The Missing Piece of Energy Access: Methodology

1 Public investment model

1.1 Summary

The model estimates the total public investment needed to increase the ownership rate of an appliance by 20% within selected developing economies by 2030. The developing economies contemplated in the model vary by appliance type, choosing those with an appliance penetration rate <75% in 2024.

The model analyzes three categories of public investments: those to (1) establish *credible policy*, (2) strengthen *market ecosystems*, and (3) improve *consumer confidence*. The model also treats separately *household appliances*—which includes lighting, fans, refrigerators, and e-cooking (electric pressure cooker or an induction cooktop)—and *business equipment*, which includes walk-in cold rooms (WICR), water pumps, and mills.

The first two categories—establish *credible policy* and strengthen *market ecosystems*—are considered for household appliances and business equipment. For establish *credible policy*, a market tipping point (achieved at 20% appliance penetration) is assumed, after which these investments are no longer required to enable enterprises to serve additional customers. Note that this assumption is likely conservative (i.e., leads to an underestimation of overall investment needs).

The third category, public investments aimed at improving *consumer confidence*, is considered only for household appliances. For these public investments, it is assumed that households that already own appliances are the wealthiest, so it leverages data from the World Bank's Poverty and Inequality platform to assess the public investment needed to increase appliance penetration by an additional 20%. The exact percent of the market that requires public investment varies significantly depending on the type of appliance, the target market, and the goals of the program. The model starts with estimated appliance penetration levels for 2024, and an exponential growth equation is used to scale up the penetration by 20% until 2030 or until a 75% penetration rate is reached. The business equipment model doesn't include this category because it is assumed that business equipment will pay back for themselves, so no additional public investments to improve consumer confidence are needed. Table 1 gives an overview of the indicators used in the models. Table 2 gives a detailed breakdown of public investment needs for all appliances.

Table 1. List of mechanisms included in each category

Relevant Model	Market Failure Category	Mechanism	Description
HA, BE	Establish Credible Policy	Quality assurance	See Table 3 for a complete breakdown of this factor.
		Policy and advocacy work	See Table 3 for a complete breakdown of this factor.
		Consumer awareness	Support for awareness campaigns intended to incline consumers to acquire the appliance.
HA, BE	Strengthen Market Ecosystems	Enterprise development support	Support for enterprises to develop their business.
		Subsidized loans	Loans for enterprises to kickstart activities until a 20% appliance penetration threshold is met.
		Consumer incentives	Rebates for customers to kickstart appliance acquisition until a 20% penetration threshold is met for household appliances and gradually phased out by 2029 for business equipment.
HA	Improve Consumer Confidence	Cash subsidy	The total amount of public investment required if every household in the deployment scenario receives a subsidy to be able to purchase it in cash, either until a 75% penetration rate is reached or the additional 20% penetration rate is reached, whichever happens first by the end of 2030.

Table 2. Public investment needed by appliance and market failure category

	Public Investment ($million)			
	Establish Credible Policy	Strengthen Market Ecosystems	Improve Consumer Confidence	Total
Lighting	432	1,068	605	2,105
Fans	228	214	1,923	2,365
Refrigerators	145	351	16,807	17,303
E-cooking	421	735	13,802	14,958

Walk-in Cold Rooms	89	157		246
Water Pumps	105	208		313
Milling Equipment	105	102		208
Total	**1,525**	**2,835**	**33,137**	**37,498**

1.2 Public investment to establish credible policy

1.2.1 Quality Assurance (QA) and Policy & Advocacy (PA)

Within this category, the methodology used to calculate cost estimates for Quality Assurance (QA) and Policy & Advocacy (PA) applies to both household appliances (excluding lighting) and business equipment. QA and PA cost assumptions were estimated based on CLASP consultant Christopher Carlsen's analysis for various activities within each category (see Table 3).

Table 3. List of activities related to the Establish Credible Policy category

	Activity	Activity duration
Quality Assurance	Stakeholder consultation & coordination	one-off
	Standards & test method development	one-off
	Standards adoption	one-off
	Awareness raising (public, private, civil society)	one-off
	Awareness raising (consumers)	one-off
	Awareness raising (consumers - periodic)	annual
	Capacity assessment	one-off
	Capacity building of QA implementers	one-off
	Conformity assessment framework development	one-off
	Conformity assessment operation	annual
	Quality mark / label development	one-off

	Quality mark / label program operation	annual
	Product registration system development	one-off
	Product registration system operation	annual
	Market surveillance development	one-off
	Market surveillance operation	annual
	Standards enforcement development	one-off
	Standards enforcement operation	annual
	Laboratory capacity building	one-off
	Laboratory operation	annual
	Monitoring & evaluation development	one-off
	Monitoring & evaluation operation	annual
	Data collection & market assessment	one-off
	Stakeholder consultation & coordination	one-off
	Strategy development	one-off
	Regulation / law development & adoption	one-off
Policy & Advocacy	Capacity assessment	one-off
	Capacity building of implementing agencies	one-off
	Awareness raising (public, private, civil society)	one-off
	Awareness raising (consumers)	one-off
	Awareness raising (consumers - periodic)	annual
	Monitoring & evaluation	annual
	Regional collaboration	one-off

