not included in this analysis that comprise an additional 9 % of energy consumption (see Figure 1). Best practice S&L programs begin by addressing the most prevalent and highest energy-using appliances which are commonly residential sector appliances including refrigerators and air conditioners.[7] Though additional energy savings are possible by establishing S&L policies for these additional economies, it will be increasingly hard to capture this potential due to the quantity of economies that need to be addressed – these countries comprise 69 % of all of the individual economies in the world. For smaller econo-

6. IEA, 2009. Statistics and Balances. http://www.iea.org/stats/index.asp

7. Stephen Wiel and James McMahon, 2005. Energy-Efficiency Labels and Standards: A Guidebook for Appliances, Equipment, and Lighting. CLASP.

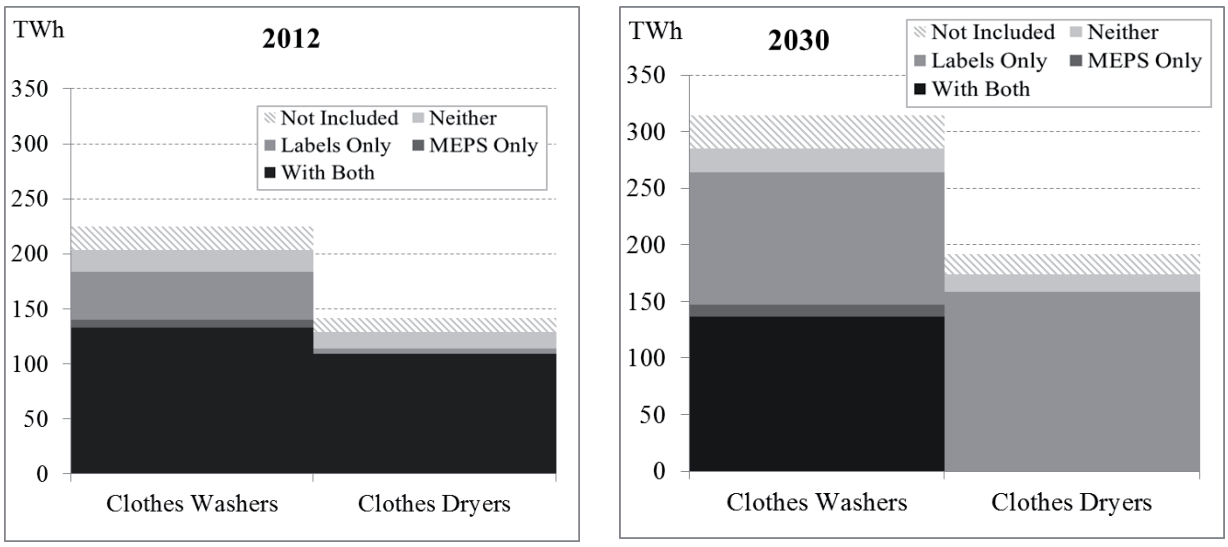

Figure 4. Energy use of residential laundry appliances in 2012 and 2030.

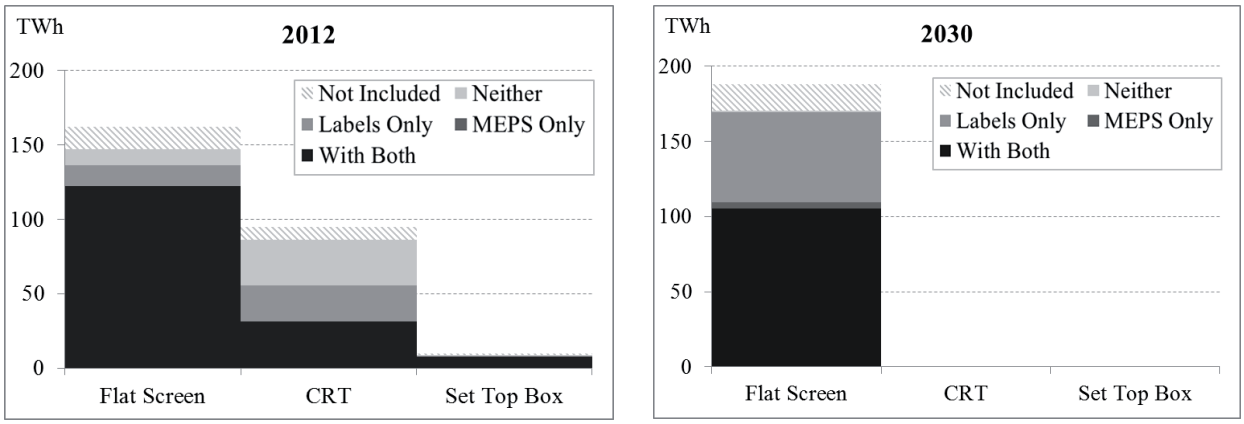

Figure 5. Energy use of residential televisions and consumer electronics in 2012 and 2030.

