



Mepsy Methodology: Model and Approach for Climate Impact Analysis

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COLLABORATION



IMPACT



TRANSPARENCY



SERVICE



CLASP's research aims to bridge the gap between analysis and action to hit net zero emissions in the appliances sector by 2050. Read ***Net Zero Heroes: Scaling Efficient Appliances for Climate Change Mitigation, Adaptation & Resilience*** to learn more about our net zero strategy.

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Abbreviation Table

ABBREVIATION	FULL TERM
BAU	Business As Usual
BAT	Best Available Technology
CDD	Cooling Degree Days
CER	CO2 Emission Reduction
DR	Discount Rate
EC	Equipment Cost
Eff	Efficiency
EF	Emission Factor
IEA	International Energy Agency
HR	Heat Rate
LCC	Life Cycle Cost
MEPS	Minimum Efficiency Performance Standard
NER	National Energy Reduction
NEC	National Equipment Cost
NOC	National Operating Cost
NPV	Net Present Value
OC	Operating Cost
PER	Primary Energy Reduction
PES	Primary Energy Savings
P	Price of Energy (per kWh)
PAMS	Policy Analysis Modeling System
PER	Primary Energy Reduction
P(x)	Probability Function
PUE	Primary Unit Energy Consumption

S	Stock (the number of units in use)
TD	Transmission Distribution
UEC	Unit Energy Consumption
UEC_Base	Base Unit Energy Consumption
UEC_BAT	Unit Energy Consumption of Best Available Technology in the current market
UEC_Efficiency	Unit Energy Consumption under Efficiency Policy
WACC	Weighted Average Cost of Capital

Glossary

Annual Operating Cost (OC): The cost of energy used by an appliance over a year, calculated by multiplying its Unit Energy Consumption (UEC) by the price of energy (P).

Business As Usual (BAU): The scenario where no new efficiency policies are implemented, representing the baseline of market behavior and energy consumption.

Best Available Technology (BAT): The most energy-efficient and commercially available technology currently on the market.

Consumer Discount Rate (DR_c): The rate used to discount future costs and savings from the consumer's perspective, applied in Life Cycle Cost (LCC) analysis.

Cooling Degree Days (CDD): A measure of how much (in degrees) and for how long (in days) the outside temperature was above a certain threshold, often used to estimate energy needs for cooling

Discount Rate (DR_w): The rate used to calculate the time value of money in financial assessments, including in the calculation of Net Present Value (NPV).

Emission Factor (EF): The amount of CO₂ emitted per unit of energy consumed, used to calculate CO₂ emissions reduction.

Equipment Cost (EC): The retail purchase cost of an appliance, including any expenses paid by the consumer when buying it.

Global Benchmark (GB) scenario: This is a low-ambition policy scenario. The global benchmarks are those efficiency levels recommended by CLASP and others such as United for Efficiency. These levels are generally considered to be quite ambitious.

Life Cycle Cost (LCC): A financial evaluation that sums the initial purchase cost of an appliance and its operating costs over its lifetime, discounted for time value.

Market Stock (Stock): The total number of appliances in use at any given time, including newly purchased units and those that remain in use from previous years.

Minimum Efficiency Performance Standard (MEPS): A regulatory standard that sets minimum efficiency requirements for appliances to reduce energy consumption.

National Equipment Cost (NEC_{st}): The total cost of all appliances in the national market, calculated by multiplying the unit equipment cost by the national appliance stock.

National Energy Consumption (NEC): The total energy consumed by all appliances in the national stock, considering their individual energy consumption over time.

Net Present Value (NPV): The sum of all future savings (in terms of reduced operating and equipment costs) adjusted for the time value of money, used to evaluate the financial benefit of implementing a policy.

Net Zero Hero (NZH) scenario: This is a high-ambition policy scenario. This scenario aligns with the targets outlined in Net Zero Heroes report published by CLASP in 2023, which calls for doubling the efficiency of ten key appliances. This action can significantly reduce energy consumption and contribute to the achievement of Net Zero Emission (NZE) goals

Operating Cost (OC): The cost incurred in using an appliance, primarily energy costs, calculated as the energy consumption of the appliance multiplied by the energy price.

Primary Energy Reduction (PER): The reduction in total primary (fossil fuel) energy use resulting from a policy, adjusted for transmission losses and heat rates.

Policy Analysis Modeling System (PAMS): A modeling system developed by Lawrence Berkeley National Laboratory. The system is used for analyzing the potential impacts of implementing energy efficiency policies, similar to Mepsy but with different assumptions and methodologies.

Primary Energy Savings (PES): The reduction in total energy consumption from a more efficient policy scenario, considering transmission and distribution losses.

Appliance Shipments: The number of new appliances sold in a given year, used in determining market stock and energy consumption patterns.

Survival Function: A statistical function (often modeled using a Weibull distribution) that represents the likelihood that an appliance will still be in use after a given number of years.

Transmission and Distribution Losses (TD): The losses that occur as energy is transmitted and distributed, affect the total energy savings and reductions calculated for national energy savings.

Unit Energy Consumption (UEC): The typical annual energy use of a appliance, based on typical user behavior and environmental conditions, and central to calculating operating costs.

Weibull Distribution: A statistical model used to describe the failure rates of appliances over time, helping estimate how long appliances will last and when they will be retired.