Public investments in QA and PA encompass costs associated with the activities detailed in Table 3 at a national level, regional, and global level; and are unique for each household appliance (excluding lighting) and each business equipment type. The cost of national activities is differentiated by a country's level of development of each category, and the model evenly divides the number of countries that are below a 75% appliance penetration level in 2024 among these three categories to obtain a total national cost. The model also assumes that the globe can be divided into nine regions to carry out regional activities, thus regional activity costs are multiplied by nine to obtain a total regional cost. The costs for each category are broken down further by the duration of the activity, which includes one-off and annual costs. The annual costs were multiplied by five to cover the cost for the whole deployment period assumed in this analysis (2025-2030). An example of the cost estimates for an appliance is detailed in the table below.

Table 4. Example of the tabular breakdown of costs for quality assurance and policy advocacy

Market-enabling category	Activity duration	National Activities			Cross-cutting activities	
		Level of national QA & policy dev.				
		Early (K USD)	Interm. (K USD)	Advanced (K USD)	Regional activities (K USD)	Global activities (K USD)
Quality Assurance (QA)	One-off	770	480	230	245	150
	Annual	260	200	135	5	0
Policy & Advocacy	One-off	220	180	150	345	0
	Annual	10	10	10	5	0

Assuming 120 countries didn't reach a 75% penetration rate in 2024 for this appliance, the total cost of quality assurance is US$ 180.8 million, and US$ 31.3 million for policy & advocacy.

1.2.2 Consumer awareness

Public investment in raising consumer awareness is intended to cover the costs of setting up an awareness campaign to persuade consumers to purchase the appliance. For *household appliances*, the investment needed for consumer awareness is only calculated for countries with an initial appliance penetration rate of <20% and is only applied until a 20% deployment is reached. The authors assume a one-off cost that varies based on the market size and applied an additional US$1 subsidy for each appliance that is deployed, until the 20% threshold is reached. For *business equipment*, there is a one-off cost for each appliance that varies depending on the total number of units expected to be deployed by 2030.

1.3 Public investment to strengthen market ecosystems

1.3.1 Enterprise Development Support (EDS)

The methodology used to estimate Enterprise Development Support (EDS) was applied to both household appliances (excluding lighting) and business equipment. EDS needs for appliance distributors were informed by the cost of existing EDS programs, scaled to meet the needs of much larger regional programs. The calculations include two components: 1) a one-off cost to set up and operate EDS facilities that is standard across appliances, and 2) a variable amount per appliance that is based largely on the number of markets being targeted for the particular appliance.

1.3.2 Consumer incentives

For household appliances, the subsidy needed to cover consumer incentives is only calculated for countries with an initial appliance penetration rate of <20% and is only applied until a 20% deployment is reached.

The consumer incentive calculations for each country include two components: (1) a one-off cost associated with establishing a consumer incentive program in the market, based on the size of the market (Table 5), and (2) an additional US$1 subsidy for each appliance that is deployed, until the 20% threshold is reached.

Table 5. Classification of market size

Market Size	
Country Category	Projected Number of Households in 2030
Small	< 7.5 million
Medium	7.5 – 30 million
Large	> 30 million

For business equipment, the same annual appliance deployment that was calculated for subsidized loans was multiplied by an annual product-specific rebate. The rebate is applied to every appliance deployed starting in 2025 and is phased out over time, reaching zero by 2028.

1.4 Public investment to improve consumer confidence

Again, these public investments apply only to household appliances because business equipment is assumed to pay for itself through the increased income it is used to generate. The authors assume that the totality of households would receive one type of subsidy described below:

- **Universal Cash:**
  Refers to the total subsidy amount required if every household in the deployment scenario receives a subsidy to be able to purchase it in cash, either until a 75% penetration rate is reached or the additional 20% penetration rate is reached, whichever happens first by end 2030. This affordability scenario quantifies the gap between the retail cost of the appliance in 2030 and the highest possible price at which all target households in the scenario can afford the appliance. This delta is the subsidy level and it is allocated to the totality of households that acquire the appliance between 2025 and 2030.

