United for Efficiency Country Savings Assessments Methodology and Assumptions

COOLING			LIGHTING	EQUIPMENT	
Residential Refrigerators	Commercial Refrigeration	Room Air Conditioners	All Lighting	Industrial Electric Motors	Distribution Transformers

BACKGROUND

United Nations Environment Programme's (UNEP) United for Efficiency (U4E) Country Savings Assessments aim to show the financial, energy, and environmental benefits of energy-efficient lighting, appliances and equipment. The Country Savings Assessments have been produced by U4E since 2012 and continuously updated for expanded scope, improved methodology and additional data collected. The assessment includes energy-efficient lighting, appliances, and equipment in 156 developing countries and emerging economies. In 2021-22, an additional analysis was undertaken for commercial refrigeration products and the underlying assumptions in the analyses for the original products were updated. The Country Saving Assessments are funded by the Global Environment Facility (GEF), the Clean Cooling Collaborative and the United Kingdom's Department for Environment Food and Rural Affairs. This document describes the approach undertaken for those analyses.

POLICY SCENARIOS

For each product, the analysis considers three different scenarios:

- **Business As Usual (BAU):** Assumes that no MEPS are introduced and that the efficiency of products in the market continues to develop in line with historical trends in the absence of regulation.
- **Minimum Ambition:** In which MEPS are introduced in line with the basic requirements of the Model Regulation Guidelines.
- **High Ambition:** In which more stringent MEPS are implemented in line with the highest levels proposed in the guidelines.

Policy implementation date: It is assumed policies are implemented in 2022 but only come fully into force by 2023. Whilst this is not a realistic time period for policy development and implementation, it demonstrates potential in a clear and consistent manner and minimizes uncertainty by using the most accurate data i.e. current.

PRESENTATION OF RESULTS

The savings potential is calculated based on the difference between total electricity consumption in the Ambition scenarios and that in the BAU scenario. Details of the method for calculating the electricity consumption for each product are described below. Other calculations presented in the results include:

1. Electricity use equivalence to the annual generation of power plants based on the assumption that a plant produced 4,380 MWh per year for each MW of installed capacity.
2. CO_2 emissions reductions use equivalence to the annual emissions from passenger cars assuming 1.8 tonnes of emissions/car/year.
3. Other benefits achieved in the Minimum and High Ambition scenarios are:
    a. Increased grid connections households (if a significant portion of the population lives off-grid, assumes 2,000 kWh/year/newly electrified household);
    b. Reduced electricity subsidies (if the country subsidizes electricity tariffs);
    c. Reduced greenhouse gas impact from the use of more environmentally friendly refrigerants with a lower Global Warming Potential;

Results are presented in an overview report for all six analyses and then product reports:

- **Cooling**: the savings potential from efficient residential refrigerators, commercial refrigeration and room air conditioners.
- **Lighting**: the savings potential from efficient lighting in the residential, commercial and outdoor sectors.
- **Equipment**: the savings potential from efficient industrial electric motors and power distribution transformers.

ASSUMPTIONS AND APPROACHES FOR PRODUCTS CATAGORIES

Cooling product: Residential Refrigerators

Product type: Combined fridge/freezer (configuration specified in Table 1)

Approach: The analysis uses the UNEP U4E Stock Model to forecast the impacts of implementing policies that improve the energy efficiency of new household refrigerators. This is a bottom-up approach, in which the potential energy savings are obtained by defining the average unit energy consumption (UEC) of new models in different scenarios and estimating the stock and sales of the refrigerators in the assessment country over time. From this, the financial and environmental savings and benefits are calculated by using the countries' macroeconomic indicators and other associated data.

Ownership over time: The assumed growth of refrigerator ownership in the model is based on the theoretical relationship between household ownership and macroeconomic indicators such as household income, urbanization and grid connection. As these increase from present day until the year 2040, so does the assumed rate of household refrigerator ownership. The total installed stock and annual sales are built from this ownership rate using the bottom-up stock model.

Product lifetime: 15 years – consistent with best available market information.