mies with lower energy consumption, regional initiatives may be more successful than individual economy S&L programs. For example, the fifteen economies that form the Economic Community of West African States (ECOWAS) are developing a regional policy on energy efficiency, including "a harmonised policy, legal and regulatory framework in energy efficiency for the ECOWAS region, including energy efficiency labels and standards[8]."

COMMERCIAL EQUIPMENT

Information by product: trends and coverage gaps

The current BUENAS results have higher-level representation of a small number of commercial product categories (lighting, space cooling, and refrigeration). As such, we present an indicative analysis for available data. This analysis only includes appliance-specific policies, and therefore does not consider implications of building codes on these appliances in the commercial sector. More in depth study of commercial energy consumption globally is needed to provide more in depth analysis.

Economy-specific opportunities for increasing coverage

The matrix in Figure 8 visually displays how S&L coverage of commercial appliances varies by economy. This matrix is compiled in the same way as the matrix created for residential appliances, with economies sorted top to bottom by most to least comprehensive coverage, and products sorted left to right by most to least comprehensive coverage. For this matrix, the row height is relative to the energy use of each economy in the commercial sector.[9]

8. The ECOWAS Energy Efficiency Policy (EEEP), 2012. Available from the ECOWAS Observatory for Renewable Energy and Energy Efficiency. http://www.ecowrex.org/sites/default/files/081012-ecowas-ee-policy-final-en.pdf

