World's Best MEPS

Identifying Top Energy Efficiency Standards for Priority Appliances

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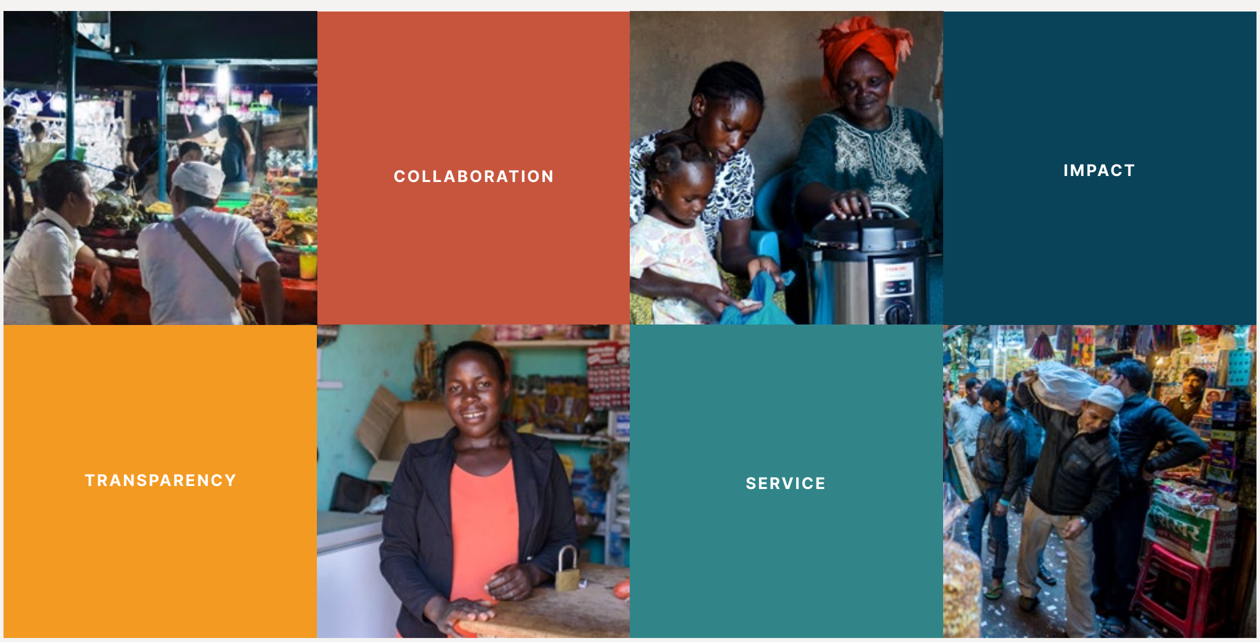
DISCLAIMER



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Executive Summary

This report evaluates and ranks the stringency of minimum energy performance standards (MEPS) requirements for the six highest energy-using appliance categories across ten of the world's highest carbon-emitting economies.

APPLIANCE CATEGORIES

- Lighting
- Electric motors
- Air conditioners
- Refrigerators
- Water heating
- Space heating

ECONOMIES

- Brazil
- Canada
- China
- European Union
- India
- Indonesia
- Japan
- South Africa
- United Kingdom
- United States

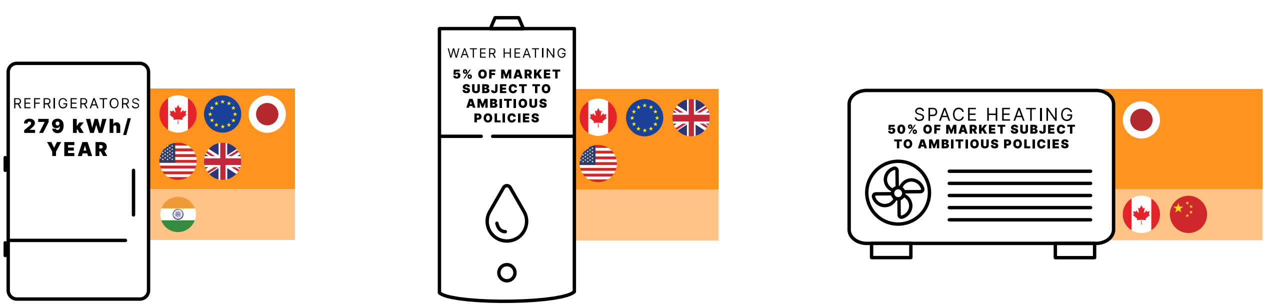
For each appliance category, we highlight economies that have adopted MEPS levels that meet or approach international targets and summarize the current policy landscape. These international targets are recommended efficiency and energy consumption levels identified in United for Efficiency's (U4E) Model Regulation Guidelines. In the absence of an existing model regulation, we performed a market analysis and analyzed Best Available Technologies (BAT) to develop our own benchmark. Our aim is to identify opportunities to drive ambition in economies with less stringent MEPS. Figure 1 is a summary of our ratings:

FIGURE 1: WORLD'S BEST MEPS PERFORMANCE TARGETS

For non-directional general service lighting products

Ratings are determined by the four efficiency classifications defined in IEC 60034-30-1 for a 3-phase induction motor (low voltage < 1000 V).

MEPS level based on minimum cooling seasonal performance factor (CSPF) required for a split system air conditioner with 7 kW (24,000 Btu/h or 2 refrigeration ton) cooling capacity



400 L representative unit at 24 °C

Ambitious policies refer to ≥ 90% active efficiency levels for gas water heaters & ≥ 100% efficiency requirements for electric storage water heaters.

Ambitious policies refer to ≥ 90% efficiency for fossil fuel space heating & ≥ 100% efficiency for electric space heating.

Meets or exceeds ambitious MEPS qualification

On the cusp of ambitious MEPS qualification

Key Findings and Recommendations

Our analysis finds that some large economies have ambitious MEPS, with many others right on the cusp. Despite these promising findings, the global community is still off track to deliver the promises of the Paris Agreement. By adopting updated MEPS aligned with international targets and best practice, governments can deliver further energy and cost savings to consumers and take action to curb the worst impacts of climate change. We urge policymakers to act on the following recommendations:

- At minimum, all economies should align their MEPS requirements for lighting, electric motors, air conditioners, and refrigerators with United for Efficiency's (U4E) Model Regulation Guidelines.
- Beyond aligning their policies with U4E Model Regulations, we recommend economies take the following product-specific actions:
  - **Lighting:** Economies should set technology-neutral MEPS at 90 lm/W[i] to enable a full transition to LED lighting. LED lighting is 50% more efficient than fluorescent lighting and does not contain mercury, a harmful neurotoxin.[1] Economies with stringent lighting MEPS should strive for even better policies and set new standards at 120 lm/W. While not in the scope of this report, we also recommend that policymakers adopt ambitious, technology-neutral MEPS for linear lighting aligned to the U4E model regulations. Linear fluorescent lighting is responsible for a large share of electricity consumption for lighting in commercial buildings.
  - **Electric Motors**: Beyond setting motor MEPS at IE3, policymakers can further reduce the energy consumption of motor systems through requirements for variable speed drives and additional applications such as pumps, fans, and air compressors.
  - **Air Conditioners (ACs)**: The technology and supply chain needed to enforce stricter MEPS in alignment with U4E AC model regulations exist. Most ACs are either produced in China or made from components sourced in China. As a result, economies have the ability to enforce the same AC MEPS as China, which aligns with U4E's recommendation (ISO CSPF 5.1 Wh/Wh).
  - **Refrigerators**: At a minimum, all economies should set MEPS at 279 kWh/year or lower. Economies that have already achieved this target should increase their stringency to match U4E's intermediate target of 223 kWh/year or less.
  - **Water Heaters**: Electric storage heat pump water heaters and condensing fossil fuel water heaters have efficiencies of more than 100% and 86%, respectively, and represent step changes in efficiency. Policymakers should target these technologies to make significant reductions in water heating energy consumption. Since heat pump and condensing technologies can have significant up-front cost, labeling policies and incentives may be a first step to grow the market in places where those technologies are not yet cost effective. In addition to increasing the efficiency *within fuels*, policymakers should explore opportunities to promote electrification.
  - **Space Heating**: Policymakers in cold climate economies should require electric heat pumps and condensing minimum efficiency levels for space heating, including requiring all air conditioners to have reversible operation.[ii] Using air conditioners for heating (i.e., a reversible heat pump) involves lower up-front cost than having two separate units, and can displace significant fossil fuel use and associated emissions. In addition to increasing the efficiency *within fuels*, policymakers should look for opportunities to promote electrification.

i The IEA Energy Efficient End Use Equipment Solid State Lighting (4E SSL) annex has also recently published model performance requirements beyond 90 lm/W.
ii It should be noted that in very cold climates, heat pump efficiency and capacity drop, such that additional measures may need to be taken to meet building heating loads.

Purpose

Minimum energy performance standards (MEPS) for appliances and equipment play a critical role in meeting ambitious international climate goals. Electric motors, air conditioners (ACs), refrigerators, and lighting account for more than 40% of global electricity consumption.[2] Doubling the aggregate efficiency of these appliances would avoid over 2 gigatons (Gt) of carbon dioxide (CO_2) emissions per year in 2030.[3] MEPS are a widely used policy instrument that work to improve the efficiency of new products sold in a given economy by defining minimum performance criteria that all new products of a given type must meet.

In this report, we evaluate the stringency of MEPS requirements for six major appliance categories:

- Lighting
- Electric motors
- Air conditioners
- Refrigerators
- Water heating
- Space heating

across ten high greenhouse-gas-emitting economies:

- Brazil
- Canada
- China
- European Union
- India
- Indonesia
- Japan
- South Africa
- United Kingdom
- United States

Our analysis is restricted to five domestic/residential appliance categories and electric motors. We selected these six appliance categories because they are commonly regulated across economies, and many have existing model regulations we could use as an international target/goalpost. In our analysis, we do not compare MEPS for residential refrigerators (refrigerator-only products) or linear lighting, two product types that are included in the global electricity consumption and GHG emissions savings figures cited above. Governments should examine regulations for these appliances also to ensure additional cost-effective energy savings are not being left on the table.

Comparing MEPS across economies is challenging and not without its limitations. There may be extenuating economic, political, and environmental factors that prevent some economies from setting ambitious MEPS requirements. We also recognize that some of the policy comparisons made in this analysis are not one-to-one; meaning that the range of products covered under an appliance-specific policy may differ depending on the economy. To account for this, we defined a standardized "reference unit" under each appliance category to calculate the MEPS level used in our comparison.

Comparing appliance MEPS, while challenging, is a worthwhile endeavor. Economies are falling short in their commitments to the Paris Climate Agreement. As a result, the global community is not on track to limit warming to well below 1.5° C, placing countries at greater risk of the worst impacts of climate change.[4] MEPS are a widely used and cost-effective tool available to governments that want to minimize the negative climate impacts of appliance use. A 2021 analysis of 12 standards and labeling programs found the administrative costs required to achieve a one-ton reduction in CO_2e ranged from $0.01 per ton to $1.00 per ton.[5]

This report serves two core functions: it identifies economies with the most ambitious MEPS, then highlights opportunities for further policy intervention across *all* economies. We intend for this report to showcase which economies are doing well and offer encouragement and recommendations to drive progress in energy efficiency so that all countries can deliver on their climate commitments. We hope these changes will be reflected in both national policies and directly incorporated into Nationally Determined Contributions under the Paris Climate Agreement[6] and plans like national net-zero emissions roadmaps.

We believe this report will be of particular value to economies already committed to improving the energy efficiency of appliances to meet their desired goals. Launched at the UN Climate Change Conference in Glasgow in 2021 (COP26), the SEAD Product Efficiency Call to Action (Call to Action) is the largest energy efficiency commitment to date. Fourteen economies pledged to double the efficiency of the average new lamp, AC, refrigerator, and industrial motor system by 2030.[i] This analysis suggests there has been little progress since COP26, with few new requirements adopted for these four product categories by Call to Action signatories and non-signatories alike.[ii] We hope that the recommendations in this report can serve as a basis for renewed action, and we will continue to monitor progress until the 2030 Call to Action deadline.

i Progress toward the doubling goal will be tracked through average product efficiency compared to a business-as-usual scenario.:
ii For example, only one economy out of the 10 analyzed has implemented lighting MEPS since COP26, and they do not eliminate the least efficient technologies. Meanwhile four have implemented or are planning to implement AC MEPS, but most of these are incremental and much smaller than what is needed for doubling efficiency by 2030.