Overview of Mepsy

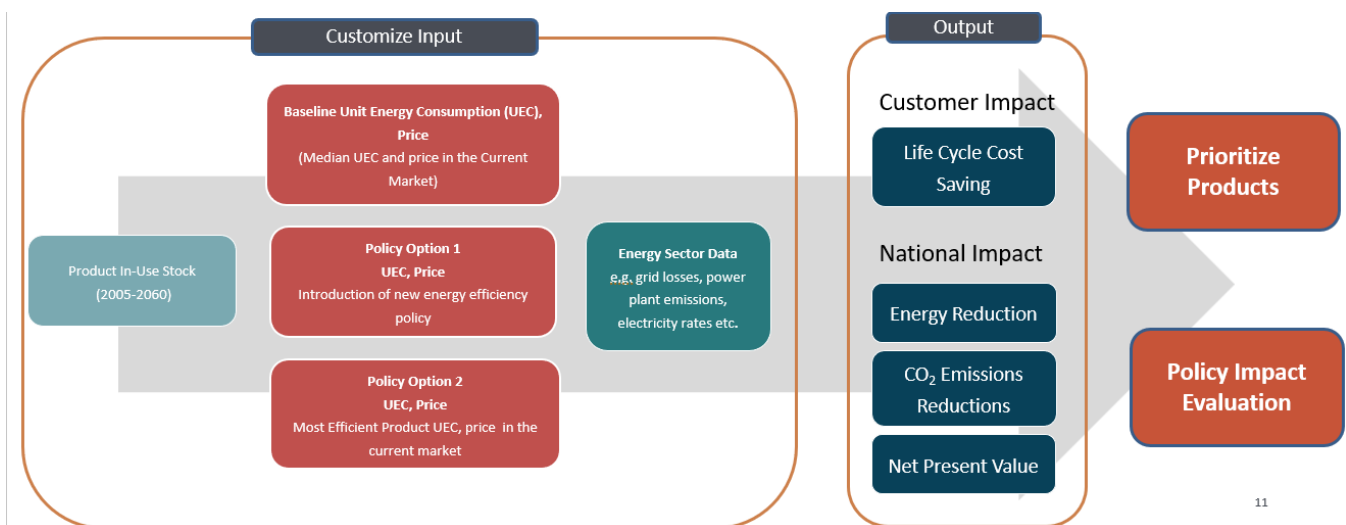
Introduction

Mepsy is a tool developed to estimate the costs and benefits of energy efficiency standards and labeling programs for appliances, equipment, and lighting (collectively “appliances”) at the national level. The tool includes multiple countries and appliances within a single model, supporting cross-country and cross-appliance comparisons. It integrates market data and allows users to customize inputs, from appliances sales to electricity tariffs, to further improve the accuracy of the results.

Mepsy is a self-contained model that provides both life cycle cost analysis and climate impact assessment, including energy consumption and CO₂ emissions. The tool helps policymakers to prioritize the most impactful appliance and evaluate the outcomes of proposed policies before they are adopted. By comparing the assessment results, analysts can identify the most effective strategies, maximizing the benefit while minimizing costs.

Mepsy uses a bottom-up approach, as illustrated in Figure 1. The potential policy impacts are obtained by defining the average unit energy consumption (UEC) and the price of new models in different scenarios. These two parameters are then applied to the appliances in-use stock in the assessment country over the analysis periods. Finally, the model factored in grid emissions, utility rates, and other variables, to estimate environmental and financial benefits from different policy options.

FIGURE 1. OVERVIEW OF THE MEPSY CALCULATION METHODOLOGY



User Interface

Mepsy is an [online tool](#) hosted by Shiny Applications—a web-based platform that allows users access via a browser. It is developed in R, and it helps run Mepsy’s calculations and visualizations within a user-friendly interface. On the platform, users can change input data, run custom analyses, and view the results without installing any additional software or having technical knowledge. Meanwhile, Shiny handles the data and calculations on the server side. This ensures Mepsy can be used remotely and securely.

Mepsy opens with a global map view (Figure 2), which shows pre-calculated impact measures such as appliance stocks, ownership, energy consumption, CO₂ emissions, and reductions under three standard scenarios: [Business-as-usual \(BAU\)](#), [Global Benchmark \(GB\)](#), and [Net Zero Hero \(NZH\)](#)(Figure 3). This view enables broad analyses to identify efficiency opportunities across multiple appliances and multiple countries.

FIGURE 2. GLOBAL MAP VIEW IN MEPSY

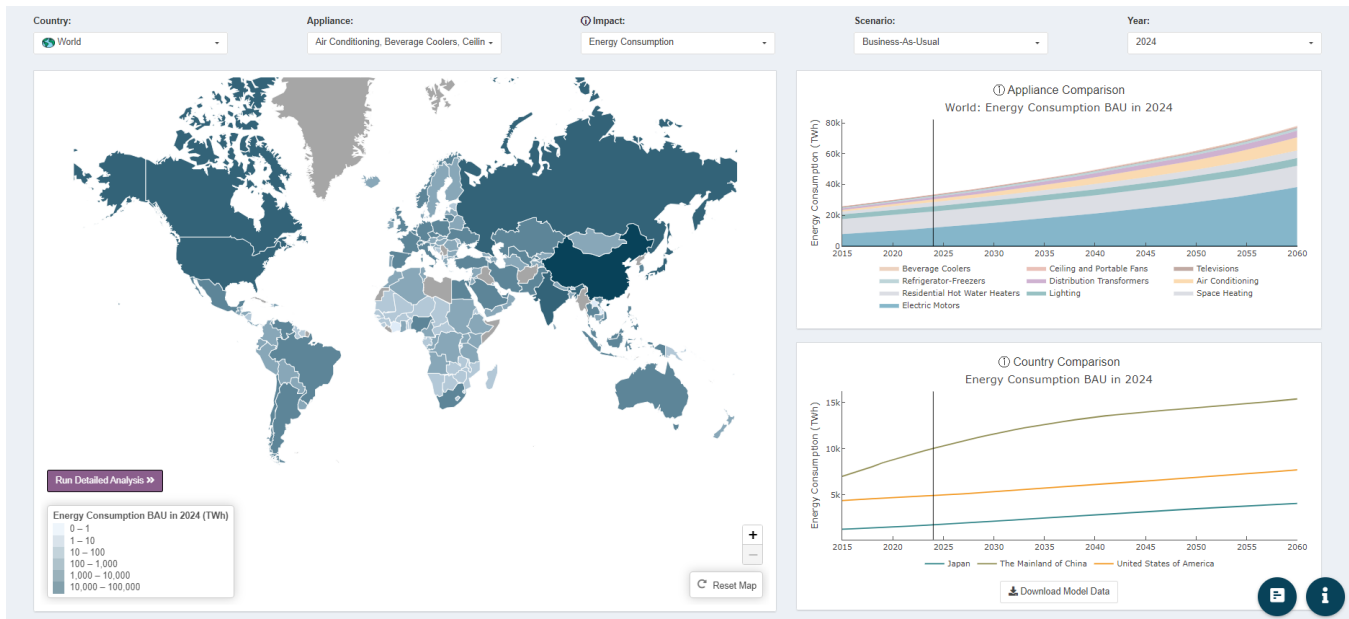
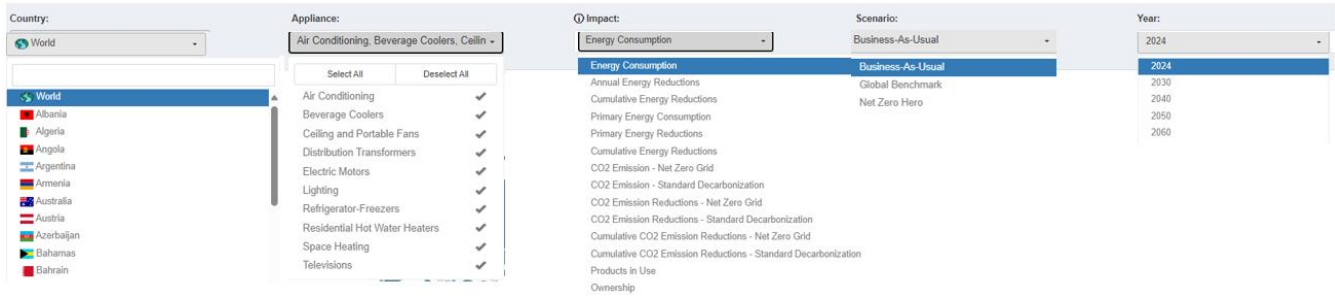
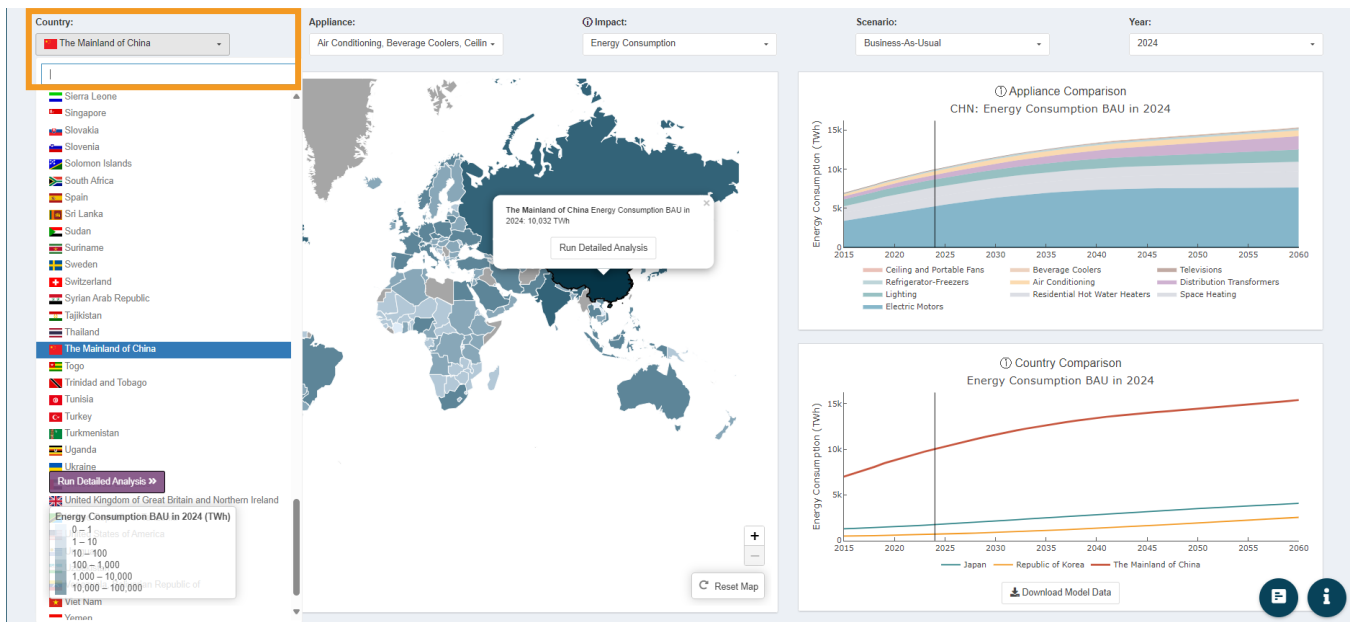


