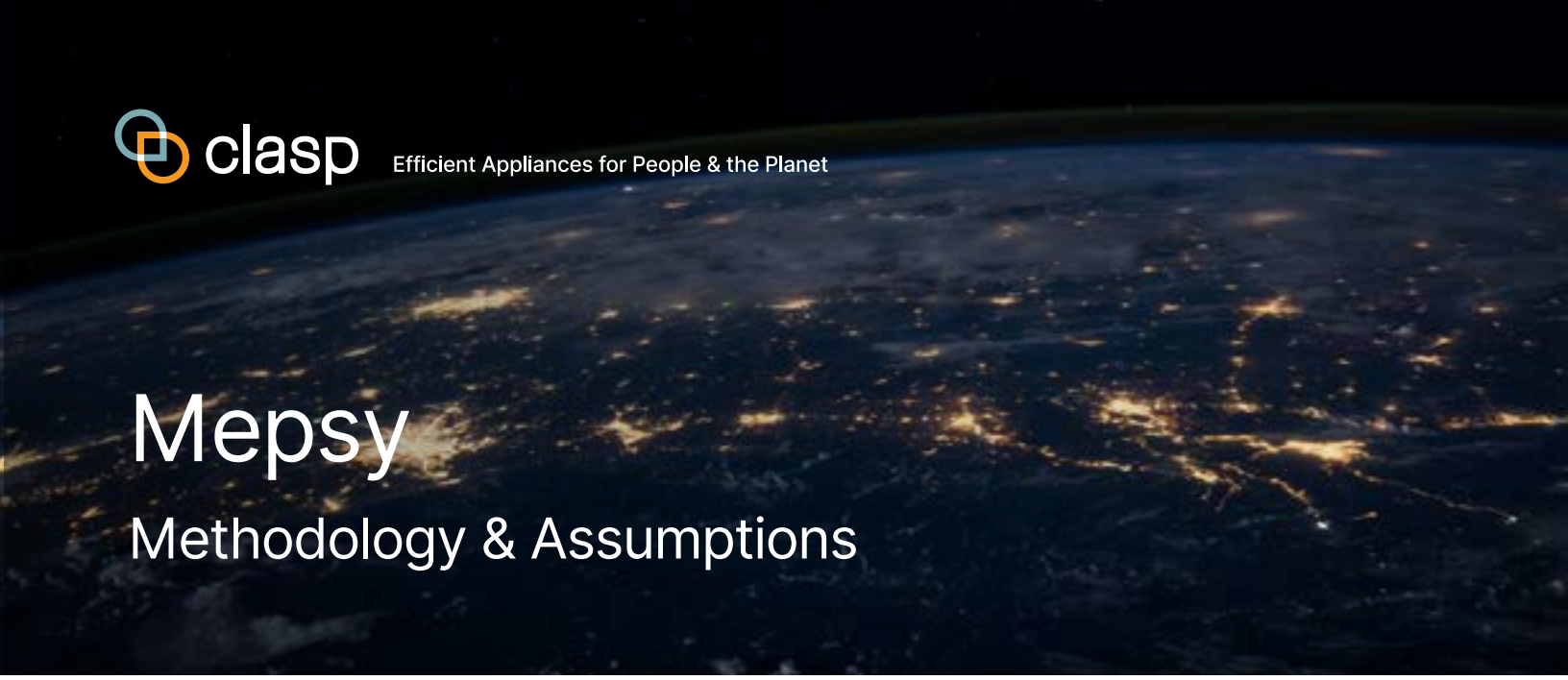


clasp Efficient Appliances for People & the Planet

Mepsy

Methodology & Assumptions

This document describes the methdology and underlying assumptions for Mepsy: The Appliance & Equipment Climate Impact Calculator.

ABOUT MEPSY

Mepsy is an online tool to model the impacts of energy and carbon reduction policies for appliances and equipment. Mepsy's dynamic, user-friendly interface is designed to help policymakers, analysts, funders and other stakeholders identify and prioritize global and national efficiency policy opportunities and project the impacts of different policy options. The tool is free to use, and the underlying product data is updated regularly from multiple data sources.