Efficiency scenarios:
- **Business As Usual:** Based on best available market data.
- **Minimum Ambition Scenario:** Based on MEPS levels defined in the United for Efficiency Model Regulation Guidelines.
- **High Ambition Scenario**: Based on the Top-tier performance levels in the United for Efficiency Model Regulation Guidelines.

In all scenarios, the energy efficiency of new products improves at 1 per cent per year.

Where good quality market-specific data has been provided by U4E stakeholders, this is used to set the typical product type and energy consumption of domestic refrigerators in the BAU analysis. In the absence of such data, assumptions for each product have been developed based on the underlying research that informed the model regulation guidelines themselves. In those cases, the following default assumptions about typical product size and consumption are used:

Table 1 Assumptions for residential refrigerator characteristics in 2019

	Volume			UEC (kWh/y) - 2019		
Region	Volume of refrigerator compartment	Volume of freezer compartment	Adjusted volume	Business As Usual (kWh/y)	Minimum Ambition UEC (kWh/y)	High Ambition UEC (kWh/y)
ASEAN	165	85	357	342	259	129
China	157	78	333	228	177	127
LAC	188	82	373	471	263	131
MENA	245	85	437	485	278	139
Oceania	210	90	413	398	273	136
Other Regions Income* <$10,000	188	82	373	607	263	131
Other Regions Income* >$10,000	188	82	373	437	263	131
South Asia	165	85	357	342	259	129
Sub-Saharan Africa	134	76	305	340	247	123
Türkiye	200	100	426	347	276	138
Ukraine	188	82	373	363	263	131

** Annual income based on 2019 GDP per capita*
*** Countries with existing MEPS in place assume that new sales meet those MEPS. Where those MEPS are in line with or exceed the MEPS in the Minimum Ambition Scenario, the Minimum Ambition Scenario is assumed to be halfway between the local MEPS and High Ambition Scenario.*

Cooling product: Commercial Refrigeration

Product type: A mix of retail display cabinets (both remote and integral), storage cabinets, drinks cabinets (beverage coolers), ice-cream freezers, vending machines and scooping cabinets.

Approach: The analysis uses the UNEP U4E Stock Model to forecast the impacts of implementing policies that improve the energy efficiency of new commercial refrigerators. This is a bottom-up approach, in which the potential energy savings are obtained by defining the average unit energy consumption (UEC) of new models in different scenarios and estimating the stock and sales of each refrigerator type in the assessment country over time. From this, the financial and environmental savings and benefits are calculated by using the countries' macroeconomic indicators and other associated data.

Stock over time: The assumed growth of commercial refrigerator stock in the model is based on a theoretical relationship between commercial refrigeration stock, population and GDP per capita, derived from regression analyses of more than 20 markets where such data exists. As population and wealth increase from present day until the year 2040, so does the assumed stock of commercial refrigerators based on a best fit s-curve of the available data. The market share of the different types of commercial refrigerator in the stock is assumed to be in line with local market data where available. In most cases, however, local data is not available and then a weighted-average of other similar markets from where data is available is used. Data and expert opinion suggests the share of the different product types changes as income levels rise. This is captured in the analysis using by comparing the country's GDP/Capita against a sliding scale of weightings of typical shares in low, mid and high-income economies.

Product lifetime: 8-9 years depending on product and based on the best available market information.

Efficiency scenarios:

- **Business As Usual:** Assumes that baseline energy consumption for each product type and subcategory aligns with the least stringent MEPS that have been introduced in all markets globally in the last 10 years. The typical product size is based on the best regional data from product databases in Australia, the EU and the USA.
- **Minimum Ambition Scenario:** Based on MEPS levels defined in the United for Efficiency Model Regulation Guidelines.
- **High Ambition Scenario**: Based on the high efficiency performance levels in the United for Efficiency Model Regulation Guidelines.

In all scenarios, the energy efficiency of new products improves at 0.5 per cent per year.