FIGURE 3. FIVE SELECTIONS IN GLOBAL MAP VIEW



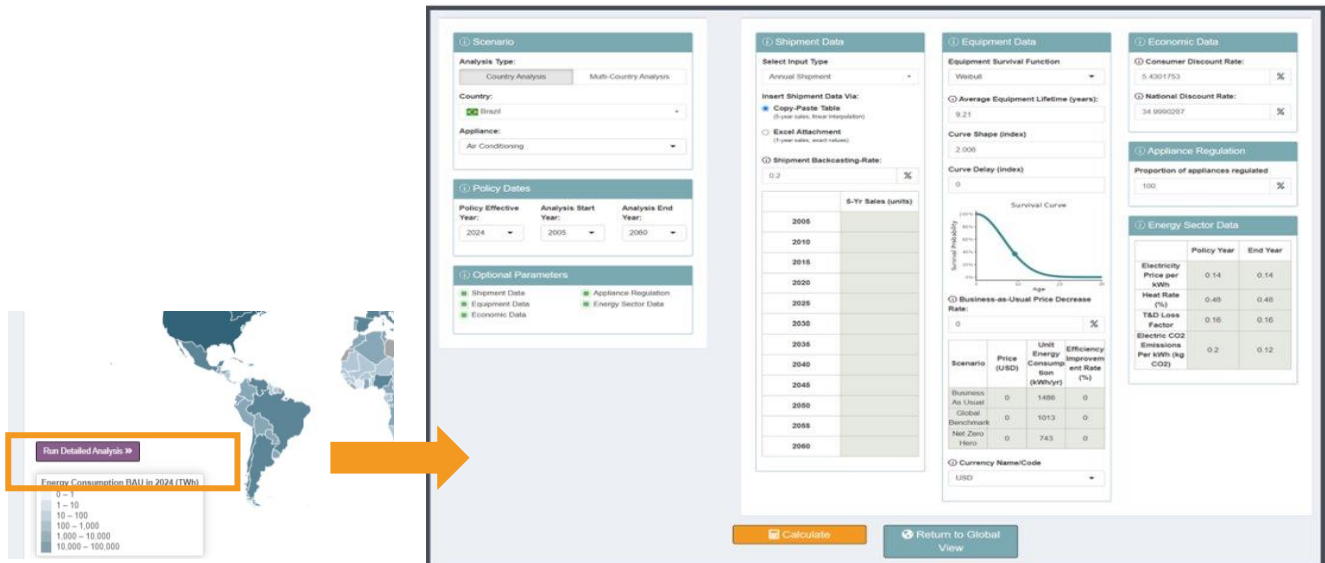
Next, clicking on a country and selecting appliances from the drop-down menu allows users to view each impact quantity for that country. This also filters the graphs to the right of the screen, enabling users to prioritize multiple products within a single country (Figure 4).