The Mepsy model is based on a bottom-up stock accounting method that accumulates unit sales and retirements to estimate the number of appliances in use in each country (the stock), and multiplies it by the average unit energy consumption (UEC) under different policy scenarios to derive the national final energy consumption. The UEC reflects the efficiency and usage of products and can be adjusted by the user to reflect the impact of efficiency standards. The national energy consumption is finally multiplied by country-specific factors reflecting the transmission and distribution losses of the electric grid, the heat rate (efficiency of fossil fuel power plants), and grid emission factor (the CO_2 intensity of the electricity generation mix) to determine CO_2 emissions and primary energy consumption. The model is pre-loaded with data that allows the user to run analyses for 162 countries.

METHODOLOGY

The calculation methodology has been used by CLASP and other organizations for decades to evaluate the potential impact of appliance and equipment energy efficiency policies around the world. Unique among efficiency policy tools, Mepsy is free to use and is regularly updated with the latest research on product shipments and efficiency. 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 product are not available, 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. Future and past shipments are extrapolated based on recent trends.

MODEL DATA AND ASSUMPTIONS

Below are general model data sources and assumptions for the following technologies: air conditioning, space heating, refrigerator-freezers, ceiling fans and portable fans, electric motors, televisions, lighting beverage coolers, distribution transformers, and residential hot water heaters. Frequently asked questions and their answers can be found here.

GENERAL

- **Transmission & distribution losses:** US Energy Information Administration (EIA), "International", Data for Electricity Consumption and Distribution losses, 2018 data or earlier.
- **Heat rate:** Various sources including ADB, World Efficiency Council, GE, Lazard, BP, World Bank, and EIA, 2010-2019.
- **Grid emission factor:** International Financial Institutions Technical Working Group (IFI TWG) "Harmonized Grid Emission Factor Data", 2019.

SPACE HEATING

- **Representative unit:** technology-dependent capacity from Pezzutto et Al. (2019). Assessment of the space heating and domestic hot water market in Europe—Open data and results. Energies, 12(9), 1760: 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, except for the following countries: USA, Canada ASHP: 10 kW; USA, Canada GSHP: 15 kW, USA condensing and non-condensing boiler/furnace (CB & NCB) 30 kW; USA ER: 10 kW; Russia ER: 5 kW; India ER: 5 kW; India CB & NCB: 15 kW; China ER: 6.5 kW.
- **Shipments:** Stocks obtained directly from national sources for each technology: Pezzutto in the EU; Hu et Al. (2017) and National Bureau of Statistics of China; US Energy Information Administration; Bhat & Rubab (2008) and Sivasakthivel et Al. (2012) in India; Natural Resources Canada); Pezzutto extrapolated to other countries based on heating degree days.
- **Efficiency:** BAU coefficients of performance (COPs) from Pezzutto: ASHP: 3.65, GSHP: 4.58, CB: 0.92; NCB 0.82; ER 0.99; MEPS based on CB replacing NCB and 50% of ASHP with 15% higher efficiency; BAT based on ASHP replacing 25% of ER and 40% of boilers; and 50% of ASHP with 15% higher efficiency.
- **Usage:** technology-dependent equivalent full-load hours from Pezzutto (2019), extrapolated to other countries based on population-weighted HDD (KAPSARC Global Degree Days Database)
- **Average Lifetime:** 25.4 years based on US data for gas boilers in Franco et Al., "Estimating Residential Appliance Lifetime for Energy Efficiency Policy Analysis" 2018.

AIR CONDITIONING

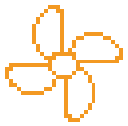
- **Representative unit:** Residential air conditioner. Size varies by country depending on ratio of 3.5 kW and 7 kW systems, from United for Efficiency (U4E). "Country Savings Assessments", September 2019.
- **Shipments:** Euromonitor, 2020.
- **Efficiency:** Varies by country depending on ratio of fixed- and variable-speed systems across the 3.5 kW and 7 kW systems, from United for Efficiency (U4E). "Country Savings Assessments", September 2019. UEC in OECD countries based on regression of cooling degree days. Net Zero Hero (NZH) UECs are set at 50% of the BAU levels to align with the ambitious targets outlined in the Net Zero Hero report.
- **Usage:** Depends on climate zone of most populous city in each country, per U4E, "Model Regulation Guidelines: Energy-efficient and Climate-friendly Air Conditioners", September 2019, p. 20.
- **Average Lifetime:** Varies by country depending on ratio of 3.5 kW and 7 kW systems. 8.4 years for 3.5 kW and 18.0 years for 7 kW systems based on US data for room and central AC in Lutz et Al., "Using National Survey Data to Estimate Lifetimes of Residential Appliances", 2011.