Methodology

The methodology used to establish individual economy scores was inspired by a combination of 4E PEET mapping and benchmarking reports, past CLASP policy comparison studies, and data and calculations used in CLASP's policy impact modeling tool Mepsy.

The thresholds for how we classify the "Best" MEPS for a particular appliance are summarized in Appendix A. When possible, we aligned these thresholds to U4E's Model Regulation Guidelines and IEA's energy performance ladders for lighting, motors, air conditioners, and refrigerators.

It is worth noting that the performance requirements we examined for Japan are not MEPS. In contrast to the other economies, Japan regulates the shipment-weighted average performance of products, rather than the minimum. It is possible that some models sold in the Japanese market fall below the indicated level. More generally, the efficiency of products in each economy may depart from the MEPS level indicated in the rest of this analysis. This means the efficiency of the average product may be better than the MEPS by a little or a lot, and obtaining a complete view of performance would require a detailed market analysis.

Analyzing the MEPS requirements is still useful, as MEPS can further improve the average performance of products by eliminating the worst performers. Frequent improvements in MEPS are needed to remove loopholes and keep up with new product introductions and technology changes.

The economies analyzed vary in climate, the typical capacities of the products, and usage of those products. The MEPS levels set in each economy ultimately depend on a variety of local factors; including the prices of efficiency options, electricity and fuel prices, consumer purchasing power and discount rates, and impacts on local industry. For all these reasons, MEPS requirements that work in one economy may not work in another. Nonetheless, by comparing across economies, we can see what is *technologically* feasible, even if it is not always economically justified or politically practical in a given place at the present time.

For each of the six appliance categories, we developed a single metric to enable such comparisons. We also standardized the product capacity used for comparison for lighting, ACs, and refrigerators, normalized the MEPS to account for different test temperatures for ACs and refrigerators, and developed a score that recognizes the differing fuel mix and equipment types used in each economy for water and space heating. These are the metrics we used to compare MEPS across economies:

- **Lighting**: minimum luminous efficacy (lm/W) requirement for a non-directional, general service lamp (GSL) for indoor lighting with a luminous flux of 800 lumens (lm) and a color rendering index (CRI) of 80.
- **Electric Motors**: IEC standard level for a 3-phase AC induction motor < 1000 V. We also assessed whether an economy had MEPS in place for motor-driven applications (e.g., pumps, fans, etc.).
- **Air Conditioners**: seasonal energy efficiency requirement for a 7 kW split-system unit converted to ISO CSPF (Wh/Wh).
- **Refrigerators**: annual energy consumption (kWh) for a standard 400 L frost-free refrigerator-freezer (300 L fresh food/100 L frozen) operating at an ambient temperature of 24°C (MEPS at 32°C were normalized to 24°C).
- **Water Heating**: percentage of the economy's water heater market or products in use ("stock" or "installed base") that are subject to policies that significantly reduce total (direct and indirect) greenhouse gas (GHG) emissions.
- **Space Heating**: percentage of the economy's space heating market or products in use that are subject to policies that significantly reduce total (direct and indirect) GHG emissions.

Results and Ratings

Lighting

We define the target for ambitious lighting MEPS at 90 lm/W for non-directional general service indoor lighting products. This target ensures that inefficient lighting products, like CFLs and incandescent bulbs, are phased out of the market and is line with U4E's model regulation MEPS requirement of 80 lm/W or greater.[7]

Of the ten economies assessed, the EU and UK are the only two to have successfully phased out CFLs and incandescent lamps through MEPS and meet the defined target (Figure 2).

Unlike the other economies included in our analysis, the EU and UK have technology-neutral standards that apply to all types of indoor lights. All other economies in this study have separate standards in place for solid state, fluorescent, and incandescent lighting. LEDs are significantly more efficient than fluorescent and incandescent lighting. Setting separate technology-specific standards allows inefficient products to persist in the market. Furthermore, it prevents the market as a whole from moving toward higher levels of efficiency. For example, if an economy developed ambitious MEPS for LED products only, that policy may not significantly reduce energy consumption or resulting GHG emissions if less-efficient CFLs and incandescent lamps are still sold in the market in large volumes.

India and Indonesia have MEPS on the cusp of our 90 lm/W threshold, but they are held back in our comparison because they have not adopted technology-neutral standards. Figure 3 shows that both economies are within 25% of meeting the criteria for ambitious MEPS for LED lighting (indicated by the grey bars). However, inefficient CFLs and incandescent lamps continue to be sold in India and Indonesia and make up a significant portion of the market and resultant lighting energy consumption in both countries. We therefore were not able to recognize the strength of their lighting MEPS overall. Economies wishing to push their entire lighting market toward greater efficiency may wish to consider a technology-neutral approach to MEPS.

Beyond energy savings and climate benefits, there are a number of reasons an economy may wish to phase out inefficient lighting through MEPS. Fluorescent lighting contains mercury, a neurotoxin that can cause harmful and long-term health effects.[8] The EU began phasing out fluorescent lamps through its Ecodesign Directive in 2019 (Commission Regulation EU No 2019/2020).[9] This was followed by several amendments to the Restriction of Hazardous Substances (RoHS) Directive adopted in December 2021[10] that resulted in a law that bans virtually all general-purpose compact fluorescent lamps[11] and linear fluorescent lamps[12] beginning in 2023. At COP26, the UK announced it would increase the stringency of lighting MEPS to 120 lm/W, but a policy has yet to be adopted.[13] If this new level is achieved, the EU could increase the stringency of its MEPS to match those in the UK given the similarities in their markets and economies.

Under an amendment to the Minamata Convention on Mercury,[i] CFLs will be banned in 2025.[14] Enforcing technology-neutral MEPS at 90 lm/W is the easiest way for economies to simultaneously comply with Minamata and ensure that there is no backsliding to incandescent or inefficient, low-quality CFLs in their market. All economies can successfully phase out CFLs and incandescent lamps by adopting a MEPS at 90 lm/W.[15]

Our analysis is limited to general service (non-linear) indoor lighting. Linear lighting, which includes linear fluorescent lamps and luminaires, also represents a significant source of energy and emissions savings. CLASP's analysis in support of amending the Minamata Convention, mentioned above, found that about 90 percent of the emissions savings potential in 2025-2030 from an accelerated phaseout of fluorescent lighting was due to linear lighting. While not in the scope of this report, we also encourage economies to adopt technology-neutral MEPS for linear lighting. United for Efficiency has published model regulation guidelines for these products, found here.

i The Minamata Convention on Mercury is a multilateral environmental agreement that addresses specific human activities which are contributing to widespread mercury pollution. Implementation of this agreement will help reduce global mercury pollution over the coming decades.

FIGURE 2: LIGHTING MEPS COMPARISON

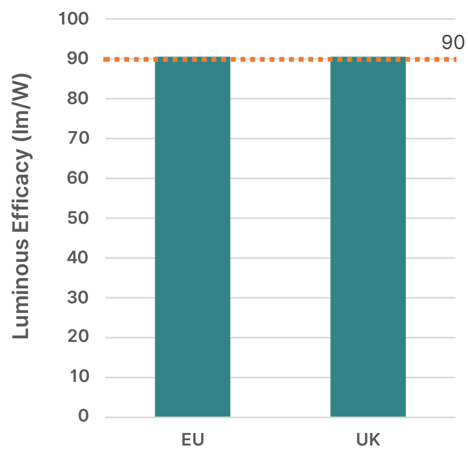
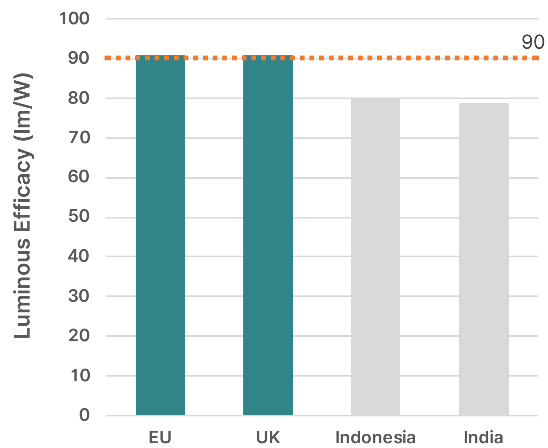


FIGURE 3: LED LIGHTING MEPS COMPARISON



***Note**: Only economies that meet/exceed the target MEPS level (dotted orange line) or are within 25% of that target are displayed in this graph. Economies shaded in teal indicate technology-neutral MEPS which move markets to more efficient lighting technologies. Economies shaded in gray have technology-specific MEPS that do not remove inefficient technologies from the market and therefore fail to capture cost-effective energy savings. Details on all 10 economies' MEPS levels are found in Appendix A.*

RECOMMENDATIONS

- To drive a shift to more efficient LED lighting, all economies should adopt a technology-neutral lighting MEPS with a minimum luminous efficacy of 90 lm/W, which is aligned with 22 African nations, the EU, and the UK, and consistent with the guidance of U4E's model regulation. Doing this before 2025 will reduce mercury pollution[ii] from CFLs and help achieve the goals of the Minamata Convention.
- Economies that already meet the 90 lm/W target could push ambition to 120 lm/W, and economies adopting 90 lm/W could set 120 lm/W as a second tier in their MEPS with a compliance date further in the future to help the regulation keep pace with the ongoing technological improvement of LED lighting.

ii Mercury is highly toxic to humans, which is why the World Health Organization lists it among the top 10 chemicals or groups of chemicals of major public health concern.

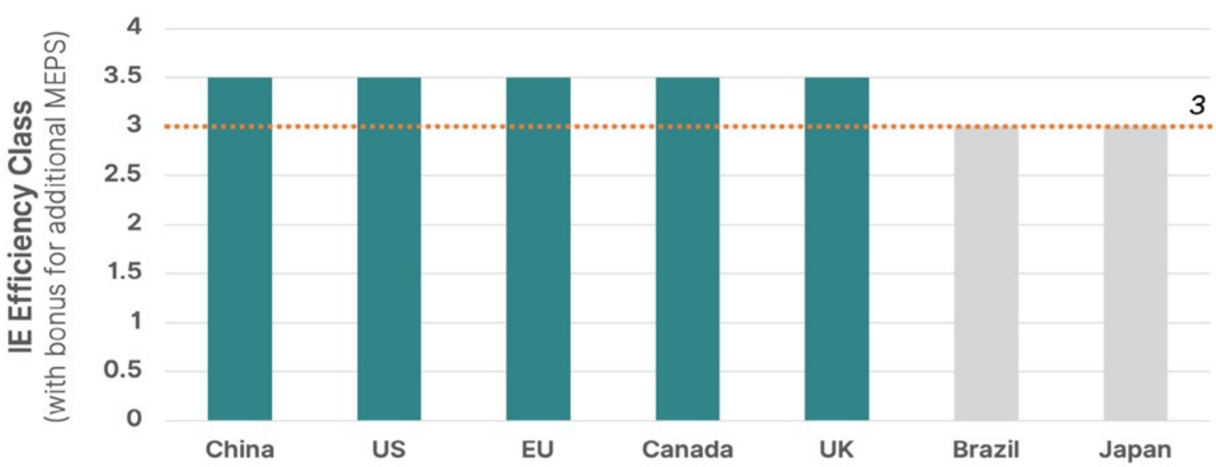
Electric Motors

We define the target for ambitious electric motor MEPS at a score greater than 3 for a 3-phase alternating current induction motor (low voltage < 1000 V).[i] This score is equivalent to U4E's model regulation recommendation of using the IE3 efficiency standard (an efficiency classification defined in IEC 60034-30-1).[16] The scores awarded to each economy correspond directly with each efficiency class such that an economy with MEPS set at IE2 would receive a score of 2, and an economy with MEPS set at IE3 would receive a score of 3, etc. Economies can receive an extra half point for including additional components such as variable speed drives or industrial pumps, fans, and air compressors in their MEPS. The maximum attainable score is 5.5.

Canada, China, the EU, UK, and US are leaders in electric motor MEPS, with Brazil and Japan within 25% of the target threshold (Figure 4).

Canada, China, the EU, UK, and US all use the IE3 efficiency level and have additional MEPS requirements for variable speed drives (VSDs), industrial pumps, fans, or air compressors. In July 2023, the EU and UK will be the first economies to set their MEPS to IE4 for some motors.[ii,17] While setting motor MEPS at higher efficiency levels is one pathway to increasing stringency, another option that may provide more cost-effective energy savings is to adopt MEPS for motor-driven systems/applications[iii] and motor controls (such as VSDs).