FIGURE 4. VIEW MULTIPLE PRODUCTS WITHIN A SINGLE COUNTRY



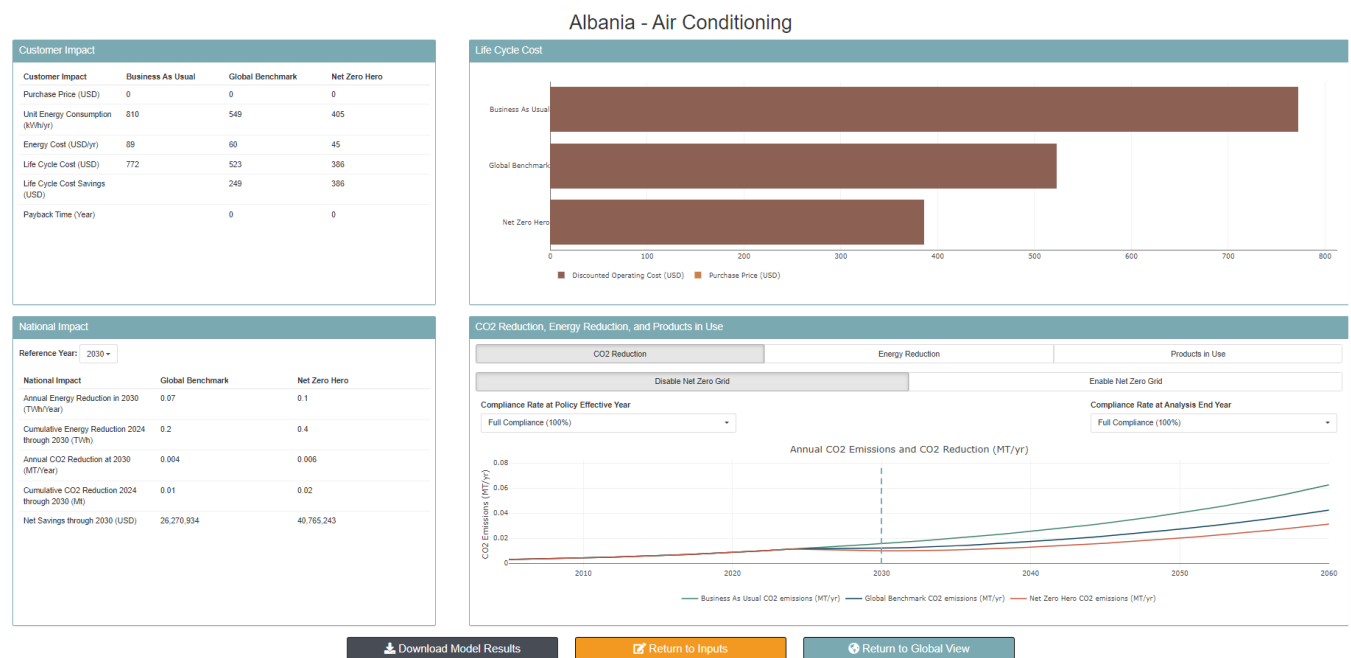
Clicking the **Run Detailed Analysis** button on the map takes the user to the Country Detailed Input, where they can view the assumptions for each country and appliance and enter custom data to evaluate different scenarios within the country, as shown in Figure 5. This enables the narrow analyses necessary to evaluate policies for a single appliance in a single country.

FIGURE 5. OPEN COUNTRY DETAILED ANALYSIS



After clicking the [Calculate](#) button, the tool directs users to the result page. As shown in Figure 6, the impact measures—including life cycle cost savings, energy and CO₂ emission reduction—across different scenarios are listed on the result page, along with visualized charts. All inputs and outputs can be downloaded as CSV files for further research purposes.

FIGURE 6. RESULT PAGE IN MEPSY



Mepsy also supports the evaluation of policies for a single appliance in multiple countries or regions. Users can simply select the regions and appliances they want to evaluate, and Mepsy will show pre-run impact measures based on BAU, GB, and NZH scenarios on the result page. All results can also be downloaded in CSV files.

FIGURE 7. MULTIPLE-COUNTRY ANALYSIS INPUT AND OUTPUT PAGES

① Scenario

Analysis Type:

Country Analysis
Multi-Country Analysis

How Should Countries be Grouped?

Geographically
UN Regions

- African Group
- Asia-Pacific States
- Eastern European States
- Latin American and Caribbean States
- Western European and other States

Appliance:

Air Conditioning
▼

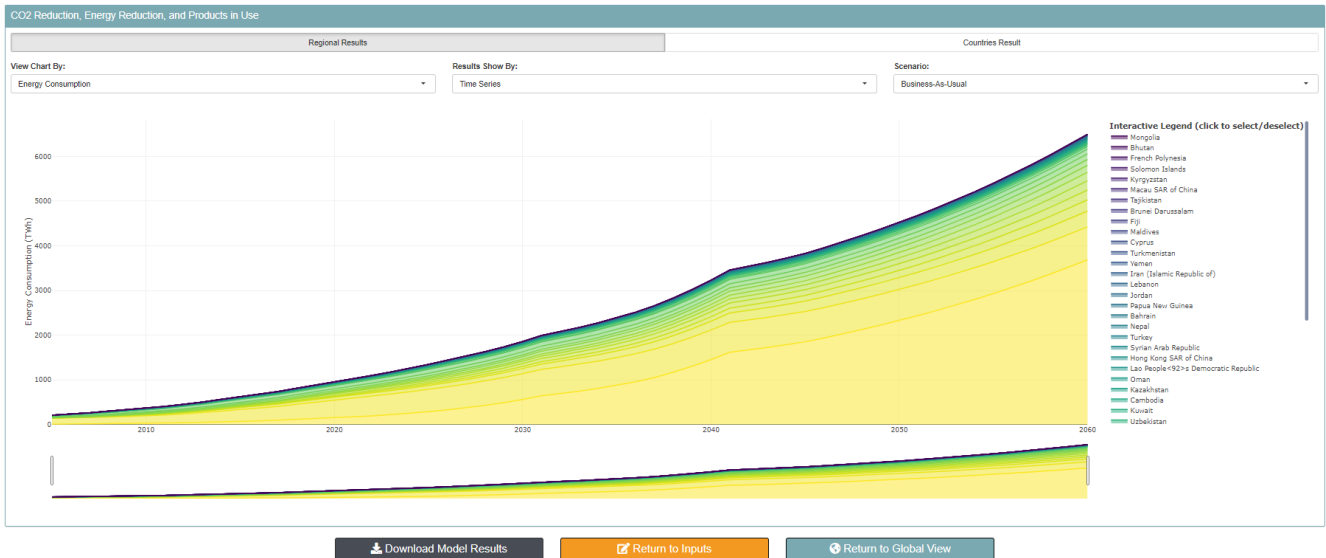
① Policy Dates

Policy Effective Year: 2024 ▼

Analysis Start Year: 2005 ▼

Analysis End Year: 2060 ▼

Multi-Country Analysis: Air Conditioning



Scope and Definition

1. Appliance Scope

REPRESENTATIVE UNITS

Currently, Mepsy includes analytical models for the top ten energy-consuming appliances, with pre-loaded data available for 162 countries (see Annex).¹ Since each appliance category includes various types of models, we selected the most common types of each category to serve as the representative unit, using its specifications, such as unit energy consumption and price in the analysis. Table 1 summarizes the representative units under each appliance category.

TABLE 1. APPLIANCE SCOPE IN MEPSY

APPLIANCE	SECTOR	REPRESENTATIVE UNITS
Room Air Conditioners	Residential	Residential air conditioner. Size varies by country depending on ratio of 3.5 kW and 7 kW systems, from United for Efficiency (U4E) ¹
Refrigerators	Residential	Residential refrigerator-freezer, with volume that varies by region, as estimated in U4E ²
Separate Fans	Residential	Portable fan: 16 in/400 mm; Ceiling fan: 48 or 52 in/1200 or 1300 m
Televisions	Residential	HD; UHD
Water Heating	Residential	Heat pump; Electric storage heater; Electric instant heater; Gas storage heater – condensing & non-condensing; Gas instant heater – condensing & non-condensing
Space Heating	Residential	Air-source heat pump (ASHP): 5.37 kW, ground-source heat pump (GSHP): 12.14 kW, boiler/furnace: 25.5 kW, electric resistance (ER): 9.76 kW
Lighting	Residential, Commercial and Industrial	Incandescent and halogen lamps; Compact Fluorescent Lamp (CFL); LED Omnidirectional and LED

¹ Mepsy follows the same methodology as the PAMS analytical model, developed by LBNL, which includes 162 countries. These countries are categorized into regions in the same way as in the PAMS model.