REFRIGERATOR-FREEZER

- **Representative unit:** Residential refrigerator-freezer, with volume that varies by region, as estimated in U4E, "U4E Country Savings Assessments: Methodology and Assumptions", 2019, p. 3.
- **Shipments:** Euromonitor, 2020 for all-refrigerators and refrigerator-freezers
- **Efficiency:** BAU, Global Benchmark UECs vary by region, as estimated in U4E, "U4E Country Savings Assessments: Methodology and Assumptions", 2019, p. 3. Net Zero Hero (NZH) UECs are set at 50% of the BAU levels to align with the ambitious targets outlined in the Net Zero Hero report.
- **Usage:** continuous
- **Average Lifetime:** 17.7 years worldwide, based on US data in Lutz et Al., "Using National Survey Data to Estimate Lifetimes of Residential Appliances", 2011.

ELECTRIC MOTORS

- **Representative unit:** 11.4 kW avg. 4-pole motor for centrifugal pumps and compressors based on stock-weighted worldwide average of medium (0.75-375 kW) and large (>375 kW) motors from Waide & Bruner, "Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems", IEA Energy Papers, No. 2011/07; 7.1 kW avg. for fans
- **Shipments:** Omdia shipments for centrifugal pumps, compressors, and industrial fans, 2020; data for 2018–2023.
- **Efficiency:** Meeting the MEPS requirements as indicated in U4E, "Accelerating the Global Adoption of Energy-Efficient Electric Motors and Motor Systems", September 2014, p. 34; For countries with no standards, 20% higher losses than IE1. Global Benchmark sets at IE3. For countries already meeting IE3, Global Benchmark sets UEC at half-way between IE3 and IE4); Net Zero Hero (NZH) UECs are set at 50% of the BAU levels to align with the ambitious targets outlined in the Net Zero Hero report.
- **Usage:** Running at 60% average capacity for 4500 hours annually, based on CLASP inhouse experts' comments.
- **Average Lifetime:** 12 years https://topmotors.ch/sites/default/files/2021- 03/E_MR_Topmotors_Market_Report_2020.pdf



CEILING AND PORTABLE FANS

- **Representative unit:** Portable fan: 16 in/400 mm; Ceiling fan: 48 or 52 in/1200 or 1300 mm
- **Shipments:** Euromonitor, 2020; data for 2005-2024
- **Efficiency:** BAU based on avg. service value in country or, if not available, latest MEPS level (e.g., 3.1 m3/min/W for ceiling fans in India; 2 m3/min/W for ceiling fans in USA); Global Benchmark scenario uses 4 m3/min/W for ceiling fans, 1.08 m3/min/W for portable (for countries where BAU is higher than 4 m3/min/W for ceiling and 1.08 m3/min/W for portable, Global Benchmark is half-way between BAU and Net Zero Hero scenario (NZH)); NZH: 6 m3/min/W for ceiling, 1.7 m3/min/W for portable.
- **Usage:** National studies in US, EU, China, Brazil, India, and Indonesia extrapolated to other countries in region based on cooling degree days.
- **Average Lifetime:** 11 years for ceiling and 10 years for portable for most countries, with some differences in South Asia, Southeast Asia, and North America based on studies in India, Indonesia, and United States.

TELEVISION

- **Representative unit:** Region-average size and ratio of high definition (HD) versus ultra high definition (UHD), from Omdia 2020, data for 2020
- **Shipments:** Omdia 2020, data for 2010–2024
- **Efficiency:** BAU: average performance of models in country databases, weighted by distribution of shipments at that screen size in the region and country studies; Global Benchmark: 2021 EU MEPS levels (1.1 EEI for UHD, 0.9 EEI for HD) applied to region average size and HD/UHD ratio (for countries where BAU is higher than forthcoming EU 2021 MEPS levels, Global Benchmark is half-way between BAU and NZH); Net Zero Hero: 11-13% better than EU 2023 MEPS levels (0.8 EEI for UHD, 0.65 EEI for HD)
- **Usage:** Regional test procedures and studies, but typically 4-5 hours in on mode, except for Australia where the test method assumes 10 (Energy Ratings Australia, "Televisions – AS/NZS 62087.2.2 Table Columns", accessed from "Product: Televisions" on February 2, 2021).
- **Average Lifetime:** 7–14 years based on national studies in the US, India, South Africa and the EU (Urban et Al., p. 46: 2017 stock estimate divided by shipments from Omdia above; "Kiran et Al., "A multivariate discrete grey model for estimating the waste from Mobile Phones, Televisions, and Personal Computers in India", Journal of Cleaner Production, forthcoming; Stats SA, "General Household Survey, 2019", p. 177 for TV penetration, divided by past shipments to estimate lifetime; European Commission, "Commission Staff Working Document Impact Assessment for Electronic Displays", January 10, 2019, p. 20.)