FIGURE 4: MOTOR MEPS COMPARISON



***Note**: Only economies that meet/exceed the target MEPS level (shown in teal) or are within 25% of that target (shown in grey) are displayed in this graph. Details on all 10 economies' MEPS levels are found in Appendix A.*

RECOMMENDATIONS

- All economies should align their motor MEPS with U4E's model regulation and require a minimum efficiency level of IE3.
- If economies already use the IE3 standard, they should adopt MEPS for additional components such as variable speed drives or industrial air compressors, fans, or pumps.
- If they already include additional components in their motor MEPS, they should strive to increase their standard to IE4 or IE5, the latter of which often requires VSDs resulting in additional energy reductions.

i It should be noted that power ranges that fall under the <1000 V drastically differ between economies. For example, in the US and CA the range is 0.75-375kW, whereas in the EU, UK & China it is 0.12-1000 kW.

ii MEPS for three-phase induction motors in the EU and UK vary depending on the size of the motor, ranging from IE2 to IE4. To select an IE efficiency class for comparison, we used the relative share of electricity demand between motor size classifications. The motor size classification representing the largest share of electricity demand would define what IE efficiency class we used in our analysis. Medium-sized three-phase motors between 0.75-1000 kW make up more than 67% of total electricity demand. EU and UK MEPS dictate that motors of this size must meet IE3 (see technical appendix for more).

iii Such as pumps, fans, air compressors, etc

Air Conditioners

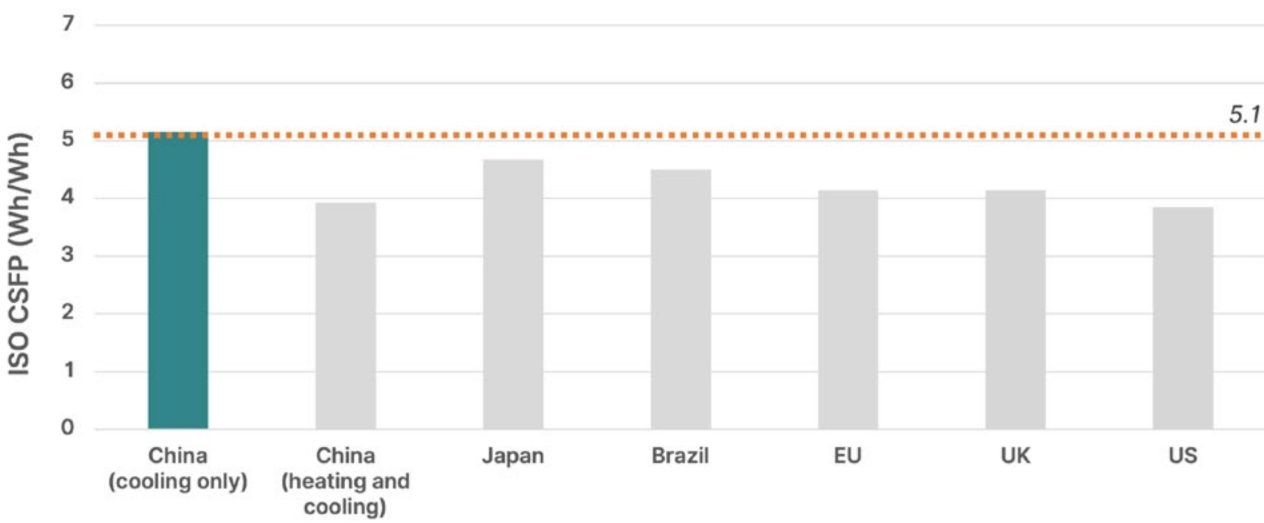
We define the target for ambitious air conditioner (AC) MEPS at or above a cooling seasonal performance factor (CSPF) of 5.1 Wh/Wh for a split system air conditioner with 7 kW (24,000 Btu/h or 2 refrigeration tons) cooling capacity. This target is aligned with the current minimum standard in U4E's model regulation.[i,18]

Our analysis found that China's AC MEPS levels for cooling-only products meet U4E's model regulation target, with Brazil, EU, UK, US, and Japan's requirements not far behind (Figure 5).

There are two scores included for China: one for cooling-only units (which are predominantly exported to other economies), and one for reversible heat pumps (which comprise 97% of China's room air conditioner (RAC) market).[19] Once again, having technology-neutral policies is encouraged, as both types of cooling units should be held to the same efficiency standard to maximize environmental benefits. China has a high demand for space cooling, and their new MEPS policy has the potential to prevent 470 Mt of CO_2 by 2030.[20] Based on U4E's recommendation, the 5.1 Wh/Wh standard applied to cooling-only products in China is the standard that all other economies should aim to reach.[21] Given that China produces 70-80% of the room ACs sold around the world,[ii] the technology and supply chain exist to make this a feasible standard.

Based on Global Cooling Prize[22] prototype performances, new AC technology has the potential to reach efficiency levels of ISO CSPF 8.5 to 9.0 Wh/Wh. While economies are not expected to attain these efficiency levels immediately, Best Available Technology (BAT) can provide insight as to what is possible to achieve when setting future MEPS targets.

FIGURE 5: AIR CONDITIONER MEPS COMPARISON



***Note**: Only economies that meet/exceed the target MEPS level (shown in teal) or are within 25% of that target (shown in grey) are displayed in this graph. Details on all 10 economies' MEPS levels are found in Appendix A.*

RECOMMENDATIONS

- All economies should align their standards with U4E's guidelines and adopt MEPS of 5.1 Wh/Wh for a 7 kW capacity as soon as possible.
- Economies that are still using an energy efficiency ratio (EER) should switch to a seasonal performance metric for both fixed and variable-speed ACs in alignment with ISO standard 16358 and the U4E model regulation.

i The more stringent 6.1 Wh/Wh recommendation in U4E's model regulation is in regards to 4.5 kW cooling capcity unit.
ii Most others are made with Chinese components.

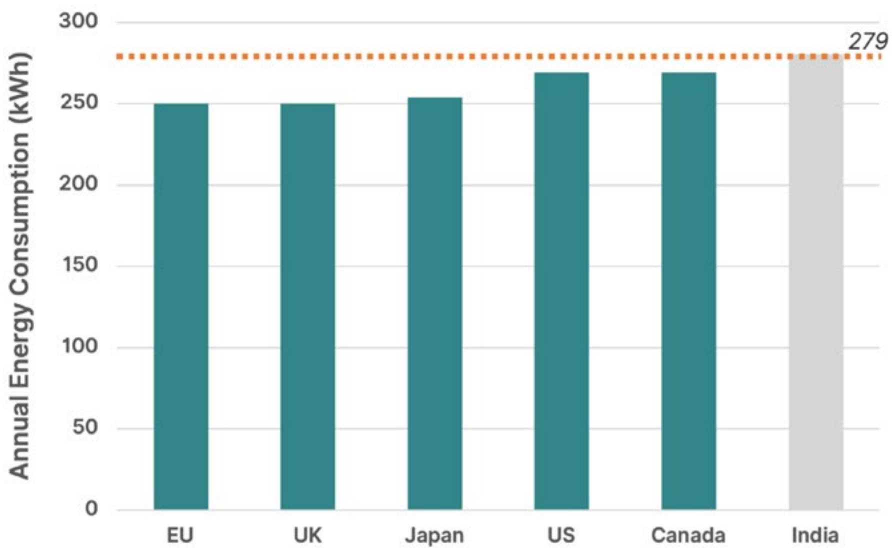
Refrigerators

We define the target for ambitious refrigerator MEPS at an annual energy consumption (AEC) of 279 kWh/year for top-mount domestic refrigerator-freezers with a total volume of 400 L. The performance is normalized to 24 °C, the average reference temperature for 16 °C and 32 °C tests, and the standard in the EU, UK, Japan, and China. This target is the recommended AEC in U4E's model regulation.[23] In contrast to the other products, a lower value indicates better MEPS for refrigerators.

Our analysis found that Canada, the EU, Japan, the UK, and US all meet U4E model regulation levels for refrigerators, with India just above the target by only 1 kWh/yr (Figure 6).

Japan has set an ambitious average efficiency target of 254 kWh for a 400 L unit through its Top Runner program, which is more stringent than the U4E recommendation of 279 kWh for that volume.[24] The U4E model regulation guideline contains additional, more stringent energy performance levels beginning at 223 kWh/year.[i,ii] We did not identify any MEPS at this level or better.

FIGURE 6: REFRIGERATOR MEPS COMPARISON



***Note**: This chart shows energy consumption, so lower values are better (in contrast to other charts in this report that show energy efficiency. Only economies that meet/exceed the target MEPS level (shown in teal) or are within 25% of that target are displayed in this graph (shown in grey). Details on all 10 economies' MEPS levels are found in Appendix A.*

RECOMMENDATIONS

- All economies should align with the U4E model regulation and enforce a maximum annual energy consumption of 279 kWh for a 400 L frost-free refrigerator-freezer at 24 °C.[25] Economies that have already adopted MEPS at that level should work to increase the stringency of their standards to U4E's intermediate tier which requires an annual energy consumption no greater than 223 kWh for a 400 L unit at 24 °C.

i Refer to Annex 3 of the regulation. This requirement is 20% lower than the annual energy consumption at the base tier.
ii U4E higher MEPS levels are primarily for labeling, procurement, and incentive program design in addition to future MEPS levels.

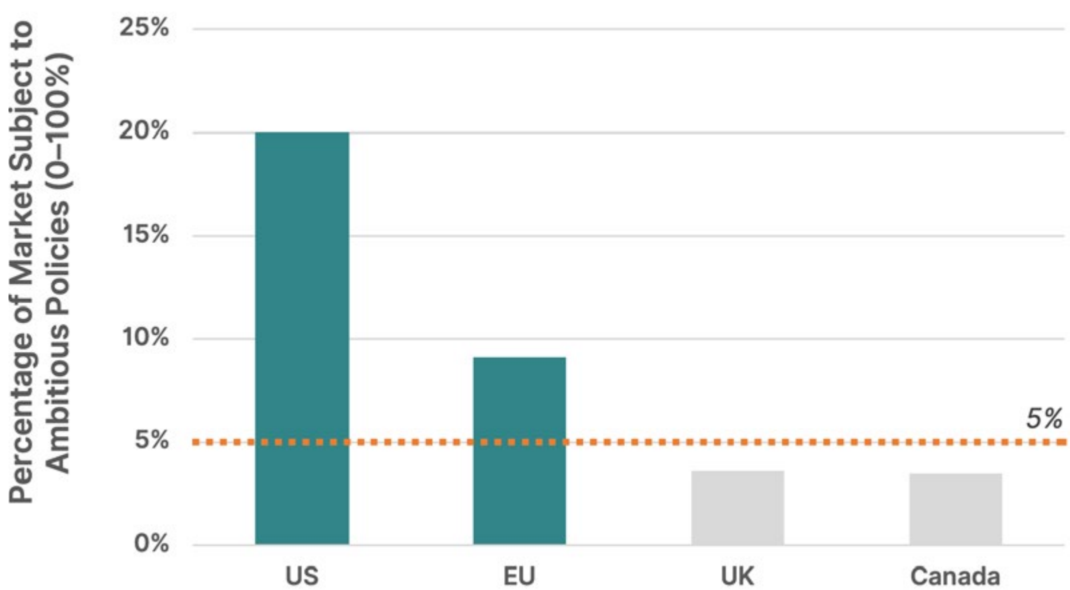
Water Heating

We define the target for ambitious water heating MEPS as having 5% of the water heater market or stock subject to policies that significantly reduce emissions. Due to challenges with normalizing the efficiency requirements for water heaters by size, climate, and usage, previously encountered by IEA Energy Efficient End Use Equipment Technology Collaboration Programme (4E TCP),[26] as well as differences in the water heater fuel and generation mix in each country, we focused on policies that encourage major shifts in efficiency *within* fuel types, typically requiring new technologies:

- ≥ 86% efficiency for fossil fuel water heaters (typically requiring condensing technology that extracts heat from the exhaust such that the flue gases condense rather than venting through the chimney)[i]
- > 100% efficiency for electric storage water heaters (requiring heat pumps that extract heat from ambient air, allowing the energy output to exceed the electricity consumed)[ii]

Our analysis found the US and EU exceed the target MEPS levels for water heating, with the UK and Canada close behind (Figure 7).