² “CSA_Methodology_September2022.Pdf,” accessed December 10, 2024, https://united4efficiency.org/wp-content/uploads/2022/07/CSA_Methodology_September2022.pdf.

		reflector; Linear Fluorescent Lamp (CFL (LFL)); LED tube; High-Intensity Discharge (HID); LED Outdoor
Motors	Industrial	11.4 kW avg. 4-pole motor for centrifugal pumps and compressors, medium (0.75-375 kW) to large (>375 kW)
Distribution Transformers	All-Purpose	Three-phase liquid-immersed; Three phase dry-type, and single-phase liquid-immersed; Representative average rated capacity values in kVA are defined per category for each country.
Beverage Cooler	Commercial	Integral or self-contained vertical glass door cabinet, with 400 L gross volume, considering typical height from 0.5 to 2.2 m, with one vertical glass door.

2. Standard Scenarios

Mepsy is designed to model the impacts of default policy scenarios. Those include:

- **Business as usual (BAU):** The model assumes that before policy being implemented, all appliances on the market operate at a well-defined baseline efficiency.
- **Global Benchmark (GB):** This is a low-ambition policy scenario. The global benchmarks are those efficiency levels recommended by CLASP and others such as United for Efficiency. For Beverage Coolers and Distribution Transformers, the GB scenario is referred to as the Efficiency Policy scenario.
- **Best Available Technology (BAT):** This scenario assumes all new appliances will operate at the highest efficiency levels currently achievable, using the most advanced and effective technologies available today. This scenario is currently only available for Beverage Cooler and Distribution Transformers.
- **Net Zero Hero (NZH):** This is a high-ambition policy scenario. This scenario aligns with the targets outlined in [Net Zero Heroes](#) report published by CLASP in 2023, which calls for doubling the efficiency of ten key appliances. This action can significantly reduce energy consumption and contribute to the achievement of [Net Zero Emission](#) (NZE) goals.

3. Grid Emissions Factors

When evaluating the impact of policies on CO₂ emissions, Mepsy uses two different sets of grid emissions factors (EF) time series, **Standard Decarbonization** and **Net Zero Grid**. Users can choose between the emission results by selecting their preferred EF assumptions.

Standard Decarbonization assumes that each country's emissions factor will steadily decline at a linear rate until 2060:

- **Prior to 2025:** each country's emission factor remains unchanged from the 2020 value. Data source listed in Table 2.
- **From 2025 to 2050:** Each country's emission factor decreases in line with the global trend of electricity CO₂ intensity, based on the calculation from Crux Global Change Assessment Model (GCAM) as outlined in Figure 8.
- **After 2050:** The emission factor will continue to decrease by 5% every five years until 2060.

Net Zero Grid refers to the target set by the International Energy Agency (IEA) in the "[Net Zero by 2050](#)" report. It assumes a more ambitious pace to achieve the net zero power grid, with the emission factor starting to decrease in 2022, reducing by 50% by 2030, and reaching zero by 2040.

FIGURE 8. AVERAGE GLOBAL ELECTRICTY CO2 INTENSITY TREND FROM 2025 TO 2050

Electricity CO2 intensity from Crux GCAM average global CO2/kWh (kg/kWh)	2025	2030	2035	2040	2045	2050
	0.37475	0.34817	0.32782	0.30586	0.28363	0.26367
	100%	93%	87%	82%	76%	70%

Data Sources

1. Data Inputs

APPLIANCE-SPECIFIC DATA AND ASSUMPTIONS

Mepsy uses appliance-specific modeling parameters to calculate unit and national energy consumption under each scenario. Wherever possible, the calculator references precise stock, sales, and energy performance data from recent CLASP in-country market studies, or country-level estimates from reputable market research firms. Where country-level data for a particular appliance is not available, our calculations are based on estimates from regional or global averages, accounting for differences in country population, economics, or climate as relevant to a particular appliance. Past shipments are extrapolated based on recent trends.

The data sources for these parameters are summarized in Table 2. Data source or can be found in the [Methodology & Assumptions](#) document accessible through the [Mepsy landing page](#).

The model uses the same structure and assumptions for all appliances. For example, a country's cooling degree days (CDD), discount rate, and carbon factor stay the same, no matter which

appliance is analyzed. However, factors such as shipments and stock, lifetime, and UEC vary from appliance to appliance.

For some types of data, CLASP uses multiple sources to fill in gaps or provide increased resolution. These different sources appear on separate rows, in order of priority (i.e., the model uses source #1, unless not available for a particular appliance, country, or year, in which case it uses source #2. Additional details on the appliance-specific data sources appear in the corresponding [appliance-specific appendices](#).

The document will be updated continuously as the team reviews and incorporates more accurate data sources as they become available. However, the core methodology remains consistent. The Mepsy online tool is version-controlled, allowing users to reference specific versions tied to particular data sets used in the tool. Since the latest version always incorporates the most up-to-date and reliable data, it is recommended that users regularly integrate new data and analysis results when it becomes available.

TABLE 2. DATA SOURCE

DATA	SOURCES	NOTE
Shipment and Stock	<ol style="list-style-type: none"> 1. CLASP primary research in countries 2. Industry and market research reports, surveys, or interviews (e.g., Euromonitor, Omdia, etc.) 3. Customs data (UN Comtrade, national customs authorities, etc.), for import-only markets to approximate market size 	See the appliance-specific appendices for detailed data sources of each appliance.
Unit Energy Consumption	<ol style="list-style-type: none"> 1. CLASP primary research and proxy data 2. Industry and market research reports or surveys/interviews (e.g., Euromonitor, Omdia, etc.) 	See the appliance-specific appendices for detailed data sources of each appliance.
Transmission and Distribution Losses	<ol style="list-style-type: none"> 1. National statistics in countries where CLASP has conducted research 2. US Energy Information Administration (EIA) Data for Electricity Consumption and Distribution losses³ 	
Heat Rate	Various sources including ADB, World Efficiency Council, GE, Lazard, BP, World Bank, and EIA	

³ "International - U.S. Energy Information Administration (EIA)," accessed December 13, 2024, <https://www.eia.gov/international/data/world>.