9. IEA, 2009. Statistics and Balances. http://www.iea.org/stats/index.asp

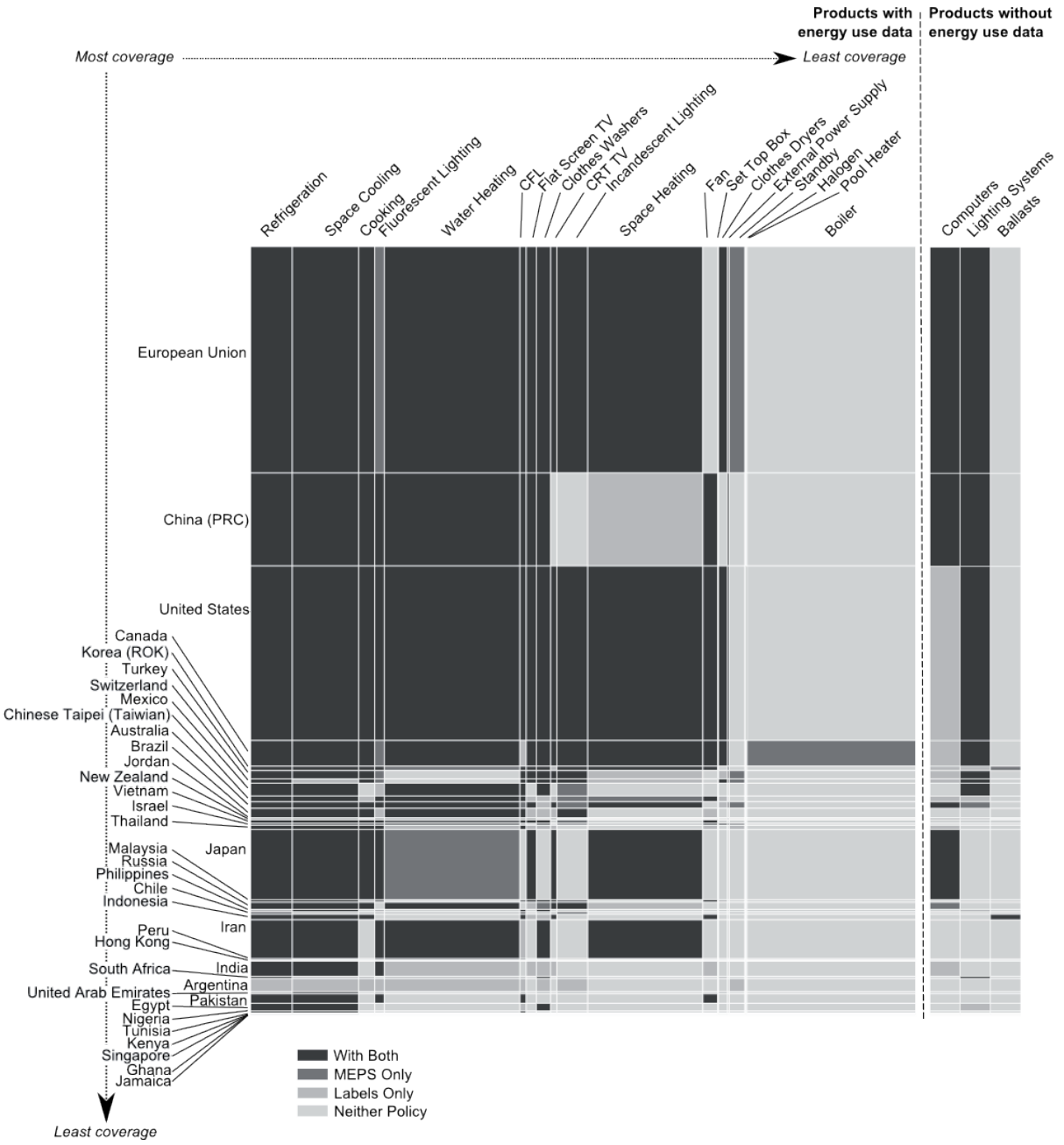

Figure 6. Matrix of economies' coverage of residential appliances.

As in the residential sector, Figure 8 shows the end uses and economies that use the most energy in the commercial sector generally have high coverage. There are opportunities for the EU and the US to gain additional coverage through labels on products that only currently have MEPS, which could provide additional information to commercial consumers to promote the purchase of high-efficiency products. In the EU these products include commercial refrigeration equipment, space heating, ventilation fans, and building circulator pumps; in the US these products include water heating, space heating, and ventilation fans. In addition, the US and China can improve their coverage of commercial products by covering boilers, which are not currently subject to any S&L policies in either economy.

Of the economies with the highest energy consumption, Japan has the biggest opportunity to improve its coverage in the commercial sector. Currently, Japan covers lighting, refrigeration, space cooling, and imaging equipment, but does not cover other commercial sector equipment.

INDUSTRIAL EQUIPMENT

For the industrial sector, this analysis focuses on electric motors and distribution transformers. This analysis does not include energy uses from specific industrial processes (e.g. cement; pulp and paper).

Information by product: trends and coverage gaps

The graphs in Figure 9 show energy demand from electric motors and distribution transformers in 2012 and 2030, only in economies modelled in BUENAS. The BUENAS definitions for each motor size are presented in Table 3. BUENAS provides the