FIGURE 7: WATER HEATING MEPS COMPARISON



***Note**: Only economies that meet/exceed the target MEPS level or are within 25% of that target are displayed in this graph. Details on all 10 economies' MEPS levels are found in Appendix A.*

i Canada set its condensing efficiency requirements for instantaneous water heaters at a Uniform Energy Factor (average efficiency under a specified draw profile and conditions, with no storage losses) of 0.86 or 0.87. Natural Resources Canada, "Gas-fired instantaneous water heaters: Energy Efficiency Regulations", December 12, 2019. https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-regulations/guide-canadas-energy-efficiency-regulations/gas-fired-instantaneous-water-heaters/22486. Meanwhile, United States Department of Energy estimates that a condensing heat exchanger would increase Uniform Energy Factor (UEF) or efficiency for instantaneous water heaters from 0.81 to 0.87–0.89. US Department of Energy, "Preliminary Analysis Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Consumer Water Heaters," March 2022, p. ES-8.

ii Heat pump water heaters can exhibit efficiencies much greater 100%. For example, heat pump water heaters currently on the market in the United States have Unified Energy Factors (average efficiency under specified conditions, including storage losses) of between 2.1 and 4.07. US Department of Energy, "Compliance Certification Management System: Water Heaters," accessed December 13, 2022. https://www.regulations.doe.gov/certification-data/CCMS-4-Water_Heaters.html#q=Product_Group_s%3A%22Water%20Heaters%22. However, policies in Europe require a minimum final efficiency of 150–160%, so 100% was chosen as a simple bright line to distinguish heat pump technologies. Policymakers should ensure that efficiency requirements for heat pumps provide operating cost and CO_2 benefits over electric resistance and fossil fuel alternatives.

Several EU Member States and US states are starting to shift their water heating energy source from fossil fuels to electricity, a necessity to lower pollution and achieve Net Zero Emissions. However, these shifts are currently accomplished through building codes that ban gas connections to new buildings and not MEPS on the water heaters themselves. Therefore, we focused on near-term appliance policies that increase the efficiency *within* each fuel type (gas and electricity). A measure of the total market share of water heaters required to achieve efficiencies >100% could be a clearer indicator in the future.[iii]

There are no meaningful efficiency improvements for instantaneous electric water heaters as they cannot always be replaced by heat pumps due to space constraints, so we excluded these from the analysis. We also excluded solar water heaters, even though they often require no electricity or fuel inputs to operate, as shifting existing gas and electric water heaters to solar may not be achievable through MEPS.[iv]

Finally, the collective impact of the policies for each water heater type was calculated by weighting them by the market or stock share of the heaters subject to these policies.

For example, in the US, even though heat pumps currently make up approximately 2% of the stock, >100% efficiency requirements apply to all larger electric storage water heaters, which are 18% of the stock, or 20% once electric instantaneous water heaters are excluded.

Since few economies at this time have policies that encourage high water heater efficiencies, we set the target at 5% of the market or stock subject to the above ambitious policies. As mentioned above, the US requires residential electric storage water heaters larger than 55 gallons (208 liters) to exceed 100% efficiency. Water heaters in this size category constitute approximately 18% of the water heater stock. In contrast, in the EU, UK, and Canada, the water heater product classes subject to ambitious requirements (heat pumps in the EU and UK, condensing instantaneous gas heaters in Canada) have much smaller shares. It is notable that in Japan, heat pump water heaters greatly outnumber electric resistance and constitute approximately 10% of total shipments, despite a lack of MEPS.

Indonesia, and Brazil were excluded from the analysis due to insignificant use of fossil fuel or electric storage water heaters.

RECOMMENDATIONS

- Policymakers should require efficiencies greater than 100% for electric storage water heaters, and greater than 86% for fossil fuel water heaters to the extent feasible. Condensing and heat pump technologies can have significant up-front cost, so labeling programs and incentives may be a first step to grow the market in places where they are not yet cost effective.
- In addition to increasing the efficiency *within fuels*, policymakers should explore opportunities to shift from fossil fuel water heaters to heat pumps and solar. Policy instruments could include technology-neutral metrics, labels, and eventually MEPS, as well as building codes and pollution (NOx) standards.

iii For example, "Long term: By 2035, all water heating technologies for sale in Canada meet an energy performance greater than 100% (EF greater than 1)." Energy and Mines Ministers' Conference, "Paving the Road to 2030 and Beyond: Market transformation road map for energy efficient equipment in the building sector Supporting the transition to a low-carbon economy", August 2018, p. 56. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/emmc/pdf/2018/en/18-00072-nrcan-road-map-eng.pdf

iv Several economies analyzed have very high solar water heater shares, including China (7–65% stock share depending on climate region), India (13% market share), and South Africa (6% stock share). Liu, Wei, Cheng Chen, Huijuan Wu, Chunhui Guo, Yuedong Chen, Wenqiu Liu, and Zhaojie Cui. "Environmental Life Cycle Assessment and Techno-Economic Analysis of Domestic Hot Water Systems in China." Energy Conversion and Management 199 (November 1, 2019): 111943. https://doi.org/10.1016/j.enconman.2019.111943. ADI Media Research, as quoted in TV Veopar Journal, Energy Efficiency Goals Encourage Breakthroughs", October 2018. https://www.tvj.co.in/energyefficiency-goals-encouragebreakthroughs/. CLASP correspondence with efficiency experts STATS SA, "General Household Survey", 2018.

Space Heating

We define the target for ambitous space heating MEPS as having 50% of the space heating market or stock subject to policies that significantly reduce emissions. As with water heating, space heating efficiencies can vary depending on ambient temperature, fuel, type, capacity, and usage. Policies cannot be compared across fuels because the emission factor of electricity consumption varies by economy.

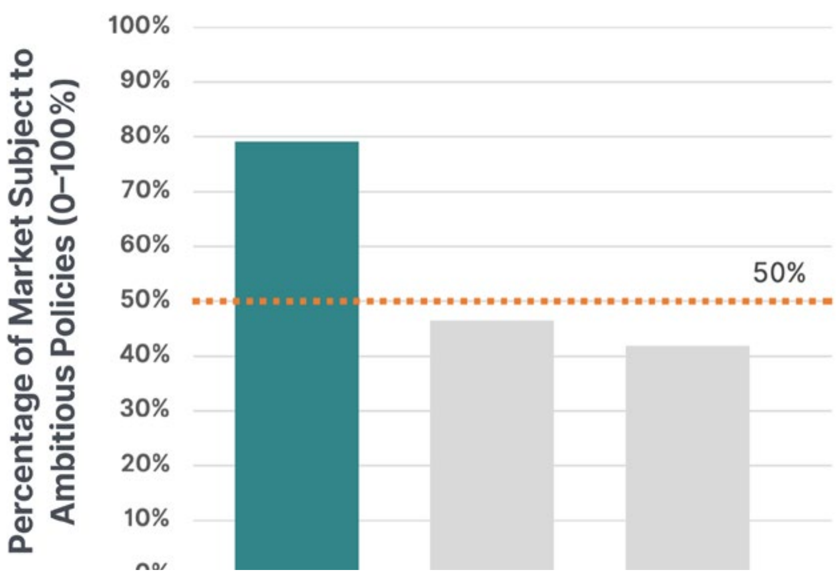
So, like with water heating, we counted policies that encourage major shifts in efficiency *within* fuel types typically requiring new technologies and multiplied them by the share of products of each type:

- ≥ 90% efficiency for fossil fuel space heating (typically requiring condensing technology that extracts heat from the exhaust such that the flue gases condense rather than venting through the chimney)[i]
- > 100% efficiency for electric space heating (requiring heat pumps that extract heat from ambient air so the energy output can exceed the electricity consumed; this can be either a requirement on electric space heating or use of reversible air conditioners for heating in winter)[ii]

As with water heating, a single metric that recognizes >100% heat pump efficiency levels regardless of fuel type would more clearly indicate progress toward Net Zero Emissions.[iii]

Our analysis finds that Japan exceeds the target MEPS level for space heating, with Canada and China not too far behind (Figure 8).

FIGURE 8: SPACE HEATING MEPS COMPARISON



***Note**: Only economies that meet/exceed the target MEPS level (shown in teal) or are within 20% of that target (shown in grey) are displayed in this graph. Details on all 10 economies' MEPS levels are found in Appendix A.*

i US Department of Energy finds that non-condensing gas furnaces operate below 82% annual fuel utilization efficiency (AFUE). Meanwhile, condensing operation raises AFUE above 90%. There are few products in-between. US Department of Energy, "Technical Support Document: Energy Efficiency Program For Consumer Products And Commercial And Industrial Equipment: Oil, Electric, and Weatherized Gas Consumer Furnaces, November 2022," p. 3-22. https://www.regulations.gov/document/EERE-2021-BT-STD-0031-0011 AFUE data for products on the US market bear this out, with a gap for most furnace and boiler product classes between low- to mid-80s% (non-condensing) and 90% and above (condensing). US Department of Energy, "Compliance Certification Management System: Furnaces," accessed December 13, 2022. https://www.regulations.doe.gov/certification-data/CCMS-4-Furnaces.html

ii As with water heating, heat pumps for space heating can have efficiencies much greater than 100%, depending on efficiency, cold-weather performance, and local climate conditions. For example, the forthcoming US MEPS is a heating seasonal performance factor 2 (HSPF2) of 7.5 Btu/W, which equals 220%. 100% was selected as a bright line to distinguish heat pump technologies. Policymakers should ensure that efficiency requirements for heat pumps provide operating cost and CO_2 benefits over electric resistance and fossil fuel alternatives.

iii For example, "Long term: By 2035, all space heating technologies for sale in Canada meet an energy performance of more than 100%." Energy and Mines Ministers' Conference, "Paving the Road to 2030 and Beyond: Market transformation road map for energy efficient equipment in the building sector Supporting the transition to a low-carbon economy", August 2018, p. 32.

Because economies have progressed more in space heating than in water heating, we set the target at 50% of products within a given economy meeting the above requirements. Japan emerges as the leader in this appliance category because 79% of its space heating stock is made up of reversible air conditioners, also known as mini-split air-source heat pumps.[27]

The heating performance is required by the test method and Top Runner requirements.[28] The situation is similar in China and South Africa, though the penetration of these reversible air conditioners is lower. Canada, on the other hand, regulates fossil fuel heating efficiency with condensing requirements for gas furnaces and gas hot water boilers.

India, Indonesia, and Brazil were excluded from the analysis due to insignificant use of space heating.

RECOMMENDATIONS

- Policymakers can require condensing efficiency requirements for space heating and encourage the use of heat pumps, in particular by requiring all air conditioners to have reversible operation. Using air conditioners for heating involves less up-front cost and can displace significant fossil fuel use and associated emissions.
- In addition to increasing the efficiency *within fuels*, policymakers should explore opportunities to shift from fossil fuel space heaters to heat pumps. Policy instruments could include technology-neutral metrics, labels, and eventually MEPS, as well as building codes and pollution (NOx) standards.

Conclusion

Our analysis finds that some economies have ambitious MEPS, with many others right on the cusp. However, meeting the Paris Agreement objectives will require significant shifts in policy and investment at the global scale, both in the appliances sector and beyond. By adopting updated MEPS aligned with international targets and best practices, governments can deliver further energy and cost savings to consumers and take action to curb the worst impacts of climate change.

We urge policymakers to act on the recommendations outlined in the Results and Ratings portion of this report. At a minimum, this entails aligning regulations with U4E's Model Regulation Guidelines and taking additional measures to phase out inefficient technologies and the use of fossil fuels. We also strongly recommend that new MEPS be technology neutral to avoid loopholes that enable less-efficient appliances to persist in the market.

We encourage policymakers to make use of CLASP's suite of policy resources, including Mepsy, a digital tool policymakers can use to model the energy and climate impacts of MEPS, and the CLASP Policy Resource Center (CPRC), a hub of information on energy efficiency, water efficiency, and quality policies for appliances and equipment. In early 2023, we will publish a digital summary of this report at clasp.ngo and may expand our analysis to include additional economies in the future.

Appendix A: Technical Appendix

Lighting

Economy ratings are determined by luminous efficacy (lm/W) requirements for non-directional general service indoor lighting products.

CHINA

China's indoor lighting policy for general service lighting covers three types of lights: LED downlight, Directional integrated LED lamps and non-directional self-ballast LED lamps.[29] For this analysis, we will be using the MEPS requirement in place for non-directional self-ballast LED lamps with a rated power between 2 and 60 Watts.