If good quality market-specific data is provided by U4E stakeholders, this is used to set the typical product type and energy consumption of specific products in the BAU analysis. In the absence of such data, the following default assumptions about typical product size and consumption are used:

Table 2 Assumptions for commercial refrigeration

	Capacity (TDA or vol)	BAU ave. AECadj (kWh/y)	Minimum Ambition ave. AECadj (kWh/y)	High Ambition ave. AECadj (kWh/y)
RDC	2.06-2.89 m^2	9,236-13,008	7,862-10,566	4,624-6,487
RSC	293-584 litres	2,841-4,068	2,368-3,415	1,008-1,590
RDC-BC	0.81-1.56 m^2	1,466-2,099	1,026-1,469	586-840
RDC-ICF	213-333 litres	1,384-1,897	1,065-1,459	532-729
RDC-SC ¬	0.66 m^2	16,448	11,119	5,560
RVM^	777 litres	3,577	2,630	1,315

***Notes**: ¬ no local data so Australia assumed as a proxy, ^ no local data so USA assumed as a proxy*
Ranges are the result of different shares of product sub-types (income driven) and typical size (region driven).

For all products, UECs are assumed to improve at 0.5% per year in all scenarios.

Cooling product: Room Air Conditioners

Product type: Room air conditioners, including portable, through the wall, window-mounted, and split systems; excluding secondary market. (Types specified in Table 3)

Approach: The analysis uses the UNEP U4E Stock Model to forecast the impacts of implementing policies that improve the energy efficiency of new room air conditioners. This is a bottom-up approach, in which the potential energy savings are obtained by defining the average UEC of new models in different scenarios and estimating the stock and sales of the room air conditioners in the assessment country over time. From this, the financial and environmental savings and benefits are calculated by using the countries' macroeconomic indicators and other associated data.

Growth rate: The assumed growth of room air conditioner sales in the model is based on two approaches. For the residential sector, it uses the theoretical relationship between household ownership and macroeconomic indicators such as household income and grid connection and also the impact of the local climate. For the commercial sector, a similar approach is taken informed by analysis by the IEA and other data sources but using forecasts of commercial electricity demand instead of household income. As each of these increase from present day until the year 2040, so does the assumed rate of ownership. The total installed stock and annual sales are built from this ownership rate using the bottom-up stock model.

Product lifetime: 12 years – consistent with best available market information.

Efficiency scenarios:

- **Business As Usual:** The Energy efficiency of the underlying technology improves at 1 per cent per year. Further, an increasing market share of variable speed models is assumed to improve overall efficiency at an additional 2% per year until new sales are entirely from that product type.
- **Minimum Ambition Scenario**: Based on MEPS levels defined in the United for Efficiency Model Regulation Guidelines.
- **High Ambition Scenario**: Based on the Top-tier performance levels in the United for Efficiency Model Regulation Guidelines.

Where good quality market-specific data has been provided by U4E stakeholders, this is used in the analysis. In the absence of such data, assumptions for each product have been developed based on the underlying research that informed the model regulation guidelines themselves. The typical product size and performance is estimated using market data on the share of new sales by capacity and technology type (fixed and variable speed models). Country specific data is used for this analysis where available and where not, proxies are used from regional data.

For room air conditioners, this process leads to the following assumptions about typical product size and consumption for countries without specific local data:

Table 3 Assumptions for typical room air conditioners characteristics in 2019

	BAU UEC (kWh/y) - 2019				Minimum Ambition UEC (kWh/y)		High Ambition UEC (kWh/y)	
Climate class	3.5 kW fixed-speed	3.5 kW variable-speed	7 kW fixed-speed	7 kW variable-speed	3.5 kW	7 kW	3.5 kW	7 kW
0A	3028	2234	6546	4831	1774	4128	1367	2890
1A	2158	1619	4671	3502	1315	3021	1014	2151
2A	1027	760	2220	1644	613	1429	470	994
3A	549	415	1187	897	338	775	260	552
0B	2517	1769	5439	3825	1543	3549	1203	2535
1B	1996	1391	4317	3004	1185	2717	928	1954
2B	1802	1417	3895	3068	1180	2690	933	1961
3B	654	498	1415	1078	400	918	313	664
3C	222	160	481	346	126	297	96	202
4A	633	486	1370	1050	394	908	307	653
5A	417	312	901	674	249	580	193	409
6A	102	74	220	160	58	136	44	94
4B	933	731	2015	1580	605	1374	472	991
5B	688	548	1488	1185	465	1042	365	767
6B	329	239	711	517	188	444	188	444
7	176	129	380	279	102	237	102	237
8	131	97	283	210	77	180	77	180