RESIDENTIAL HOT WATER HEATERS

- **Representative unit:** Five residential hot water heater categories—(1) Heat pump, (2) Electric storage heater, (3) Electric instant heater, (4) Gas storage heater – condensing & non-condensing, (5) Gas instant heater – condensing & non-condensing
- **Shipments:** BSRIA's World Market for Water Heating & Solar Thermal Report 2019-2024 and World Renewables – Heat Pump Market, both from 2020. Market volume trajectory for 21 countries.
- **Efficiency scenarios:**
    - **Business-As-Usual**, Coefficient of Performance (COP) is defined from the estimated efficiencies reported in Liu et al.'s publication, "Environmental life cycle assessment and techno-economic analysis of domestic hot water systems in China", reported for Region 3 (hot summer/cold winter). Standing loss assumptions are derived from IEA 4E's Benchmarking Report for domestic gas and electric, storage, instantaneous and heat pump water heaters.
    - **Efficiency Policy**, represents installations of high efficiency Heat Pump (COP increase from 225% to 237%) and transition from Non-condensing Gas Heater to Condensing Gas Heater (COP increase from 85% to 96%).
    - Best Available Technology, represents phase-out of Gas Storage Heater to High Efficiency Heat Pump (COP increase from 96% for condensing and 87.5% for non-condensing to 237%)
- **Usage:** Hot water needs are estimated from the average daily household hot water consumption, the average inlet water temperature, and the average set temperature—two hot water need profiles are defined to group countries.
- **Average lifetime:** (1) Heat pump: 15 years, (2) Electric storage heater: 8 years, (3) Electric instant heater: 8 years, (4) Gas storage heater – condensing & non-condensing: 12 years, (5) Gas instant heater – condensing & non-condensing: 8 years.

DISTRIBUTION TRANSFORMERS

- **Representative unit:** Three categories of Distribution Transformers—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.
- **Shipments:** Industry stakeholder input for 2008 to 2018 period, providing annual capacity and unit count of new and total distribution transformers installation for 58 economies. In order to establish national capacities for all 162 countries included in Mepsy, mapping of capacity profile is done for the missing countries—setting similar capacity profile from the available 58 major economies based on geographical proximity and country size. To finalize the mapping process, filling unavailable data for the remaining 104 countries, proportional assignment of capacities was done based on the energy consumption ratio obtained from the net electricity consumption projections released in the IEA's 2014 World Energy Outlook.
- **Efficiency scenarios:** U4E Levels defined in the published model regulation for distribution transformers were used as reference to determine typical energy losses of the scenarios As for the baseline assumption, the model refers to the efficiency equations published as part of the SEAD Initiative Analyzes Potential for Alignment of Distribution Transformer Efficiency Levels program (https://www.clasp.ngo/research/all/sead-initiative-analyzes-potential-for-alignment-of-distribution-transformer-efficiency-levels/), SEAD Distribution Transformers Report Part 3: Energy Efficiency Class Definitions (https://www.clasp.ngo/wp-content/uploads/2021/01/Distribution-Transformers-Internationally-Comparable-Test-Methods-and-Efficiency-Class-Definitions-Part-3-Energy-Efficiency-Class-Definitions.pdf).
    - **Business As Usual** as baseline, reflecting the estimated current efficiency level of distribution transformers market, at SEAD Non-Evaluation level for countries without MEPS present, and at SEAD Tier 2 for countries with MEPS in-force;
    - **Efficiency Policy**, representing implementation of MEPS requirements to efficiency level equivalent to U4E Level 1;
    - **Best Available Technology**, for adoption of high efficiency units at U4E Level 2 efficiency rating.
- **Usage:** continuous, 8760 hours per year—365 days per year, 24 hours per day
- **Average Lifetime:** 20-35 years, assigned based on category and country grouping (based on industrial activity—less industrialized (20-25 years), normal (25-30 years), and industrialized (30-35 years)