Under this categorization and using table 1 in GB 30255-2019, China's luminous efficacy requirement for indoor LED lighting is 65 lm/W.

China has a separate GB standard in place for CFLs, meaning their score cannot be determined by the LED MEPS alone.[30]

UNITED STATES

The U.S. standard for general service lighting covers all indoor general service lamps.[31] This regulation is technology neutral in that it encompasses incandescent, halogen, CFL and LED lamps into the category of "general service lamp", however it only sets a minimum luminous efficacy for general service lamps is 45 lm/W.[i] At this level, CFLs are still allowed to be sold in the U.S.

EUROPEAN UNION

The EU's lighting policy is technology-neutral in that it applies to all light sources, regardless of the technology.[32] Energy efficiency requirements in this policy are reported in Ponmax instead of in lumens per watt. Using the flux and lamp characteristics of 800 lm and a CRI of 80, the MEPS requirement = 8.82 Ponmax (W).

Calculation:

Ponmax (W) = $C \times (L + (\Phi / (F \times \eta))) \times R$, where:

$C = 1.08$
$L = 1.5$
$\Phi = 800$
$F = 1$
$\eta = 120$
$R = 1$

To convert from Ponmax to lm/W, we divide luminous flux (lm) by Ponmax (W)

800 lm/8.82 W = 91 lm/W

i.e., the luminous efficacy requirement is 91 lm/W.

INDIA

For general service lamps, India has a labeling standard that applies to self-ballasted LED lamps.[33] It is technically a labeling policy, but since it is mandatory and a certain number of stars is required, it is de facto MEPS.

All indoor LED lighting products must at least meet the two-star label requirement. Using table 3.2 in the LED lamp labelling policy, the luminous efficacy requirement is 90 lm/W.

However, India still has a separate lighting standard in place for CFLs, meaning India's lighting regulation score cannot be determined by the LED MEPS because less efficient CFLs are allowed to be sold due to the separate standard. If India combined all their General Service Lamp technologies into one standard and set the minimum for those lamps at 90 lm/W or greater, this would phase-out CFLs, bring them into compliance with Minamata, reduce mercury pollution, and save energy and greenhouse gas emissions inexpensively.

INDONESIA

Like India, Indonesia still has a separate lighting requirement lower than 80 lm/W in place for CFLs, meaning their score cannot be determined by the LED MEPS level. As with India, Indonesia

i In December 2022, the US Department of Energy issued a notice for a proposed rule for general service lamps. If adopted, general service lamps manufactured on or after July 25, 2028 must meet a minimum energy performance standard of 124 lm/W for an 800 lm lamp. However, for this analysis, we kept the MEPS level at 45 lm/W because a final rule has not been issued.

may consider developing technology-neutral MEPS for general service lamps that includes all technologies and adopts a minimum level of at least 90 lm/W, phasing out the inefficient and mercury-containing technology. This would bring Indonesia, the country that hosted the Conference of the Parties for the Minamata Convention where CFLs were phased out, into compliance with those requirements that take effect in 2025.

BRAZIL

As indicated by an ordinance from the Brazil Ministry of Mines and Energy, Brazil's indoor lighting policy is for CFLs only — there are no MEPS in place for LEDs.[34]

To determine which MEPS is relevant to the product scope our analysis covers, we used Table 1 in the aforementioned ordinance and converted watts to lumens using the reported wattage range in the left column and luminous efficacy in the right column. We found that 800 lumens is within the 12–15 W range. For that wattage the luminous efficacy requirement is 56 lm/W.

UNITED KINGDOM

The UK's statutory instrument on lighting[35] has the same MEPS requirement as the EU. All the same calculations and lamp characteristics from the EU section were used to determine the luminous efficacy in the UK, which is 91 lm/W.

JAPAN

Japan's lighting policy covers lighting equipment having a ballast or control device (including CFLs and LEDs).[36] Japan sets different efficacy requirements for daylight and warm white. The daylight efficacy requirement is 100 lm/W, and the warm-white efficacy requirement is 50 lm/W. It is unclear why such a substantial difference is necessary for CFL and LED technologies, as warm-white products do not experience such a large shift in efficacy. Furthermore, it should be noted that Japan's efficacy targets are not MEPS, but rather represent fleet average performance levels, self-reported by industry. Due to the fact that Japan's Top Runner scheme still allows low-efficiency products like mercury-containing CFLs to be sold in their market, their score cannot be based on their LED-only policy.

CANADA

Canada's lighting policy covers energy efficiency standards for general service lamps having a luminous flux between 310–2600 lumens.[37]

FIGURE 9: CANADA'S LIGHTING MEPS

ITEM	ENERGY-USING PRODUCT	ENERGY EFFICIENCY STANDARD	PERIOD OF MANUFACTURE
1	General service lamps that have a luminous flux of < 750 lm	Nominal power ≤ 29 W Life ≥ 1 000 hours Colour rendering index ≥ 80	On or after December 31, 2014
2	General service lamps that have a luminous flux of ≥ 750 lm and < 1 050 lm	Nominal power ≤ 43 W Life ≥ 1 000 hours Colour rendering index ≥ 80	On or after December 31, 2014
3	General service lamps that have a luminous flux of ≥ 1 050 lm and < 1 490 lm	Nominal power ≤ 53 W Life ≥ 1 000 hours Colour rendering index ≥ 80	On or after January 1, 2014
4	General service lamps that have a luminous flux of ≥ 1 490 lm	Nominal power ≤ 72 W Life ≥ 1 000 hours Colour rendering index ≥ 80	On or after January 1, 2014

Using our standardized 800 lumens, the requirement we're interested in is "Item 3" in the energy-using product column in Figure 9. To get the luminous efficacy from what is reported in the chart above we must divide lumens by watts.

Calculation:

Using the efficiency standard for "Item 3" and our standard of 800 lumens

800 lm / 53 W = 15 lm/W

The luminous efficacy for the product scope were interested in is 15 lm/W. Normally, Canada would harmonize with their largest trading partner, the United States, however at this point in time, the US is at 45 lm/W and Canada is only at 15 lm/W — a level that still allows halogen lamps to be sold.

SOUTH AFRICA

South Africa's lighting policy is for incandescent lamps with a power rating up to 1500 W.[38] The following equation is used to determine the luminous efficacy requirement:

FIGURE 10: SOUTH AFRICA LIGHTING MEPS REQUIREMENTS

PARAMETERS	REQUIREMENT
Lamp efficacy	$\geq \phi/(0.704 \times \sqrt{\phi} + 0.0392 \times \phi)$ lm/W
Lumen Maintenance	≥ 85% measured at 75% of rated life
Lamp Life	≥ 1000 hrs
Failure Rate	≤ 5.0% at 100 hrs

Where; ϕ = initial rated luminous flux in lumens (lm)

Once again, we use our standardized luminous flux (Φ) of 800 lumens and get that the luminous efficacy is 16 lm/W — similar to the Canadian level, allowing inefficient halogen to continue to be sold.

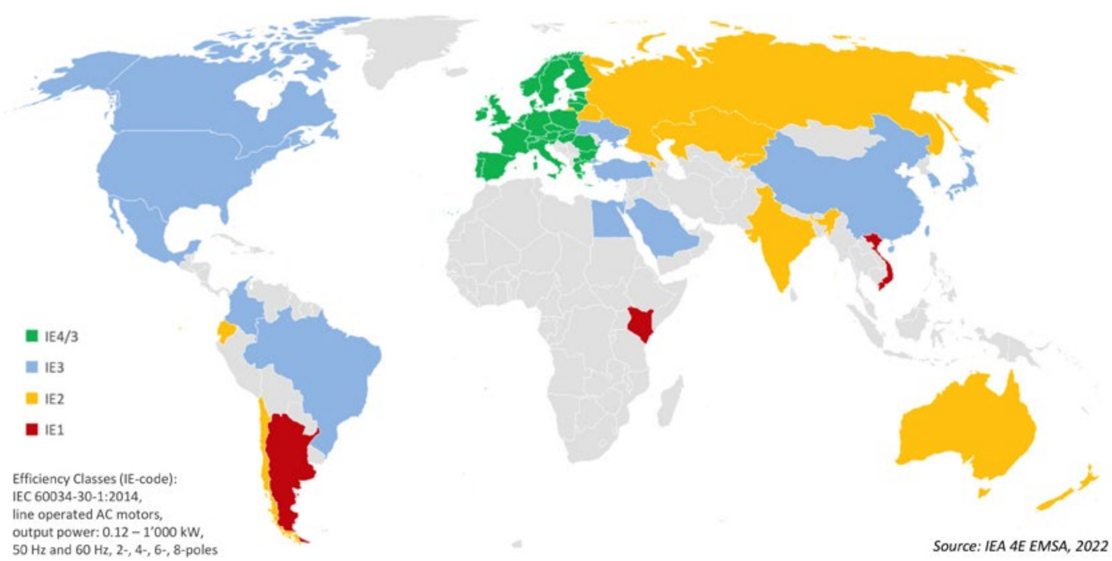
It should be noted that South Africa has been working on an updated MEPS policy for general service lamps which would adopt a level of 90 lm/W. Work on this policy began in 2018 and was published as draft in the South African Gazette in March 2021.[39]

Unfortunately, no progress has been made in the subsequent 18 months, even though South Africa is currently experiencing rolling power cuts for more than a decade due to shortages of electricity.[40]

Electric Motors

Economy ratings are determined by the four efficiency classifications defined in IEC 60034-30-1 for a 3-phase induction motor (low voltage < 1000 V).[i] The scores awarded to each economy correspond directly with each efficiency class such that an economy with MEPS set at IE2 would receive a score of 2 and an economy with MEPS set at IE3 would receive a score of 3, etc. Economies can receive an extra half point for including additional components such as variable speed drives or industrial pumps, fans, or air compressors in their MEPS. The maximum attainable score is 5.5 (i.e., if MEPS are set at IE5 and the economy has energy performance requirements for additional components). Figures 11 and 12 provide an overview of global motor MEPS standards.

FIGURE 11: WORLDWIDE MOTOR MEPS



i It should be noted that power ranges that fall under the < 1000 V drastically differ between economies. For example, in the US and CA the range is 0.75-375kW, whereas in the EU, UK &CN is is 0.12-1000 kW.

FIGURE 12: IEC AND ISO STANDARDS AND MEPS FOR MOTORS AND ADDITIONAL PRODUCTS

Component	Scope	Testing Standard	Efficiency Classification Standard				Performance Requirement
				efficiency metric	P [I]	EP [I]	Mandatory MEPS [II]
Motor	3-phase induction motors (Low Voltage < 1'000 V)	IEC 60034-2-1 IEC 60034-2-3	IEC 60034-30-1 IEC 60034-30-2	IE	x		30+ countries/regions, see
Converter	Variable Frequency Converter (VFC, VSD)	IEC 61800-9-2	IEC 61800-9-2	IE	x		EU
Pump	Rotodynamic water pump	ISO 9906	EU: EN 16480	MEI	x		EU *)
			EU: EN17038-1;-2	EEI		x	EU *)
			US: DOE	PEI		x	USA
			CN: GB19762	EI	x		China
Fans	Industrial	ISO 5801	ISO 12759-1	general information			
			ISO 12759-2	standard losses			
			ISO 12759-3	FEG	x		China
			ISO 12759-4	FMEG		x	EU *)
			ISO 12759-5	JFMEG			
			ISO 12759-6 (CD)	FEI		x	USA **)
Air compressor	Compressor package	ISO 1217	ISO 1217	Compressor efficiency grade		x	China
			ISO 1217, Am.1:2016	Isentropic efficiency		x	USA

01.12.2022

Note: I P = product; EP = extended product (motor, control, transmission, pump/fan/compressor)
II MEPS = Minimum Energy Performance Standard (set as requirement by regulators)

*) Under revision
**) Under development

CHINA

China has set its MEPS for 3-phase AC induction motors at IE3 and has additional requirements for pumps, fans, and air compressors.[41] We assigned China a score of 3.5 in this appliance category.

UNITED STATES

The US has largely set its MEPS for 3-phase AC induction motors at IE3 and includes additional requirements for pumps, fans, and air compressors.[42] We assigned the US a score of 3.5 in this appliance category.