Grid Emission Factor	<ol style="list-style-type: none"> 1. National statistics in countries where CLASP has conducted research 2. International Financial Institutions Technical Working Group (IFI TWG) Grid Factors⁴ 	Mepsy applies two sets of dynamic grid emission factors in the analysis. Details are outlined in Section 3. Evolution of Grid Emission Factor
Lifetime	<ol style="list-style-type: none"> 1. Detailed surveys and interviews with manufacturers and consumers 2. Academic and industry research 	
Electricity Price	<ol style="list-style-type: none"> 1. Residential appliance: IFC's AIMM Framework⁵ 2. Commercial appliance: World Bank Electric Price by Country⁶ 	
Consumer Discount Rate (Deposit interest rate)	World Bank Deposit Interest Rate (%) ⁷	Used in the Life Cycle Cost analysis to calculate benefits for consumers after switching to more efficient appliances.
National Discount Rate (Real interest rate)	World Bank Real Interest Rate (%) ⁸	Used in the National Net Present Value analysis to calculate the total financial benefits of implementing a new policy in one country.

2. Projections beyond 2030

APPLIANCE STOCK

Appliance stock and national end-use consumption are usually driven by population growth and trends in appliance ownership rates.^{9,10} Especially for developing countries, ownership rates of home electric appliances depend critically on household income levels, degree of urbanization, and the ratio of access to electricity. Therefore, Mepsy bases stock projections through 2050 on

⁴ "Harmonized_Grid_Emission_factor_data_set.Xlsx," accessed December 13, 2024, https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Funfccc.int%2Fsites%2Fdefault%2Ffiles%2Fresource%2FHarm%2FHarmonized_Grid_Emission_factor_data_set.xlsx&wdOrigin=BROWSELINK.

⁵ "AIMM Dimensions," Text/HTML, IFC, accessed December 13, 2024, <https://www.ifc.org/en/our-impact/measuring-and-monitoring/aimm-dimensions>.

⁶ "Doing Business | DataBank," accessed December 13, 2024, <https://databank.worldbank.org/Electric-Prices-by-Country/id/7b12e700>.

⁷ "World Development Indicators | DataBank," accessed December 13, 2024, <https://databank.worldbank.org/reports.aspx?source=2&series=FR.INR.DPST&country=>.

⁸ "World Bank Open Data," World Bank Open Data, accessed September 25, 2023, <https://data.worldbank.org>.

⁹ Michael A McNeil, Virginie E Letschert, and Robert D Van Buskirk, "Methodology for the Policy Analysis Modeling System," n.d.

¹⁰ Michael A. McNeil and Virginie E. Letschert, "Modeling Diffusion of Electrical Appliances in the Residential Sector," *Energy and Buildings* 42, no. 6 (June 1, 2010): 783–90, <https://doi.org/10.1016/j.enbuild.2009.11.015>.

multivariate regression modeling, relating the latest year of ownership response to macroeconomic parameters (including household monthly income, electrification rate, urbanization rate, household room number, and cooling capacity). Various combinations of parameters were tested in the regression model to examine the correlation between these factors and ownership. For more details, please refer to the [Mepsy landing page](#).

Next, CLASP combines population forecasts with an income model and econometric parameters to project the national ownership rate for each year in the forecast model. The final step in estimating the national appliance stock from 2020 to 2050 involves multiplying the forecasted ownership rate by the number of national households to determine the total stock.

To project the stock from 2050 to 2060, we use the annual growth rate of sales from 2040 to 2050 and extrapolate it through 2060.

3. Data Constraints

Market Data and Model Updates: The development of the Mepsy model aims to use the most up-to-date market data and parameters. However, the model preparation began in 2019, and although the team has worked to update the dataset with more recent information, some of the data may still be a few years old. Efforts to refresh the data are ongoing, but there may be instances where certain information is missing or not as current as desired.

Proxy Data for Missing Sources: In cases where data for specific countries is unavailable, the model relies on proxy data. This proxy data is drawn from regional or global averages, and while it serves as a substitute, it may not fully represent the unique characteristics of each country.

Mepsy Outputs

Mepsy is designed to evaluate efficiency policy options and help policymakers make the most beneficial decisions. The model assumes that, before a policy is implemented, all appliances on the market operate at a well-defined baseline efficiency. After introducing an energy efficiency program, such as the Minimum Efficiency Performance Standard (MEPS), the efficiency of every appliance on the market is expected to exceed the minimum requirements set by the standard. This leads to several changes in the market, including improved average appliance efficiency and potential shifts in consumer behavior and market prices. To assess the impact of these changes, the tool evaluates the costs and benefits of efficiency standards from two distinct but related perspectives¹¹:

¹¹ Mepsy uses similar metrics as other policy evaluation tools, such as [Policy Analysis Modeling System](#) (PAMS-MEPS)

- Consumer perspective: examines costs and benefits from the perspective of the individual customers after implementing new policy options. The calculation is also called Life Cycle Cost (LCC) analysis.
- National perspective: the output includes national energy savings and emission reductions after implementing new policy options.

Consumer Perspective

1. Life Cycle Cost (LCC) Analysis

The LCC of appliances and equipment includes the purchase price and operating costs. The two main components are the **Equipment Cost (EC)**, which is the retail price paid by the consumer, and the **Operating Cost (OC)**, which covers the cost of energy, such as electricity tariffs, for using the equipment. The equation for calculating Life Cycle Cost for any given appliance is:

$$LCC = EC + \sum_{n=1}^L \frac{OC}{(1 + DR_C)^n}$$

Where EC is equipment cost (retail price), n is the years since purchase, OC is the annual operating cost, and DR_C is the consumer discount rate. Operating cost is summed over the course of an appliance's lifetime L .

Annual Operating Cost for energy is calculated by multiplying Unit Energy Consumption (UEC , kWh/year) by the price of energy (P , in local currency or US dollars per kWh). UEC is assumed as the typical annual energy usage for each appliance, according to local usage patterns and climate conditions. Energy price may be estimated as the average price paid by a customer for one unit of energy.

$$OC = UEC \times P$$

Installation and maintenance are not modeled explicitly; however, installation can be included by the user by adding installation into the purchase price.

National Perspective

Energy use and CO₂ emissions are the key metrics Mepsy uses to evaluate energy efficiency policies. By comparing energy consumption under new policy assumptions with the baseline

scenario, the resulting energy savings demonstrate how improved policies can reduce nationwide energy use, lower energy intensity, and improved resource efficiency. CO₂ emission reductions highlight the environmental benefits, particularly in lowering the carbon footprint.

To calculate these broader impacts at the national level, the first step is to estimate the number of appliances in use during the analysis period. This is done by accounting for the stock based on the shipment data.

1. Shipment and Stock Accounting

Similar to the Policy Analysis Modeling System (PAMS-MEPS), Mepsy uses a bottom-up approach to track the accumulation and retirement of appliances over time. Appliances sold in a certain year are added to the existing stock and then consume energy throughout their lifespan until they are retired.

The key difference between Mepsy and PAMS-MEPS is that Mepsy uses shipment data from market research firms or CLASP's market assessments, while PAMS-MEPS relies on macro-economic models to estimate appliance penetration based on factors like income and climate. Additionally, when calculating the annual stock of appliances, Mepsy applies retirement functions, such as Weibull distribution to reflect appliance aging and failure trends.