Lighting

Product type: On-grid lighting including residential, professional and outdoor

Approach and growth rate: This is a mixed model using a bottom-up approach to estimate the stock of each lamp type in 2018 and a top-down analysis to project electricity use into the future. The model starts from the regional stock estimates for the individual lamp types in 2018 from 3 separate sources validated against market data for countries where that is available. This stock is allocated to the residential, commercial and outdoor sectors based on best available market data and expert review. This stock data is then used to estimate light service or demand in 2018 (teralumen-hours) based on estimates of typical wattage and operating hours in each sector.

Lighting service is then projected forward to 2040 using the International Energy Agency's (IEA) World Energy Outlook projection of electricity demand for commercial and residential buildings (which is a floor space projection), which takes the global lighting service from 133,500 Tlm-hr/yr in 2018 to 199,800 Tlm-hr/yr in 2040, an increase of 50 per cent in lighting service demand.

The model then runs three scenarios:

- **Business As usual:** markets transition to more efficient lamps using projections derived from real data on current trends and expert opinion. Existing local MEPS are included in the baseline scenario for those countries that have them.
- **Minimum Ambition Scenario**: sees the immediate phasing out of Incandescent, Halogen, T8 and T12 Linear Fluorescent tubes and High Intensity Discharge (HID) lamps for indoor use. Stocks are replaced in line with product lifetime and usage rates in each country.
- **High Ambition Scenario:** In addition to the lamps phased out in the policy scenario, Compact Fluorescent Lamps (CFL), T5 Linear Fluorescent Tubes and HID lamps for outdoor use are also removed from the market using the same methodology.

Finally, the changing share in stock allows average efficacy values to be calculated for each country and sector over time, and these are then divided back into the lumen service stock model to calculate the electricity demand to provide that lighting service.

Product characteristics (including typical wattage, efficacy, lifetime, operating hours): varies depending on both the lighting technology; General Service Lamps (GSL; incandescent, compact fluorescent lamp and halogen), LFL (linear fluorescent lamps), HID, LED and the application (residential, professional and outdoor). Assumptions are consistent with market information.

Equipment product: Industrial Electric Motors

Product type: Three-phase induction motors, ranging from 0.75kW to 375kW, used in the industrial sector.

Approach: A top-down approach was used as the industrial electric motors' consumption data for many of the countries under analysis was not available. Motor sales were estimated by developing a relationship between the US$ value of a country's annual industrial or manufacturing output (sectoral GDP) and the amount of electricity consumed annually by Electric Motor-Driven Systems in that country's industrial sector. This was used to estimate historical Electric Motor-Driven Systems electricity consumption in industrial sector from historical industrial GDP data for countries under analysis.

Growth rate: The approach assumes a growth of sales in motors in line with Intergovernmental Panel on Climate Change (IPCC) future industrial GDP growth rate projections until the year 2040.

The model then runs three scenarios:

- **Business As Usual or base case scenario** – Two different BAU scenarios were defined: IE1 scenario and IE0 scenario. IE0 is an estimated motor efficiency level, which is lower than IE1 and used to account for the fact that the average motor efficiency can be well below IE1 levels in less developed countries. IE1 Scenario is used for more developed countries where IE1 efficiency is assumed to be the base case motor efficiency. (Except some countries which have implemented higher MEPS).

- **Minimum and High Ambition Scenarios:** the policy level recommended in the UNEP-U4E model regulation guidelines is IE3 but for motors, this has been defined as an ambitious policy level because, at the time of the analysis, no country has implemented more stringent MEPS (although the EU has IE4 planned for 2023). Consequently, the Minimum Ambition Scenario level is set at IE2 which is a potential interim level for countries not wanting to go straight to IE3 or higher.