EUROPEAN UNION

The EU has set its MEPS for 3-phase AC induction motors at IE3 but will soon adopt a new policy with varying requirements by motor size (Figure 13). 3-phase AC induction motors with a rated power between 0.12 and 0.75 kW must meet IE2, 3-phase AC induction motors with a rated power between 0.75 and 1,000 kW must meet IE3, and 3-phase AC induction motors with a rated power between 75 and 200 kW must meet IE4. with that splits the requirement for motors less than 1,000 V between IE4, IE3 and IE2.[43]

MEPS for 3-phase induction motors in the EU vary depending on the size of the motor, ranging from IE2 to IE4. To select an IE efficiency class for comparison, we used the relative share of electricity demand between motor size classifications. The motor size classification representing the largest share of electricity demand would define what IE efficiency class we used in our analysis. Medium-sized 3-phase motors between 0.75–1000 kW make up more than 67% of total electricity demand.[44] EU MEPS dictate that motors of this size must meet IE3. The EU also has additional parameters for converters, pumps, and fans (0.5 points).[45] We assigned the EU a score of 3.5 in this appliance category.

INDIA

India set its MEPS for 3-phase AC induction motors at IE2 and does not include additional requirements for pumps, fans, and air compressors.[46]

INDONESIA

Indonesia does not have MEPS in place for 3-phase AC induction motors. We assigned Indonesia a score of 0 in this appliance category.

BRAZIL

Brazil set its MEPS for 3-phase AC induction motors at IE3 and does not include any additional components in their MEPS. We assigned Brazil a score of 3 in this appliance category.[47]

UNITED KINGDOM

In the UK, the current policy in place is at IE3, but will be switching to a new standard that splits the requirement for a < 1000 V motor between IE4 and IE2 by July 2023.[48]

The UK has set its MEPS for 3-phase AC induction motors at IE3 but will soon adopt a new policy with varying requirements by motor size (Figure 13). 3-phase AC induction motors with a rated power between 0.12 and 0.75 kW must meet IE2, 3-phase AC induction motors with a rated power between 0.75 and 1,000 kW must meet IE3, and 3-phase AC induction motors with a rated power between 75 and 200 kW must meet IE4. with that splits the requirement for motors less than 1,000 V between IE4, IE3 and IE2 by July 2023.[49]

MEPS for 3-phase induction motors in the UK vary depending on the size of the motor, ranging from IE2 to IE4. To select an IE efficiency class for comparison, we used the relative share of electricity demand between motor size classifications. The motor size classification representing the largest share of electricity demand would define what IE efficiency class we used in our analysis. Medium-sized 3-phase motors between 0.75-1000 kW make up more than 67% of total electricity demand.[50] UK MEPS dictate that motors of this size must meet IE3. The UK also has additional parameters for converters, pumps, and fans (0.5 points).[51] We assigned the UK a score of 3.5 in this appliance category.

FIGURE 13: ENERGY EFFICIENCY REQUIREMENTS FOR MOTORS IN THE EUROPEAN UNION AND UK

ENERGY EFFICIENCY REQUIREMENTS FOR MOTORS

(a) from 1 July 2021:

(i) the energy efficiency of three-phase motors with a rated output equal to or above 0,75 kW and equal to or below 1 000 kW, with 2, 4, 6 or 8 poles, which are not Ex eb increased safety motors, shall correspond to at least the IE3 efficiency level set out in Table 2;

(ii) the energy efficiency of three-phase motors with a rated output equal to or above 0,12 kW and below 0,75 kW, with 2, 4, 6 or 8 poles, which are not Ex eb increased safety motors, shall correspond to at least the IE2 efficiency level set out in Table 1;

(b) from 1 July 2023:

(i) the energy efficiency of Ex eb increased safety motors with a rated output equal to or above 0,12 kW and equal to or below 1 000 kW, with 2, 4, 6 or 8 poles, and single-phase motors with a rated output equal to or above 0,12 kW shall correspond to at least the IE2 efficiency level set out in Table 1;

(ii) the energy efficiency of three-phase motors which are not brake motors, Ex eb increased safety motors, or other explosion-protected motors, with a rated output equal to or above 75 kW and equal to or below 200 kW, with 2, 4, or 6 poles, shall correspond to at least the IE4 efficiency level set out in Table 3.

JAPAN

Japan set its MEPS for 3-phase AC induction motors at IE3 for motors (3 points) and does not include any additional parameters for converters, pumps, and fans.[52] We assigned Japan a score of 3 in this appliance category.

CANADA

Canada set its MEPS for 3-phase AC induction motors at IE 3 for motors and has MEPS for pumps.[53] We assigned Canada a score of 3.5 in this appliance category.

SOUTH AFRICA

South Africa does not have any MEPS for 3-phase AC induction motors. We assigned South Africa a score of 0 in this appliance category.

While there is no policy in place, South Africa is developing a regulation on motors with support from CLASP. The National Regulator for Compulsory Specifications is currently developing the regulations at IE3. However, we could not assign a score of 3 to South Africa because the policy has not been formally adopted.

Air Conditioners

Economy ratings are determined by the MEPS seasonal requirement in ISO CSPF (Wh/Wh) for split system air conditioners operating at 7 kW (24,000 Btu/h) cooling capacity. The difference in seasonal efficiency metrics is primarily due to the outside temperature profiles used to aggregate steady-state and cyclic ratings into a seasonal efficiency value, as well as the ways of evaluating (measuring or calculating) performance at part-load operation into the metric. The seasonal efficiency metrics used in Brazil, China, India, Japan, South Korea, and economies in ASEAN are largely consistent with ISO 16358 defined metrics (i.e., CSPF, HSPF, and APF), except they use region-specific climatic conditions and some adjustments. SEERs used in the United States and Europe require more data points in outside temperature and part-load conditions than those used in the Asian economies or the ISO 16358 standard.

To address the need for comparative information, some studies established relationships among the AC efficiency performance metrics by using performance data-based regression analyses. If an economy's seasonal requirement is not reported in Wh/Wh, it is estimated into ISO CSPF using the methodology outlined in the 2020 paper, "Lost in translation: Overcoming divergent seasonal performance metrics to strengthen air conditioner energy-efficiency policies." If an economy does not report their requirements using a seasonal unit of measure (I.e., still using EER), they will be automatically determined as below the best MEPS threshold. Below are the policy sources, unit conversion equations, and final seasonal energy efficiency requirement in Wh/Wh.

Note: When the methodology states that the conversion done is from "Lost in Translation," refer to the table on page 11 of the report to find the equation and economy specific variable values used to perform the conversion to ISO CSPF.[54]

CHINA

China's AC policy has different requirements for cooling-only units (reported in China SEER) and heating/cooling units (reported in China APF)[55]. Reversible heat pumps make up 97% of China's RAC market.[56] However, China is also the main manufacturer for cooling-only units that are exported to other economies. For this reason, we included two separate scores for China for each respective appliance category.

The energy efficiency requirement for China's cooling-only units is 4.4 Wh/Wh (China SEER). The conversion to ISO CSPF has been done by U4E and the seasonal energy efficiency requirement is 5.1 Wh/Wh.[57]

The energy efficiency requirement for China's heating and cooling units with a variable speed 4.5 kW ≤ 9.5 kW is 3.5 China APF. Using the ISO CSPF conversion from "Lost in Translation," the seasonal energy efficiency requirement is 3.9 Wh/Wh.

UNITED STATES

In the U.S. the minimum seasonal energy efficiency requirement for split system air conditioners is 14 Btu/Wh (US SEER)[58,i,ii]

i Note that the US has different standards depending on the region. In the south/south east the standard is more ambitious (14.5 btu/Wh), but we are using the least ambitious one to stay consistent with ranking economies on their least stringent policies.

ii Even though the US has changed its performance metric to SEER2, we will be using US SEER to simplify the conversion equation.

To convert to ISO CSPF, we will be using the conversion equation from "Lost in Translation." After the conversion, we need to divide the output value by 3.412 since the initial metric was in Btu/Wh and not Wh/Wh. The final seasonal energy efficiency requirement in ISO CSPF is 3.85 Wh/Wh.

EUROPEAN UNION

The EU energy efficiency requirements for a 7 kW split system AC and a GWP >150 is 4.3 (EU SEER).[59,iii] This requirement was implemented in 2012 but updated in 2017.

Using the ISO CSPF conversion from "Lost in Translation," the seasonal energy efficiency requirement is 4.14 Wh/Wh.

INDIA

India's AC standard is reported in ISEER, and for a 7 kW split system the requirement is 3.3 (ISEER).[60] Using the conversion method in "Lost in Translation," the ISO CSPF season energy efficiency metric is 3.5 Wh/Wh

INDONESIA

Indonesia's AC standard is already reported in Wh/Wh, and for a split system with a capacity less than 27,000 Btu/hr (7.9 kW) the ISO CSPF energy efficiency requirement is 3.1 Wh/Wh.[61]

BRAZIL

Brazil's AC policy requires a seasonal energy efficiency requirement of 4.5 Wh/Wh (Brazil IDRS) for split-system units.[62] The Brazil IDRS is based on the ISO 16358 calculation method for CSPF, but with Brazil-specific temperature bin hours and one optional test point. The ISO CSPF used here is ISO CSPF with the ISO 16358 temperature bin hours and two required test points.[63] This means that depending on the exact model, the seasonal energy efficiency requirement in Brazil IDRS will not be a one-to-one comparison with ISO CSPF. Using CVC's Refrigeration Equipment Energy Efficiency Online Calculation System,[iv] we found that for a 7 kW split AC, the Brazil IDRS may be exactly the same as the ISO CSPF or can differ slightly. Due to negligible differences for our particular product type, we will be using the seasonal energy efficiency requirement of 4.5 Wh/Wh to determine Brazil's score.

UNITED KINGDOM

The UK follows the same regulation and calculation as the EU. The seasonal energy efficiency requirement is 4.14 Wh/Wh.

JAPAN

Japan's home-use air conditioner regulations are reported in APF, indicating that their regulations are for reversible heat pumps.[64] For a unit between 6.3 and 28 kW, the APF requirement is 4.5.

To convert from ISO CSPF, we used the alternative exponential method outlined in "Lost in Translation." The reasoning for using the exponential method is that while the regression equations are derived for fixed- and variable-speed units, all residential ACs (actually heat pumps) are variable-speed units in Japan. For variable-speed units, ISO CSPF is expected to be greater than Japan APF in absolute values, so the estimated value for Japan may be a little different from other economies. After the conversions, the seasonal energy efficiency requirement is 4.67 Wh/Wh.

CANADA

Canada's regulation for split-system central ACs requires an energy performance standard of at least 13.0 W/W (SEER). They have proposed an amendment to this regulation to match the US's standard of 14 SEER, but it has yet to be approved.[65]

Using the standard conversion method from "Lost in Translation," the ISO CSPF seasonal energy efficiency requirement is 3.62 Wh/Wh.