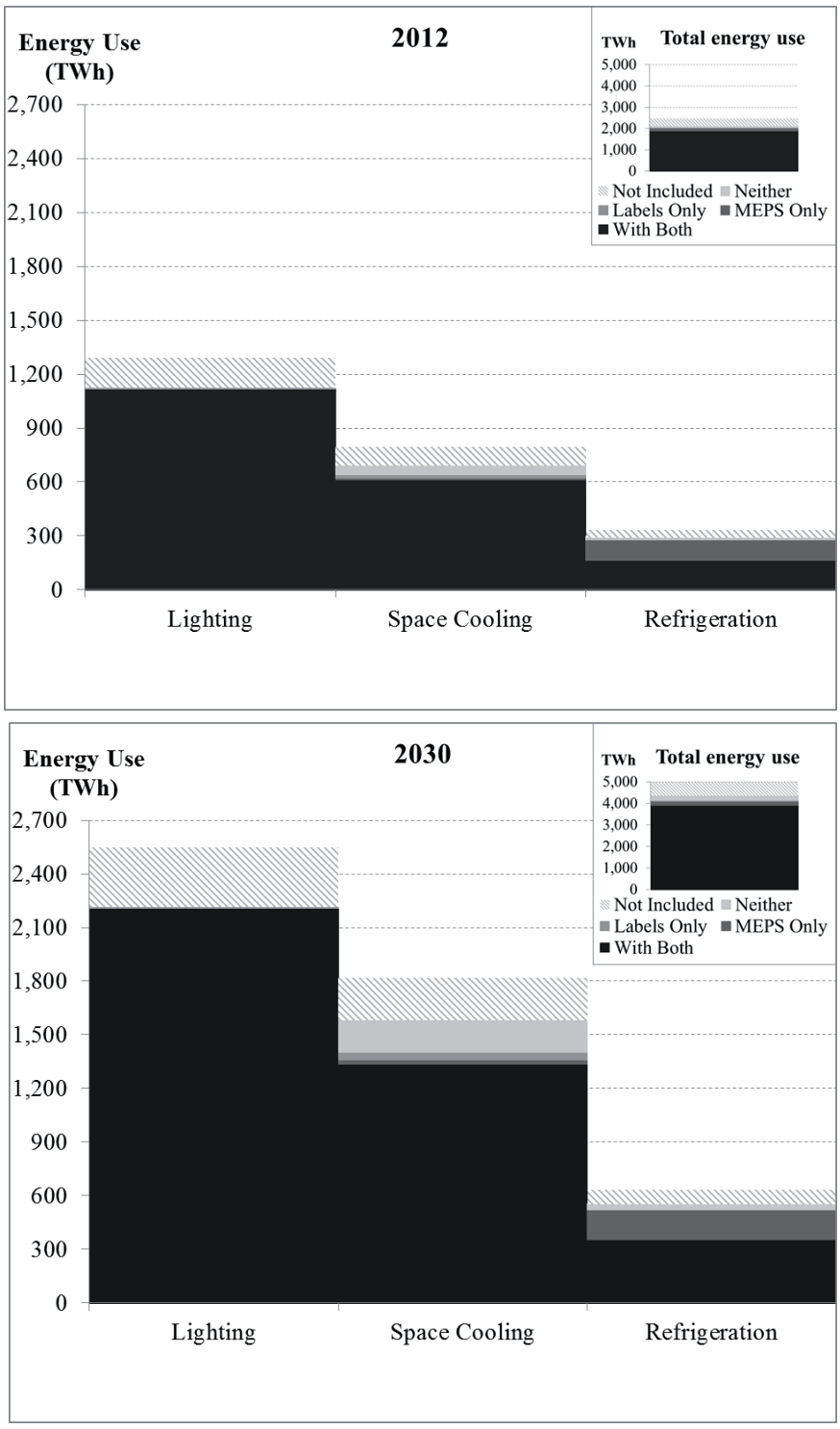

Figure 7. Energy use of commercial products in 2012 and 2030.

energy demand for small motors only in the US; however, since coverage for small motors exists in several economies around the world, this analysis extrapolates small motor energy use in the remaining economies by applying the US ratio of small motors to the other industrial products modelled (medium motors, large motors, and distribution transformers). It is apparent from the total energy use graphs in Figure 9 that in 2012 and 2030, approximately two-thirds of the energy use from these products is not covered by S&L policies.

The biggest opportunity for increasing coverage of energy consumption is through S&L policies for large motors. Large motors consume a significant amount of energy, although these motors are already very efficient and they can be much more difficult to make policies for as they are often custom built. A previous study[10] noted that:

10. Paul Waide, 2011. Opportunities for Success and CO2 Savings from Appliance Energy Efficiency Harmonization.

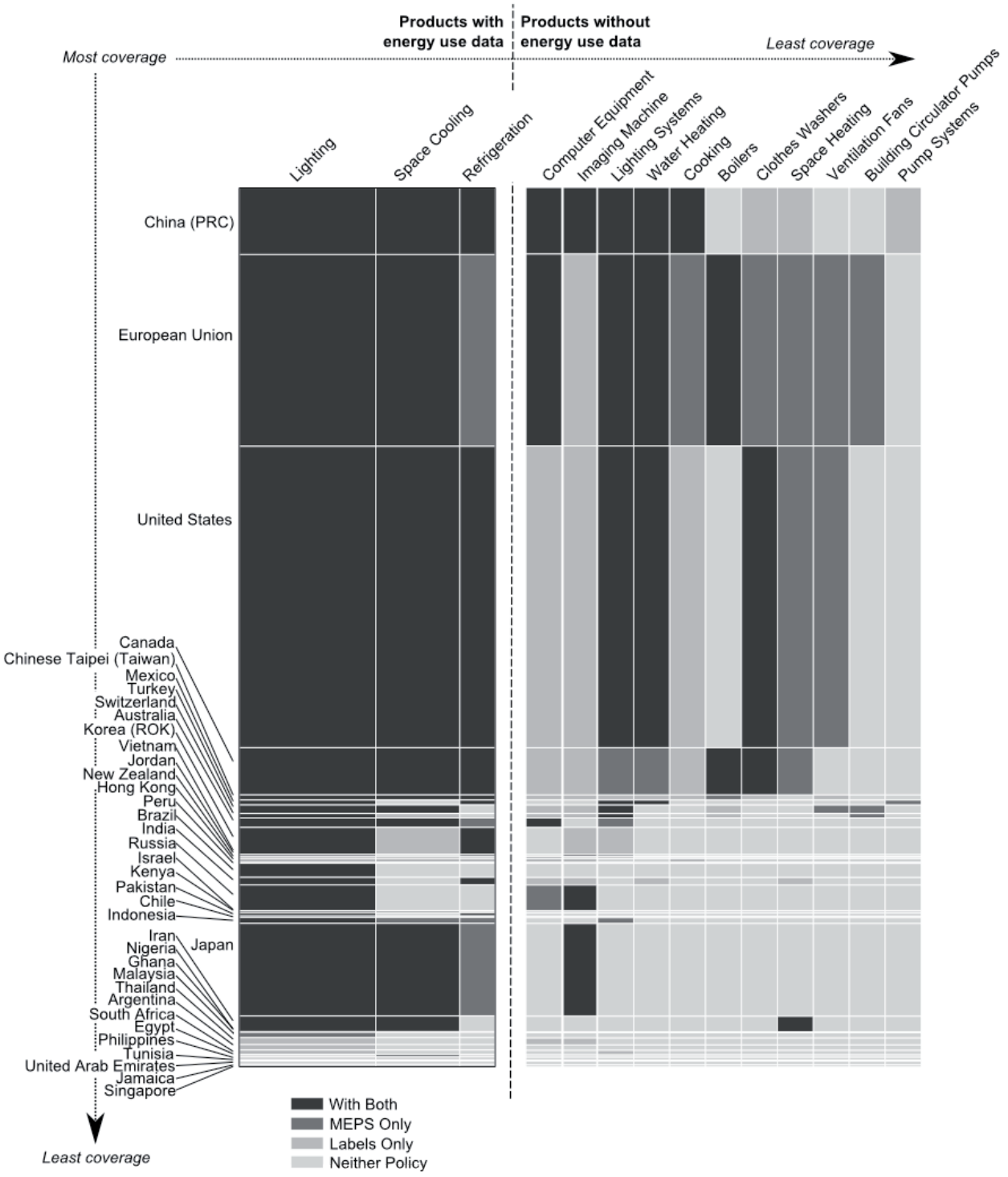

Figure 8. Matrix of economies' coverage of commercial appliances.

Large electric motors[11], of greater than 375 kW output power, are usually high voltage AC motors that are custom designed, built to order and are assembled with an electro-mechanical system on site. They comprise just 0.03 % of the electric motor stock in terms of numbers, but account for about 23 % of all motor power consumption … These motors are not currently subject to minimum energy performance regulations in any part of the world.

This analysis does not address the energy use of electric motor-driven systems, which in many cases can deliver even greater energy savings of 20 to 30 %.[12]

11. This study uses a different definition for large motors (over 375 kW output power) than the one used in BUENAS (over 75 kW output power).

12. Paul Waide and Conrad Brunner, 2011. Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems. International Energy Agency.