BEVERAGE COOLERS

- **Representative unit:** 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. The representative unit is assumed to be configured without energy management device, hence requiring manual setting of target temperature and manual switch off.
- **Shipments:** Grand View Research, "Commercial Refrigeration Equipment Market Size, Share & Trends Analysis Report By Product, By Application, By System Type (Self-contained, Remotely Operated), By Capacity, By Region, And Segment Forecasts, 2015-2027"
- **Efficiency scenarios:** Annual unit energy consumption estimates are based on "ISO 23593 - Refrigerated display cabinets" standard test method as reference, with target storage temperature assumed to be at 3.5°C (K1) for all countries, and ambient temperatures at 25°C & 60% RH (CC1) in "cool ambient" countries, generally the Global North, and 32°C & 65% RH (CC2) in "warm ambient" countries, generally the Global South.
  - **Business As Usual**, reflecting the best estimates for typical energy use of 7 kWh/day for K1-CC1 and 10 kWh/day for K1-CC2;
  - **Efficiency Policy**, representing reduction by at least 30% from deployment of new intermediate efficiency units, at 5 kWh/day for K1-CC1 and 6.5 kWh/day for K1-CC2;
  - **Best Available Technology**, reduction by at least 60% against the baseline from deployment of new high efficiency units, at 1.7 kWh/day for K1-CC1 and 3.1 kWh/day for K1-CC2
- **Usage:** 365 days per year
- **Average Lifetime:** 8 years

LIGHTING

- **Representative unit:** Seven lighting technologies to cover the full range – incandescent / halogen, compact fluorescent lamps (CFL), linear fluorescent lamps (LFL), high intensity discharge (HID) lamps, and three light emitting diode (LED) retrofits for these conventional sources: general service LED lamps, tubular LED lamps and outdoor LED lamps. Efficacy, wattage and lifetime values are defined for each technology.
- **Shipments:** Guidehouse. Market Data: Energy Efficient Lighting for Commercial Markets, published 1Q 2019, Market Data: Industrial and High Bay Lighting, published 4Q 2019, Market Data: Outdoor Lighting Systems, published 3Q 2020, Market Data: Residential Energy Efficiency Lighting and Lighting Controls, published 1Q 2021. Intra-sectoral shipment apportionment made based on UNEP U4E global market analysis.
- **Efficiency scenarios:** (1) Global Benchmark levels to phase-out conventional lighting technologies (i.e., non-LED); (2) Net Zero Hero levels to evaluate high energy savings scenario with high-efficacy LED lamps (all conventional lighting technologies phased-out); (3) the African Lighting Amendment to the Minamata Convention on Mercury to phase-out CFL and LFL only.
- **Efficiency, wattage, sectoral operating hours, and lamp lifetime:**

TECHNOLOGY	EFFICACY	WATTAGE	OPERATING HOURS		LIFETIME	
			DOMESTIC	PROFESSIONAL	DOMESTIC	PROFESSIONAL
	LUMENS/ WATT	WATTS	HOURS	HOURS	YEARS	YEARS
Incandescent/Halogen	12	70	1.5	10	2.2	0.3
Compact Fluorescent	55	15	3	10	6.4	1.9
LED General Service	varies	varies	3	10	13.7	4.1
Linear Fluorescent	60	40	8	10	6.2	4.9
LED Tubular	varies	varies	8	10	13.7	11.0
High Intensity Discharge	90	135	11	11	5.0	5.0
LED Outdoor	varies	varies	11	11	12.5	12.5

COMPLIANCE

- **Compliance feature:** The compliance feature in the Mepsy provides a more accurate picture on energy and CO2 reduction predictions, by incorporating estimated compliance rate with policy.
- **Compliance rate:** Varies between Full Compliance (100%) and Low (50%), and initially pre-set at Full Compliance. The lowest range of 50% compliance rate was estimated to account that some of the products on the market are compliant with proposed policies even in cases when no compliance processes nor policy enforcement are in place.
- **Compliance rate change:** The tool is pre-set with the same compliance rate for the policy analysis period - between Policy Effective Year and Analysis End Year - under assumption that estimated compliance rate in the market will not change. However, the user can choose different estimated compliance rate for the Analysis End Year as compared to Policy Effective Year if they anticipate improvements or changes in policy enforcement. The rate of change in the compliance rate is assumed incremental between the two years.
- **Impacts:** The same compliance adjustment is incorporated in BAT or Net Zero Hero and Efficiency Policy or Global Benchmark scenarios for CO_2 and energy reduction estimates.