SOUTH AFRICA

South Africa's energy efficiency requirement for split-system ACs in energy class B is 3 EER/COP.[66] Since the requirements are expressed in COP, they cannot be converted to a seasonal metric that recognizes part-load efficiencies achievable by inverters, and so deemed as below the best MEPS threshold.

iii The energy efficiency requirement is found in the annex of the policy
iv Can be accessed at https://zl.cvc.org.cn/brazil_269/brdlt1.htm

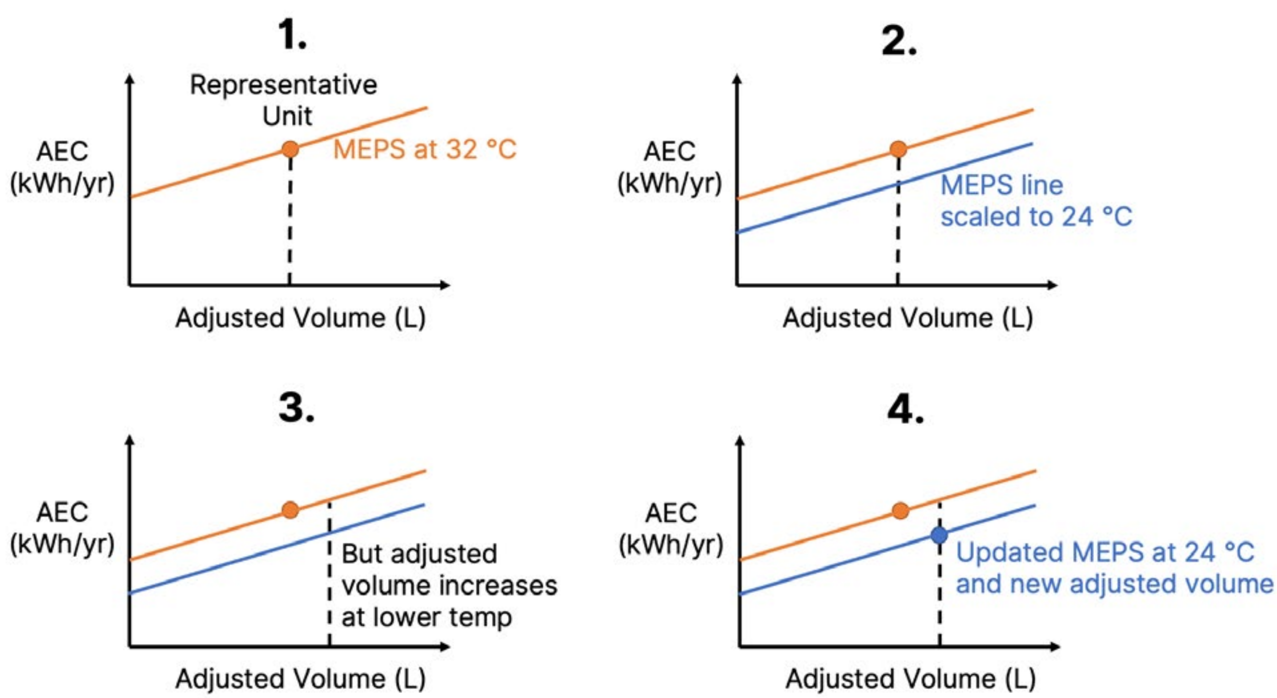
Refrigerators

Economy rankings are determined from annual energy consumption (AEC) requirement measured in kWh/year for two-compartment frost-free domestic refrigerator-freezers with a volume of 400 L (300 L fresh-food compartment (4 °C)) and 100 L 4-star three-star freezer compartment (-18 °C). If a MEPS is reported in an energy efficiency index (EEI), we converted it into an AEC.

Finally, the AECs were adjusted for ambient temperature. Refrigerators tested at a higher temperature to reflect a warmer climate will perform worse than those tested at lower temperatures as they will lose more heat to the environment and the heat pump will be less efficient, as it is more difficult to reject heat at the higher temperature. Therefore, regulations using a higher reference ambient temperature will appear less stringent unless they are adjusted. We adjusted all requirements to a reference temperature of 24 °C, which is the temperature representative of the average of the 16 and 32 °C tests required in China, the EU, Japan, and UK. Requirements referenced only to 32 °C were reduced by 29%, while requirements referenced to 25 °C were reduced by 3%.[67] We did not account for any other differences among the test methods, which could have a secondary impact on the performance of refrigerators and therefore the relative stringency of the standards.

We performed a second temperature adjustment for any requirements that referenced an adjusted volume. While the energy consumption will decrease from 32 °C to 24 °C, the adjusted volume will *increase* as the freezer has more impact compared to the fresh-food compartment at the lower temperature. One way to think about it is that at the higher temperature, both compartments are working harder to maintain the temperature, so the difference between them is smaller.

Below is an illustration of the two sets of adjustments.



And table below has the correction for the Adjusted Volume:

	TOTAL VOLUME	ADJUSTED VOLUME AT 32 °C (LOCAL TEST/ MEPS)	ADJUSTED VOLUME AT 24 °C
Fresh Food	300	300 × (32 to 4 °C compartment temp) / (32 to 4 °C reference temp) = 300	300 × (24 to 4 °C compartment temp) / (24 to 4 °C reference temp) = 300
Frozen	100	100 × (32 to -18 °C compartment temp) /(32 to 4 °C refer-ence temp) = 179	100 × (24 to -18 °C compartment temp) / (24 to 4 °C reference temp) = 210
TOTAL	**400**	**479**	**510**

We also explored a second method of adjusting the MEPS referenced to 32 °C, whereby the volumes of both the fresh and frozen food compartments were reduced to reflect their lower cooling demand at 24 °C. For example, the 300 L fresh food compartment at 32 °C would be equivalent to a 214 L fresh food compartment at 24 °C. The MEPS requirement was calculated based on these new volumes, then divided by a factor of 1.22 to reflect the better coefficient of performance at the lower ambient temperature.

However, this second method did not have a large impact on the results, with the same economies meeting the U4E model requirements for the representative model.

Below are the policy sources, unit conversion equations, and final AEC in kWh/year.

CHINA

China's refrigerator regulation provides an equation for minimum daily energy consumption.[68] Using our standardized refrigerator characteristics, we calculated the energy consumption of a 400 L refrigerator-freezer at the lowest performance tier (Tier 5) at 1.12 kWh/day, which is 408 kWh/year.

China's refrigerators are already tested and evaluated at an average of 16 and 32 °C, so no further temperature adjustments were needed.

US

The MEPS for refrigerator-freezers with an automatic defrost with top-mounted freezers without an automatic ice maker (product class 3) is equal to 0.285av + 233.7, where av is the adjusted volume.[69] The US uses a factor of 1.63 to adjust the freezer volume.[70]

Adjusted volume calculation:

$AV = \text{size} \times (\text{frac} + (1 - \text{frac}) \times 1.63)$ Equation 2

where

AV = Adjusted volume (cubic feet)

size = "Nominal" refrigerator/freezer volume (cubic feet)

frac = Fraction of refrigerator volume devoted to fresh-food storage ($0 \leq \text{frac} \leq 1$)

The resulting annual energy consumption is 366 kWh/yr. The US tests at 32 °C, so we reduced the requirement by 29% to reflect 24 °C, the average of 16 and 32 °C, resulting in 260 kWh/yr. Finally, we adjusted the volume to 510 L using the reference temperature of 24 °C, which increased the requirement to 269 kWh/yr.

EU

The EU's Ecodesign regulation sets MEPS for most refrigerators at an Energy Efficiency Index (EEI) of 125, which can be found in Table 1 of Annex 2.[71] Starting on 1 March 2024, this requirement will become more stringent and shift to an EEI of 100.

Annex III of the EU's Ecodesign regulation spell out the measurement method of the annual energy (AE) of a refrigerator and calculation of the standard annual energy (SAE), which can be combined into the EEI for comparison against the standard:

Calculations:

EEI = AE/SAE

SAE is calculated based on the refrigerator total volume, the volumes of the compartments, and parameters related to the number and type of the compartments:

$$\mathrm{SAE} = \mathrm{C} \times \mathrm{D} \times \sum_{c=1}^{n} \mathrm{A_c} \times \mathrm{B_c} \times [\mathrm{V_c}/\mathrm{V}] \times (\mathrm{N_c} + \mathrm{V} \times \mathrm{r_c} \times \mathrm{M_c})$$

For the representative unit (400 L; 300 L fresh food and 100 L frozen compartment; 4-star; at -18ºC) we calculated SAE to be 0.4, resulting in an AE = EEI/SAE of 250 kWh.

EU's refrigerators are already tested and evaluated at an average of 16 and 32 °C, so no further temperature adjustments were needed.

INDONESIA

Indonesia's minimum energy performance requirement for refrigerators is equivalent to (0.85 x adjusted volume) + 270 kWh.[72] The adjusted volume is calculated by multiplying volume of each compartment by a factor related to the fresh food reference temperature of 4 °C in IEC 62552:2015.

Adjusted volume calculation:

Vadj = Vfresh × (32-Tfresh)/(32-Tref) +
Vfrozen × (32-Tfrozen)/(32-Tref)

Tref = 4; Tfresh = 4; Tfrozen = -18

Vadj = 479 L

Using the calculated adjusted volume of 479 L, the annual energy consumption requirement comes out to 677 kWh.

Indonesia tests at 32 °C, so we reduced the requirement by 29% to reflect 24 °C, the average temperature at 16 and 32 °C, resulting in 481 kWh. Finally, we adjusted the volume to 510 L using the reference temperature of 24 °C, which increased the requirement to 499 kWh/yr.

UK

UK still retains the EU Ecodesign regulation, so the calculation was as in the EU. The annual energy consumption requirement is 250 kWh. There is no need to adjust for ambient temperature.

INDIA

India's policy is officially just a labeling program, but the label is mandatory and products need to at least achieve the 1-star level to be on the market, making it a de facto MEPS.[73]

The test conditions in India are 3 °C for fresh food and -15 °C[74] for frozen. Note that these different temperatures did not have a significant impact on the adjusted volume compared to the current IEC standard of 4 °C and -18 °C, as the two differences largely cancel each other out.

India tests at 32 °C, so we reduced the requirement by 29% to reflect 24 °C, the average temperature at 16 and 32 °C, resulting in 271 kWh. Finally, we adjusted the volume to 510 L using the reference temperature of 24 °C, which increased the requirement to 280 kWh/yr.

BRAZIL

Brazil's refrigerator policy has a MEPS requirement of 698 kWh when using an adjusted volume of 479 L.[75]

Brazil tests at 32 °C, so we reduced the requirement by 29% to reflect 24 °C, the average temperature at 16 and 32 °C, resulting in 496 kWh. Finally, we adjusted the volume to 510 L using the reference temperature of 24 °C, which increased the requirement to 524 kWh/yr.

CANADA

Canada's policy provides equations for maximum energy consumption limits for various refrigerator types.[76] These are the same as the US, so the same calculation steps apply.

JAPAN

Japan's policy provides equations for maximum annual energy consumption based on product type and cooling system.[77]

CATEGORY				STANDARD ENERGY CONSUMPTION EFFICIENCY CALCULATION FORMULA
CATEGORY NAME	REFRIGERATOR TYPE	COOLING TYPE	RATED INTERNAL VOLUME	
a	Refrigerator and refrigerator-freezer	Cold air-natural convection type	—	$E_3 = 0.735V_3 + 122$
b		Cold air-forced circulation type	Up to 375 liters	$E_3 = 0.199V_3 + 265$
c			Over 375 liters	$E_3 = 0.281V_3 + 112$

Adjusted volume equation:

Remarks: E_3 and V_3 express the following numerical values.

E_3: Standard energy consumption efficiency (unit: kWh/year)

V_3: Adjusted internal volume (unit: liter)

It is a total sum of the values obtained by multiplying the rated internal volume of each storage compartment by the adjusted internal volume coefficient respectively, which shall be obtained from the following formula and rounded to the nearest integer.

$$V_3 = \sum_{i=1}^{n} (K_{ci} \cdot V_i)$$

K_{ci}: Adjusted internal volume coefficient, which is a value given in the right column of the table below for each type of storage compartment given in the left column.

V_i: Rated internal volume, which is a value for each type of storage compartment given in the left column of the table below. (unit: liter)

n: Number of storage compartments in a refrigerator or a refrigerator-freezer

TYPE OF STORAGE COMPARTMENT	ADJUSTED INTERNAL VOLUME COEFFICIENT K_{ci}
Pantry	0.38
Cellar	0.62
Refrigeration	1
Chiller	1.1
Zero-star	1.19
One-star	1.48
Two-star	1.76
Three-star or four-star	2.05

Calculation:

Using refrigeration of 300 L and freezer of 100 L, adjust volume = (300 × 1) +(100 × 2.05) = 505 L

Using the adjusted volume of 505 L, the annual energy consumption requirement is 254 kWh. Japan's refrigerators are already tested and evaluated at an average of 16 and 32 °C, so no further temperature adjustments were needed.

SOUTH AFRICA

South Africa's policy requires a minimum of Class B for refrigerators.[78] Class B in Table AA.5 of SANS 62552 requires an energy efficiency index (I) of 75; I = AC/SC × 100, where AC is the annual energy consumption and SC is the standard annual energy consumption. SC is calculated by the formula in Appendix AA of SANS 62552:2008.

Three climate classes are used in South Africa (Tropical/T, Subtropical/ST, and Temperate/N), and the standard has different requirements and calculation methods for each. We used the least stringent Tropical class requirements. Using our standard 400 L fridge size, the annual energy consumption requirement is 672 kWh. South Africa tests Tropical class at 32 °C, so we reduced the requirement by 29% to reflect 24 °C, the average temperature at 16 and 32 °C, resulting in 477 kWh/yr. However, we did not adjust the volume as the MEPS equation takes each compartment volume separately, rather than as an adjusted volume.

For reference, the requirement for Subtropical was 635 kWh/yr (tested at 25 °C, so 616 kWh/yr when reduced by 3% to reflect 24 °C reference temperature) and the requirement for Temperate was 598 kWh/yr (also tested at 25 °C, so 580 kWh/yr when reduced by 3% to reflect 24 °C reference temperature).