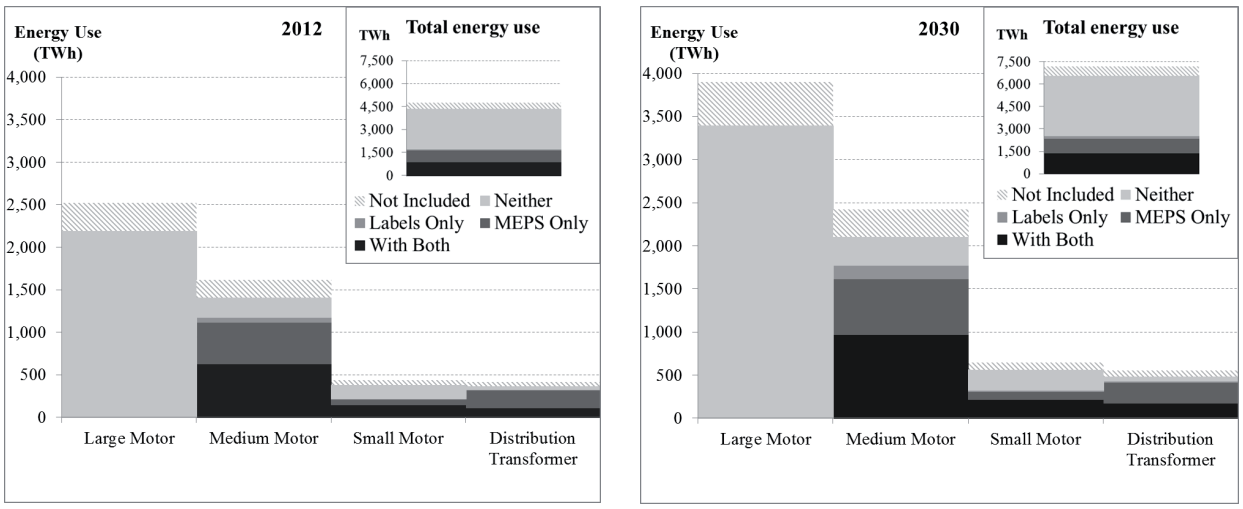

Figure 9. Energy use of industrial electric motors and distribution transformers in 2012 and 2030.

Economy-specific opportunities for increasing coverage

The matrix in Figure 10 visually displays how S&L coverage of electric motors and distribution transformers varies by economy. This matrix is compiled in the same way as the matrices created for residential and commercial appliances, with economies sorted top to bottom by most to least comprehensive coverage, and products sorted left to right by most to least comprehensive coverage. For this matrix, the row height is relative to the energy use of each economy in the industrial sector.[13]

Figure 10 again emphasizes the opportunity for all economies to improve their S&L policy coverage of electric motors and distribution transformers. This matrix includes variable speed drives (VSDs) to show policy coverage, not energy use, since VSDs can be used with any size motor.

In addition to the absence of coverage for large motors, Figure 10 shows that variable speed drives are only covered by two economies. As with standby power in the residential sector, this is somewhat misleading since some economies, such as the EU, have S&L policies regarding variable speed drives incorporated into other motor policies. However, this is an important component of motors that can greatly affect their efficiency and therefore should be examined in each economy.

Table 3. BUENAS definitions for motor sizes.

Motor size	Range (kW)
Small	0.75–7.5
Medium	7.5–75
Large	>75

Conclusions

S&L policy coverage in the residential sector is fairly comprehensive. With the exception of boilers (discussed in the space heating section above), there are very few remaining opportunities to increase S&L policy coverage for a large amount of energy use through a single policy (i.e., a single end use in a single economy). Therefore, it is important to focus on increasing the stringency of existing regulations while also complementing labels with MEPS, MEPS with labels, and both with other market transformation policies such as incentive programs. In the commercial sector, although several high energy consuming product categories are covered, there are larger opportunities for increased product coverage as compared to the residential sector. In the industrial sector, all economies can improve their S&L policy coverage of electric motors and distribution transformers. Large electric motors provide the biggest opportunity for increasing S&L policy coverage over energy use in this sector. The analysis presented here, however, largely does not address the energy use of systems, which in many cases can deliver even greater energy savings – such as in the case of motor systems.

While economies that consume 91 % of global energy are covered in this analysis, 69 % of all of the individual economies in the world are not included. For smaller economies with lower energy consumption, regional initiatives may be more successful than individual economy S&L programs.