SURVIVAL FUNCTION: WEIBULL DISTRIBUTION

The function is applied to the number of shipments for a given year, providing the ratio between the actively used units and the retired units for future years under evaluation. Mepsy defines two statistical functions to represent the lifetime probability distribution. It also allows users to set the survival function of the appliance being evaluated. By adjusting the parameters, users can shape the phase-out curve to define the annual survival probability of appliances in use.

Weibull Distribution is widely used to model survival probabilities $P(x)$ of appliances¹² and calculate the surviving stocks of a certain year (y), based on the cumulative survival appliances from the previous year ($Stock(y - 1)$).

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^\beta}$$

$P(x)$ is the probability that the appliance is still in use at a certain age (x);

x is the appliance age; α is the scale parameter, which corresponds to the decay length in an exponential distribution, also known as lifetime. β is the shape parameter, which determines how the failure rate changes through time, and θ is the delay parameter, which provides for a delay

¹² LBNL. Lutz et al. 2011. Using National Survey Data to Estimate Lifetimes of Residential Appliances. <https://www.osti.gov/biblio/1182737>

before any failures occur. Mepsy refers to LBNL study to determine the average lifetime (α), values for shape (β) and delay (θ) for most of the residential appliances (see Table 3).¹³

For lighting, we apply the S-curve survival function in stock accounting for domestic and professional lighting¹⁴, defined based on operating hours and related lifetime. Details are listed in the technical appendix for lighting.

Mepsy accumulates unit sales and appliances surviving from the previous year to calculate the total in-use appliance stocks in a certain year (y).

$$Stock(y) = Shipment(y) + Survival(y)$$

$$Survival(y) = \sum_x [Stock(y-1) \times P(x)]$$

The $Stock(y)$ is the number of appliances in use each year. $Shipment(y)$ is each country's sales number collected from resources, including market research companies and national surveys.

TABLE 3. PARAMETERS FOR RETIREMENT FUNCTION IN MEPSY

APPLIANCE	AVERAGE LIFETIME (A)	SHAPE (B)	DELAY (θ)
Room Air Conditioners	8.4 years for 3.5 kW; 18 years for 7 kW; National average value varies by country, depending on the distribution ratio of 3.5 kW and 7 kW units.	2.0	0
Refrigerators	17.7 years	1.3	8.874
Fans	10 years	1.5	0
Televisions	7–14 years based on national studies	1.8	1.0
Water Heating	Heat pump: 15 years, Electric storage heater: 8 years, Electric instant heater: 8 years, Gas storage heater – condensing & non-condensing: 12 years, Gas instant heater – condensing & non-condensing: 8 years	2.0	0

¹³ James D. Lutz et al., "Using National Survey Data to Estimate Lifetimes of Residential Appliances," *HVAC&R Research* 17, no. 5 (October 3, 2011), <https://www.osti.gov/biblio/1182737>.

¹⁴ Professional lighting in Mepsy including commercial and industrial lighting.

Space Heating	25.4 years	3.2	1.0
Lighting ¹⁵	2.2-12.5 for domestic lighting. 0.3-12.5 for professional lighting	1	0
Motors	12 years ¹⁶	1.2	1.0
Distribution Transformers	20-35 years, assigned based on category and country grouping	2.0	0
Beverage Cooler	8 years ¹⁷	2.0	0

2. National Net Present Value

The national net present value is the sum of the equipment costs and consumer operating costs over the analysis period. This is the metric used to calculate the national financial benefit of implementing the new policy. The calculation of Net Present Value involves several steps.

National Equipment Cost ($NECst$) is calculated by the unit Equipment Cost ($ECst$) by multiplying the unit price of equipment by the total stock (S) in the year y .

$$NECst(y) = ECst(y) \times S(y)$$

National Operating Cost ($NOCst$) is calculated by multiplying the National Energy Consumption (NEC) by the energy price (P).

$$NOCst(y) = NEC(y) \times P$$

The net savings for each year come from the difference in costs between the efficient policy scenario and the baseline, represented as $NOCst(y)_{Base-Eff}$ and $NECst(y)_{Base-Eff}$. The Net Present Value (NPV) of a certain policy option is the sum of net savings for each year over a specific forecast period. Each year's savings are adjusted by the national discount rate to account for the time value of money.

$$NPV = \sum_y (NOCst(y)_{Base-Eff} + NECst(y)_{Base-Eff}) * (1 + DR_N)^{-(y-y_0)}$$

¹⁵ Lighting uses the Sigmoid survival function to calculate the survival probability

¹⁶ "E_MR_Topmotors_Market_Report_2020.Pdf," accessed January 10, 2025, https://topmotors.ch/sites/default/files/2021-03/E_MR_Topmotors_Market_Report_2020.pdf.

¹⁷ According to expert recommendations. For more details please refer to the Technical Appendix -Beverage Cooler

Where:

$NOCst(y)_{Base-Eff}$ is the difference in national operating costs between the efficient policy scenario and the baseline in the year y ;

$NECst(y)_{Base-Eff}$ is the difference in national energy costs between the efficient policy scenario and the baseline in the year y ;

DR_N is the National discount rate

y_0 is the starting year (the current year or the policy implementation year)

3. Energy Consumption Reduction

The National Perspective projects the total national outcome including both energy and carbon emission reduction. The national perspective calculations are called **National Energy Reduction (NER)** and **CO₂ Emission Reduction (CER)** calculations. The National Energy Reduction is the total primary (input) fossil fuel energy saved in efficiency policy scenarios versus the **baseline (also called BAU)**, which accounts for the stock and shipments of different appliances.

$$NER = NEC_{Base} - NEC_{Efficiency Policy}$$

NEC is the total energy consumption of the national stock of appliances in year y , the calculation of NEC is given by:

$$NEC(y) = \sum_{age} Stock(y, age) \times UEC(y - age)$$

Where the Unit Energy Consumption (UEC , kWh/year) of each cohort is determined based on the year of purchase ($y-age$), UEC would differ among the BAU and Efficiency policy scenarios for years after the implementation date of policies. The relationship between the BAU UEC and MEPS/BAT UEC is:

$$UEC_{Efficiency policy} = UEC_{Base} \times Efficiency policy / Eff_{Base}$$

Apart from calculating National Energy Savings, Mepsy also estimates the Primary Energy Consumption (total inputs of fossil fuel energy), which is the key indicator of national utility and environmental impacts. Primary Energy Reduction (PER) is calculated from the national energy reduction by factoring in the electricity generation fuel mix, and transmission and distribution losses. The formula for PER is:

$$PER = \frac{NER}{1 - TD} \times HR$$

Where TD is the percentage of energy lost in transmission and distribution, and HR is the heat rate.