Water Heating

Comparing water heater efficiency policies is complicated due to multiple product types (storage versus instantaneous), fuel (gas versus electric), different national usage profiles, and different national air and water temperatures (which significantly affect heat pump performance). All of these factors result in disparate test methods and standards requirements (including within an economy).

IEA Energy Efficient End-use Equipment (4E) benchmarked the policies for most types of water heaters across seven economies (Australia, Canada, China, the EU, Japan, Korea, and the United States) in 2017, and while the requirements for some water heater types and economies could be compared, other comparisons were listed as "indicative" or not performed at all because the local metrics combined water heating efficiency and standing losses in a way that could not be disaggregated and then re-weighted to reflect conditions and usage in other economies.[79]

Moreover, the efficiency differences between products and policies *within* water heater types (e.g., more- or less-efficient electric resistance) were less than the differences *between* types (e.g., electric resistance compared to electric heat pump). In this analysis, we therefore sidestep the issue of detailed comparison between policy requirements for individual product types and instead analyze whether policy requirements advance two major efficiency opportunities for water heaters today:

1. Greater than or equal to 86% active efficiency levels for gas water heaters, requiring condensing technology (both storage and instantaneous)

2. Greater than 100% efficiency requirements for electric storage water heaters, thereby requiring heat pump technology

The other major opportunities left out of this comparison are:

1. Converting gas water heaters to heat pumps (e.g., through a technology-neutral, greater than 100% efficiency requirement). However, no economy analyzed has so far implemented such a requirement.

2. Encouraging the use of solar thermal water heating. Again, no economy has policies that require the use of solar thermal heating; however, some economies are leaders in encouraging their deployment through incentives (e.g., India where 13% of water heaters were solar in 2018)[80].

The presence of the above policies for each type of water heater are weighted by the share of water heaters of that type (either stock or sales, as available) to calculate a final weighted score between 0 and 100%.

BRAZIL

The majority of water heaters in Brazil (95%) are electric instantaneous,[81] incorporated into the showerhead. There are no efficiency requirements for these products, nor could they be easily replaced with heat pumps as most plumbing in Brazilian homes is single pipe/cold water only.

An additional 300,000 households have gas water heaters (representing 1% of the water heater stock). Despite this small number, Brazil does have requirements. These are set below condensing efficiency levels.[82] However, due to their low penetration, the economy is marked as N/A in the comparison.

NÍVEIS MÍNIMOS DE EFICIÊNCIA ENERGÉTICA DE AQUECEDORES DE ÁGUA

TIPO DE AQUECEDOR	NÍVEL MÍNIMO DE EFICIÊNCIA ENERGÉTICA
Instantâneo	76%
Acumulação	72%
Obs.: Para aparelhos do tipo acumulação, o nível mínimo do nível de eficiência é aplicável para aqueles cujo volume do reservatório térmico seja de até 250 litros.	

CANADA

Only the standby losses of electric water heaters are regulated in Canada,[83] and the requirements are set below the 100% efficiency of heat pumps.

The requirements for gas storage water heaters do not require condensing efficiency, with requirements of a UEF below 0.7 at their most stringent.[84] However, the requirements for instantaneous gas water heaters are more stringent, requiring condensing efficiency, with a UEF of 0.86–0.87.[85]

The Comprehensive Energy Use Database[86] does not publish separate stock data for instantaneous water heaters, so we assumed the proportion of gas water heaters that are instantaneous is the same as in the United States (3%), resulting in 0.53 million gas instantaneous, 7.8 million gas storage, and 6.9 million electric storage (resistance and heat pump). We assumed no electric instantaneous due to the cold climate.

CHINA

China has standards for both gas and electric storage water heaters (MEPS is the highest grade in the tables below).

ENERGY EFFICIENCY GRADES OF GAS DHW SYSTEMS

HEATING LOAD (%)	ENERGY EFFICIENCY (%)		
	GRADE 1	GRADE 2	GRADE 3
100	98	89	86
50	94	85	82

Data Source: GB 20665-2015

ENERGY EFFICIENCY GRADES OF ELECTRIC DHW SYSTEMS

ENERGY EFFICIENCY GRADE	INHERENT ENERGY COEFFICIENT (ε) IN 24H IN GB 21519-2008	ENERGY EFFICIENCY (%) CALCULATED BY LIU ET AL.[87]
1	0.6	90
2	0.7	82
3	0.8	74
4	0.9	68
5	1.0	60

EU

The EU has fuel-neutral efficiency requirements expressed in terms of *primary* energy efficiency (electric resistance and heat pump efficiencies must be divided by 2.5 to reflect the energy conversion losses in electricity generation).

In other words, the requirements for smaller electric water heaters are 80–92.5% final energy efficiency, while those for smaller gas are 32–37%, well below condensing levels.[88] However, an additional requirement requires higher efficiencies for XXL, 3XL, and 4XL categories (≥ 300 L). Final efficiencies must be greater than 150–160% for the larger electric storage and 60–64% for gas, as seen in the requirements below.

From 26 September 2017, the water heating energy efficiency of water heaters shall not fall below the following values:

DECLARED LOAD PROFILE	3XS	XXS	XS	S	M	L	XL	XXL	3XL	4XL
Water heating energy efficiency	32%	32%	32%	32%	36%	37%	37%	37% [Superseded by below req.]	37% [Superseded by below req.]	38% [Superseded by below req.]

From 26 September 2018 the water heating energy efficiency of water heaters shall not fall below the following values:

DECLARED LOAD PROFILE	XXL	3XL	4XL
Water heating energy efficiency	60%	64%	64%

We compared the sales of the larger electric water heaters to the stock of water heaters of each type to estimate the impact of the standards.[89]

INDIA

Only the standby power of electric storage water heaters is regulated in India and at levels below the 100% efficiency of heat pumps. Meanwhile, gas water heater efficiency requirements are set at 70% for storage and 82–84% for instantaneous, below condensing efficiencies.[90]

INDONESIA

Water heaters are not regulated in Indonesia. CLASP's 2019 Residential End-use Survey estimated that only 0.2% of gas usage went to water heating, with the remainder going to cooking. Piped gas is only available in some cities, reducing its usage. The lack of regulation therefore reflects lack of use, and not lack of ambition, and the economy is marked as N/A in the comparison.

JAPAN

Top Runner efficiency requirements for electric water heaters only cover heat pumps using CO_2 refrigerant. While these requirements are world leading[91] and Japan has a high penetration of heat pump water heaters (heat pumps outnumber electric resistance), electric resistance storage heaters continue to be sold in Japan.[92]

Top Runner efficiency requirements for gas water heaters are bifurcated depending on whether the water heater uses forced or natural ventilation. Condensing technology requires forced venting; retaining a separate product class for naturally vented products ensures that these products remain in the market.[93]

In the target fiscal (2025) year and each subsequent fiscal year, for each category, the weighted average value obtained by weighting energy consumption efficiency with shipment volume shall not be below the target standard value in the table below.

CATEGORY			[TARGET STANDARD VALUE] STANDARD ENERGY CONSUMPTION EFFICIENCY
CATEGORY NAME	PURPOSE	VENTILATION TYPE	
I	Gas instant water heaters	Natural ventilation type	77.50%
II	Gas instant water heaters	Forced ventilation type	84.37% × α II i
III	Bathtub gas water heaters		87.21% × α III i

SOUTH AFRICA

Only the standby loss of electric water heaters is regulated in South Africa, and that is set below the 100% efficiency requirement that would encourage a transition to heat pumps.[94] Meanwhile, only 1% of households have gas water heaters.[95]

UNITED KINGDOM

Same as EU, though with a different distribution of stock among the technologies and sizes, resulting in a lower share of water heaters required to exceed the > 100% efficiency characteristic of heat pumps.

UNITED STATES

Uniform energy factor (UEF) requirement for > 55 gal (208 L) electric storage requires greater than 100% efficiency. There is no requirement for condensing efficiency levels for gas storage (< 0.7 UEF for ≤ 55 gal and < 0.8 UEF for > 55 gal) or gas instantaneous (0.80–0.81 UEF).[96,97] 45% of water heaters are electric storage, 44% are gas storage, and 3% are gas instantaneous. Furthermore, 18% of water heaters are electric and 50 gallons or larger (roughly the size targeted by the regulations).[98]

Space Heating

Similar to water heaters, space heating can use a variety of fuels (gas, oil, electricity) and methods for generating heat (electric resistance or heat pump). In addition, some heating systems use water or steam to heat radiators (boilers), while others heat the air directly (furnaces, electric radiators, baseboard heaters, heat pumps). Policies differ based on these factors as well as the capacity of the equipment, its form factor, installation location, and venting. Finally, they take into account climatic conditions, which especially affect the performance of heat pumps.

This complexity makes it difficult to conduct a clear comparison between economies, so as with water heating, we are focusing on the major opportunities for efficiency improvements which exist between heating product types rather than within them. As before, we analyze whether policy requirements advance three major efficiency opportunities:

1. Greater than or equal to 90% active efficiency levels for fossil fuel space heating, requiring condensing technology (both furnaces and boilers, if present in an economy)
2. Greater than 100% efficiency requirements for electric resistance heating, thereby requiring heat pump technology
3. Requiring air conditioners to also provide heating through two-way operation, like a heat pump. The vast majority of ACs in China, Japan, and South Africa are two-way heat pumps, and using them to carry more of the heating load has been proposed as an electrification strategy in Japan[99] and the United States[100]

These policies are weighted by the proportion of space heating stock to which they apply, resulting in a single 0–100% score.

The other major opportunities left out of this comparison are:

4. Converting gas space heating to heat pumps (e.g., through a technology-neutral, greater than 100% efficiency requirement). However, no economy analyzed has so far implemented such a requirement.
5. Encouraging the use of solar thermal water heating. Again, no economy has policies that require the use of solar thermal heating).

BRAZIL

There are no standards for space heating in Brazil and not much use of space heating,[101,102] so Brazil has been excluded from this comparison.

CANADA

Canada has set condensing requirements for gas furnaces (95%) and hot-water boilers (90%). Only steam boilers remain below condensing levels (82%).[103]

Electric furnaces only have a fan efficiency requirement,[104] and there is no requirement for air conditioners to provide heating (air conditioners and heat pumps are in separate product classes).[105]

The stock of fossil fuel furnaces and boilers is approximately 8.8 million, electric resistance heating is 4.5 million, and heat pumps is 0.85 million. Gas is 80% of fossil fuel heating and oil 20%, so we assumed that approximately 75% of fossil fuel heating would be subject to the condensing requirements.[106]

CHINA

Mandatory gas boiler efficiency requirements are at 85%, below condensing level.[107]

Electric resistance heating is not regulated, though present in approximately 100 million households.[108] However, most air conditioners also provide heating, resulting in another 100 million households with heat pumps.[109]

EU

The EU requires non-condensing efficiency levels for boilers at 85% for 10–70 kW and 75% for ≤ 10 kW.[110]

There are no requirements for electric heating efficiency and no requirements or use of air conditioners for heating.

INDIA

There are no standards for space heating in India and not much use of space heating,[111] so India has been excluded from this comparison.

INDONESIA

There are no standards for space heating in Indonesia and not much use of space heating,[112] so Indonesia has been excluded from this comparison.

JAPAN

Japan's Top Runner requirements for gas heaters are set at 82%, below condensing levels. Electric resistance heating is not commonly used. However, all air conditioners in Japan are reversible and therefore can also heat, leading to high use of heat pumps for heating. Approximately 9.6 million reversible air conditioners are sold each year, compared to 2.6 million fossil fuel heaters (mainly oil).[113]

SOUTH AFRICA

The vast majority of air conditioners in South Africa are reversible and therefore can heat, leading to high use of heat pumps for heating. Approximately 1 million households have air conditioners. 9.3 million households report using electricity for heating, leaving 8.2 million with electric resistance heating. Finally, 1.6 million use fossil fuel heating.[114]

UNITED KINGDOM

The space heating and air conditioning requirements in the UK are the same as in the EU.[115,116]

UNITED STATES

In the US, non-weatherized gas furnace efficiency is set at 80%, and gas-fired boiler efficiency is at 80–82%, both below condensing levels.[117]

Electric furnace efficiency is set at 78%. There are no requirements for electric boilers[118] and heat pumps are in a separate product class from air conditioners, meaning that there is no heating requirement for air conditioners.[119]

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