A large portion of the initial savings from appliance S&L policies around the world have already been achieved through MEPS and/or labels on high energy-consuming products in high energy-consuming economies. For many product categories, especially in the residential sector, the largest energy savings will therefore come from increased stringency of policies rather than increased coverage of additional product categories. There remains a need to focus increased S&L policy coverage on products and economies with large anticipated growth rates in energy use (such as air conditioners in India, China, and Brazil), while also accelerating the implementation of initial policies on lower energy-consuming products and economies.

13. International Energy Agency, 2009. Statistics and Balances. http://www.iea.org/stats/index.asp

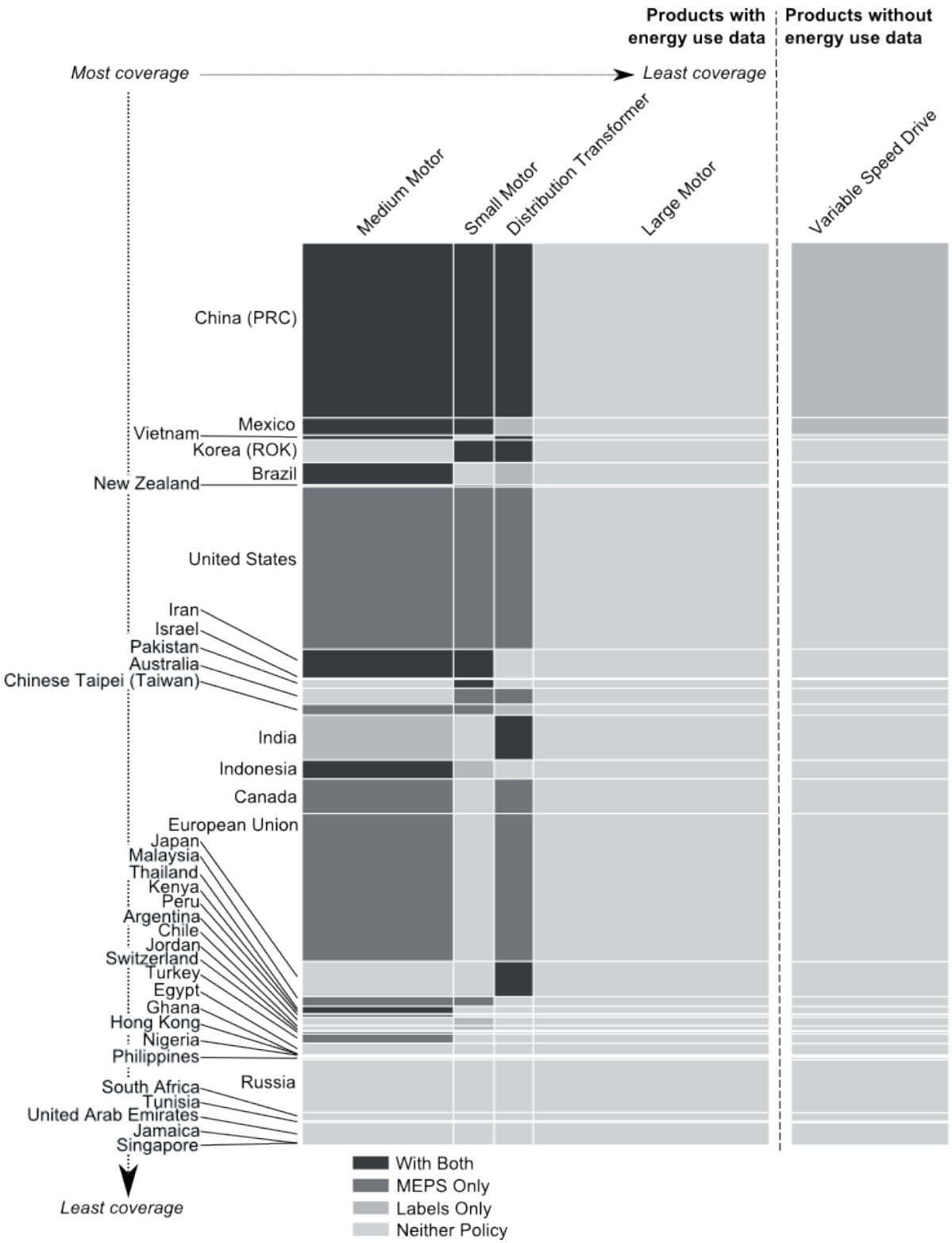

Figure 10. Matrix of economies' coverage of electric motors and distribution transformers.