4. Carbon Dioxide Emission Reduction

Finally, CO₂ Emission Reduction (CER) is calculated from energy reduction, by applying emission factors (EF in MtCO₂/TWh = kgCO₂/kWh) to the national energy reduction according to:

$$CER = \frac{NER}{1 - TD} \times EF$$

Annex: 162 Country List

COUNTRY	ISO A3	REGION
Albania	ALB	Southern Europe
Algeria	DZA	Northern Africa
Angola	AGO	Middle Africa
Argentina	ARG	South America
Armenia	ARM	Western Asia
Australia	AUS	Australia and New Zealand
Austria	AUT	Western Europe
Azerbaijan	AZE	Western Asia
Bahamas	BHS	Caribbean
Bahrain	BHR	Western Asia
Bangladesh	BGD	Southern Asia
Barbados	BRB	Caribbean
Belarus	BLR	Eastern Europe
Belgium	BEL	Western Europe
Belize	BLZ	Central America
Benin	BEN	Western Africa
Bhutan	BTN	Southern Asia
Bolivia	BOL	South America
Bosnia and Herzegovina	BIH	Southern Europe
Botswana	BWA	Southern Africa
Brazil	BRA	South America
Brunei Darussalam	BRN	South-Eastern Asia
Bulgaria	BGR	Eastern Europe
Burkina Faso	BFA	Western Africa
Burundi	BDI	Eastern Africa
Cambodia	KHM	South-Eastern Asia
Cameroon	CMR	Middle Africa
Canada	CAN	Northern America
Cape Verde	CPV	Western Africa
Central African Republic	CAF	Middle Africa
Chad	TCD	Middle Africa
Chile	CHL	South America
China	CHN	Eastern Asia
Colombia	COL	South America

Comoros	COM	Eastern Africa
Congo	COG	Middle Africa
Congo, Dem. Rep. of the	COD	Middle Africa
Costa Rica	CRI	Central America
Côte d'Ivoire	CIV	Western Africa
Croatia	HRV	Southern Europe
Cyprus	CYP	Western Asia
Czech Republic	CZE	Eastern Europe
Denmark	DNK	Northern Europe
Djibouti	DJI	Eastern Africa
Dominican Republic	DOM	Caribbean
Ecuador	ECU	South America
Egypt	EGY	Northern Africa
El Salvador	SLV	Central America
Equatorial Guinea	GNQ	Middle Africa
Eritrea	ERI	Eastern Africa
Estonia	EST	Northern Europe
Ethiopia	ETH	Eastern Africa
Fiji	FJI	Melanesia
Finland	FIN	Northern Europe
France	FRA	Western Europe
French Polynesia	PYF	Polynesia
Gabon	GAB	Middle Africa
Gambia	GMB	Western Africa
Georgia	GEO	Western Asia
Germany	DEU	Western Europe
Ghana	GHA	Western Africa
Greece	GRC	Southern Europe
Guatemala	GTM	Central America
Guinea	GIN	Western Africa
Guinea-Bissau	GNB	Western Africa
Guyana	GUY	South America
Haiti	HTI	Caribbean
Honduras	HND	Central America
Hong Kong, China (SAR)	HKG	Eastern Asia
Hungary	HUN	Eastern Europe
Iceland	ISL	Northern Europe
India	IND	Southern Asia
Indonesia	IDN	South-Eastern Asia
Iran, Islamic Rep. of	IRN	Southern Asia
Ireland	IRL	Northern Europe

Israel	ISR	Western Asia
Italy	ITA	Southern Europe
Jamaica	JAM	Caribbean
Japan	JPN	Eastern Asia
Jordan	JOR	Western Asia
Kazakhstan	KAZ	Central Asia
Kenya	KEN	Eastern Africa
Korea, Rep. of	KOR	Eastern Asia
Kuwait	KWT	Western Asia
Kyrgyzstan	KGZ	Central Asia
Lao People's Dem. Rep.	LAO	South-Eastern Asia
Latvia	LVA	Northern Europe
Lebanon	LBN	Western Asia
Lesotho	LSO	Southern Africa
Lithuania	LTU	Northern Europe
Luxembourg	LUX	Western Europe
Macau	MAC	Eastern Asia
Macedonia, TFYR	MKD	Southern Europe
Madagascar	MDG	Eastern Africa
Malawi	MWI	Eastern Africa
Malaysia	MYS	South-Eastern Asia
Maldives	MDV	Southern Asia
Mali	MLI	Western Africa
Malta	MLT	Southern Europe
Mauritania	MRT	Western Africa
Mauritius	MUS	Eastern Africa
Mexico	MEX	Central America
Moldova, Rep. of	MDA	Eastern Europe
Mongolia	MNG	Eastern Asia
Morocco	MAR	Northern Africa
Mozambique	MOZ	Eastern Africa
Namibia	NAM	Southern Africa
Nepal	NPL	Southern Asia
Netherlands	NLD	Western Europe
New Zealand	NZL	Australia and New Zealand
Nicaragua	NIC	Central America
Niger	NER	Western Africa
Nigeria	NGA	Western Africa
Norway	NOR	Northern Europe
Oman	OMN	Western Asia
Pakistan	PAK	Southern Asia

Panama	PAN	Central America
Papua New Guinea	PNG	Melanesia
Paraguay	PRY	South America
Peru	PER	South America
Philippines	PHL	South-Eastern Asia
Poland	POL	Eastern Europe
Portugal	PRT	Southern Europe
Romania	ROU	Eastern Europe
Russian Federation	RUS	Eastern Europe
Rwanda	RWA	Eastern Africa
Saudi Arabia	SAU	Western Asia
Senegal	SEN	Western Africa
Sierra Leone	SLE	Western Africa
Singapore	SGP	South-Eastern Asia
Slovakia	SVK	Eastern Europe
Slovenia	SVN	Southern Europe
Solomon Islands	SLB	Melanesia
South Africa	ZAF	Southern Africa
Spain	ESP	Southern Europe
Sri Lanka	LKA	Southern Asia
Sudan	SDN	Northern Africa
Suriname	SUR	South America
Swaziland	SWZ	Southern Africa
Sweden	SWE	Northern Europe
Switzerland	CHE	Western Europe
Syrian Arab Republic	SYR	Western Asia
Tajikistan	TJK	Central Asia
Tanzania, U. Rep. of	TZA	Eastern Africa
Thailand	THA	South-Eastern Asia
Togo	TGO	Western Africa
Trinidad and Tobago	TTO	Caribbean
Tunisia	TUN	Northern Africa
Turkey	TUR	Western Asia
Turkmenistan	TKM	Central Asia
Uganda	UGA	Eastern Africa
Ukraine	UKR	Eastern Europe
United Arab Emirates	ARE	Western Asia
United Kingdom	GBR	Northern Europe
United States	USA	Northern America
Uruguay	URY	South America
Uzbekistan	UZB	Central Asia

Venezuela	VEN	South America
Viet Nam	VNM	South-Eastern Asia
Yemen	YEM	Western Asia
Zambia	ZMB	Eastern Africa
Zimbabwe	ZWE	Eastern Africa



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