Product lifetime: 15 years – consistent with best available market information. Other product characteristics are shown in Table 4. The electric consumption is allocated to each motor size shown based on a detailed stock model from the Indian market which, in the absence of equivalent data from other markets, is considered to be a reasonable approximation for this analysis.

Table 4 Product assumptions for motors

Motor type	Average Size	Full load efficiency (%)		
		Business as Usual*	Minimum Ambition Scenario	High Ambition Scenario
Small: 0.18 – 7.5 kW (frame size: up to 132)	2.2 kW	IE0: 75.4% IE1: 79.7%	IE2: 84.3%	IE3: 86.7%
Medium: 11 – 40 kW (frame size: 160 – 200)	15 kW	IE0: 86.8% IE1: 88.7%	IE2: 90.6%	IE3: 92.1%
Large: 37 – 180 kW (frame size: 225 – 355)	75 kW	IE0: 91.4% IE1: 92.7%	IE2: 94.0%	IE3: 95.0%
Extra Large***: > 180 kW (frame size: ≥ 400)	500 kW	IE0: 92.9% IE1: 94.0%	IE1: 94.0%	IE1: 94.0%

** Except for countries with MEPS in place*

Based on the above assumptions, energy savings can be estimated without the need to know typical UECs or the number of motors sold in a given year in each country. By knowing the following:

1. The percentage improvement in efficiency between BAU and the two policy scenarios (which can be calculated from the data in Table 4 – it is assumed that there is no efficiency improvement in the BAU scenario during the period of analysis)
2. The % of the electricity use that by stock that is replaced in a given year which is estimated based on lifetime (from which stock turnover can be estimated),
3. The growth in electricity demand, and
4. How electricity is used in the different motors sizes

The total electricity use in each scenario is estimated and from that the savings in each policy scenario.

Equipment products: Distributions Transformers

Product type: Distribution transformers using three-phase liquid-filled, single-phase liquid-filled and three-phase dry-type as representative product types.

Approach: As with the industrial electric motors analysis, a top-down approach is used because, with limited stock data available, this is the most robust approach. The installed capacity of distribution transformers is estimated from data on total electricity use in each country and assumptions on average power factor, load factor and hours of use. The installed Megavolt Ampere (MVA) is then separated between the residential, commercial and industrial sectors based on the share of electricity consumption in each. It is then further allocated to three product types using market data from manufacturers.

Growth rate: The approach assumes a growth in electricity demand in line with the IEA's World Energy Outlook projections in each sector until the year 2040.

The model then runs three scenarios:

- **Business As Usual scenario** – no policy intervention. It is assumed in all markets that the stock and sales of distribution transformers have losses in line with those assumed in the CENELEC harmonization research for the development of the EU standards. In this scenario, these are losses are assumed to remain the same throughout the period of the analysis.
- **Minimum and High Ambition Scenarios:** There will be two policy scenarios to show the savings possible from regulating at two levels of stringency. These will see MEPS set as level 1 and level 2 as defined in the Model Regulation Guidelines.

Product lifetime: 20 years – consistent with best available market information. Other product characteristics are shown in Table 5.

Table 5 Product assumptions for distribution transformers

			Total annual losses in kWh in the		
Distribution Transformer type	**Sector**	**Typical Size**	**BAU Scenario**	**Minimum Ambition Scenario *Level 1***	**High Ambition Scenario *Level 2***
Three-phase liquid-filled	Residential	250 kVA	13,841	9,746	7,512
	Commercial	400 kVA	19,710	13,841	10,508
	Industrial	800 kVA	27,419	19,491	14,804
Single-phase liquid-filled	Residential	50 kVA	4,227	3,197	2,352
	Commercial	N/A	N/A	N/A	N/A
	Industrial	N/A	N/A	N/A	N/A
Three-phase dry-type	Residential	N/A	N/A	N/A	N/A
	Commercial	630 kVA	31,536	26,280	24,221
	Industrial	630 kVA	31,536	26,280	24,221

As with motors, these assumptions on the losses in different scenarios, lifetime (and from that stock turnover), growth and how installed capacity is distributed between the different sectors and product types sizes allows the calculation of annual savings in the two policy scenarios. Again, using this approach means that there is no need to estimate UECs or the number of distribution transformers sold in a given year in each country.

MAIN DATA RESOURCES USED FOR UNDERLYING ASSUMPTIONS

Where available, robust local data is used in the analysis, which has been obtained via:

- Questionnaires and surveys issued to country officials.
- Regional analysis work with support from the African Energy Commission (AFREC) and the ASEAN Centre for Energy (ACE).
- Surveys completed by U4E partners and technical experts.
- Regional and country projects undertaken by U4E and its partners.
- Relevant published reports.

Otherwise, data and assumptions for each country are based on the following default sources:

- Market size is based on data from industry partners, the UN COMTRADE database and market penetration forecasts generated by UNEP-U4E Country Savings Assessment Models using data on some combination of population, GDP per capita, industrial GDP, climate, electrification rate, urbanization rate the sources of which are listed below.
- Population (2021 and future forecasts) comes from the UN Population Division.
- GDP per capita data (2021) and Industrial GDP (2021) comes from the World Bank with future growth forecasts derived from the Shared Socioeconomic Pathway (SSP3) used in the Intergovernmental Panel on Climate Change's (IPCC) most recent published database.
- Current total electricity consumption comes primarily from the World Bank and the U.S. Energy Information Administration (EIA) with future forecasts derived from the International Energy Agency's (IEA) World Energy Outlook 2020 and Africa Energy Outlook 2019.
- Future electricity consumption was calculated using these current consumption figures and growth forecasts provided by the International Energy Agency's (IEA) World Energy Outlook 2020 and Africa Energy Outlook 2019.
- Residential electricity tariffs are based on World Bank data.
- Transmission and distribution loss factor is a regional average calculated from electricity production and consumption data published by the IEA.
- Electrification levels come from the IEA's Word Energy Outlook 2018 and the World Bank;
- Cooling Degree Days are based on average monthly temperatures from weatherbase.com, degreedays.net or given by wunderground.com.
- CO_2 emission factors come from the Institute of Global Environmental Strategies (IGES) and the IEA and are assumed constant in future years.
- Product typical characteristics are based on analysis from the UNEP-U4E Model Regulation Guidelines and other data from UNEP-U4E industry partners and technical experts including the Lawrence Berkeley National Laboratory (LBNL), the International Copper Association (ICA) and GIZ.
- The approach for calculating the potential direct emission saving of cooling products is based on market data and expert input from GIZ, HFC Outlook and LBNL including on the typical current mix of refrigerants fillings, leakage rates and end of life emissions in the BAU compared to the best alternative low-GWP refrigerant.

In a small number of instances, where no country specific data is available, proxy data from similar markets is used.

LIST OF ACRONYMS

BAU	Business As Usual
CFL	Compact Fluorescent Lamps
CO_2	Carbon Dioxide
EIA	U.S. Energy Information Administration
GDP	Gross Domestic Product
GEF	Global Environment Facility
GSL/GLS	General Service Lamps
GWh	Gigawatt-hours
hid	High Intensity Discharge
ICA	International Copper Association
IEA	International Energy Agency
IGES	Institute of Global Environmental Strategies
IPCC	Intergovernmental Panel on Climate Change
K-CEP	Kigali Cooling Efficiency Program
kVA	Kilovolt Ampere
kW	Kilowatts
kWh	Kilowatt-hours
LBNL	US Lawrence Berkeley National Laboratory
LED	Light-Emitting Diode
LFL	Linear Fluorescent Lamps
MEPS	Minimum Energy Performance Standard
MVA	Megavolt Ampere
MW	Megawatt
MWh	Megawatt-hour
PWh	Petawatt-hour
Tlm-hr	Teralumen-hours
TWh	Terawatt-hour
U4E	United for Efficiency
UEC	Unit Energy Consumption
UNEP	United Nations Environment Programme
yr	Year