1.5 Model description

1.5.1 Appliance penetration rate → How country-level appliance penetration rates were estimated

- Extensive research was conducted to gather current penetration rate data for household appliances—namely electric cooking devices, lighting, fans, and refrigerators—across a representative sample of countries.
- Factors influencing these penetration rates were identified and analyzed against known rates for each appliance:
  - Annual sales of the appliance
  - Imports (units/cap)
  - Cooling Degree Days
  - GDP/cap
  - Poverty Headcount < US$ 2.15/day
  - Electricity access rate
  - Electricity generation per capita
  - Reliability of electricity supply and transparency of tariff index
  - Electricity prices
  - Urbanization rate
- Through an iterative weighting process, the factors most closely correlating with appliance penetration were determined, and optimal regression models were developed. However, due to the inability to establish a suitable regression model for fans, benchmarks were instead established based on electrification rates, GDP per capita, and air conditioner penetration rates.
- Subsequently, penetration rates for each appliance were estimated for countries lacking existing data.

1.5.2 Affordability → How the amount of public investment needed to improve consumer confidence was determined

Assumptions:

- For each appliance, a series of cost assumptions were made, including:
  - Appliance FOB cost in 2024
  - Appliance FOB cost annual change
  - Appliance retail costs in 2024
  - Appliance retail costs annual change
  - Lease term (the specific duration for which a lease agreement is in effect)
  - Retail mark-up on products
  - Cash affordability threshold as share of monthly expenditures
  - Lease affordability threshold as share of monthly expenditures

Values for these were selected based on extensive desk research and consultation with experts.

Description of calculations:

- National poverty headcount shares at various income levels (from US$2.00 to US$20.00 per day) were collected to infer spending power.
- Based on the assumption above, the cost evolution for FOB, retail, and monthly lease were calculated for each appliance on an annual basis for the years between 2024 and 2030.
- Based on the cost evolution of the appliance, affordability benchmarks were determined on an annual basis for the years between 2024 and 2030. These include:
  - Min. monthly expenditure to afford cash purchase
  - Min. daily expenditure to afford cash purchase
  - Min. monthly expenditure to afford lease
  - Min. daily expenditure to afford lease
  - % of HHs that can afford cash purchase
  - Difference between target and affordability for cash purchase
  - % of HHs that can afford lease
  - Difference between target and affordability for lease
- Per-person expenditure needed for cash purchase and for lease of the appliance were calculated on an annual basis for the years between 2024 and 2030 based on the estimated prices of the appliance during that time period and household size.
- By comparing the per-person expenditure needed to the poverty threshold, the share of population that can afford both a cash purchase and to lease the appliance was estimated.

- The price at which 75% of the population can afford the appliance with a cash purchase and with lease was calculated and was used to determine the subsidy required to reach this target.
- With the share of households that require a subsidy by 2030, the total cost of targeted subsidies was calculated for each country.

1.6 Alternative approach for lighting

Because in-depth modeling was conducted as part of the development of ESMAP's 2024 Off-grid Solar Market Trends Report, the authors leveraged this existing work and reverse engineered public investments in credible policy, market ecosystem, and consumer confidence for lighting. The report's modeling includes the following assumptions and calculations:

Assumptions

- Number of solar home systems (SHS) to be deployed by 2030
- Cost of three light bulbs and wires. The ESMAP report includes costs for Tier 1 SHS that includes the power system. To remain consistent with the cost assumptions for other appliances we separated the cost of lighting and the power supply.
- Affordability threshold
- Number of people without access to electricity and that need to be electrified by 2030
- Grant share of total funding

Calculations

- Annual rollout of Tier 1 SHS was calculated assuming a constant deployment rate of about 18% between 2025 and 2030.
- Annual cost was determined based on the estimated cost of three light bulbs and wires.

2 Other Assumptions

To derive the number of beneficiaries (persons) from the number of households served, we assumed 4.3 persons per household. This is the simple average of the forecasted values for 2030 for each of the 120 countries in scope. Historical data were drawn from the UN Household Size and Composition dataset.

For each of the appliances in scope, CLASP estimated product lifetime, retail price, annual energy consumption, greenhouse gas emissions avoided, and number of households served per appliance in service. The values used are shown in the following table:

Appliance	Avg. Lifetime (yr)	Avg. Retail Price ($/unit)	Avg. Unit Energy Consumption (kWh/yr)	CO_2(e) Emissions Avoided (kg/yr)	Households Served per Unit in Service
Lighting	5	203	43	n/a	1
Fans	5	27	88	n/a	1
Refrigerators	10	140	250	n/a	1
E-cooking	5	119	730	2,000	1
Walk-in Cold Rooms	15	16,023	6,432	5,000	100
Water Pumps	5	650	264	2,200	1
Milling Equipment	10	1,625	486	2,000	100

Notes:

- Lighting: Assumes three 6 W bulbs operated for 6.5 hours/day, 365 days/yr. The price shown here includes the power supply (battery, PV module, and control unit) and is representative of a high-quality VeraSol-certified solar home system in the 11-20 Wp range. An average retail price of $15 ($5 x 3 light points) was used in the model.
- Fans: Assumes a 40 W fan operated for 6 hours/day, 365 days/yr.
- Refrigerators: Assumes a refrigerator with 100-liter capacity operated 24 hours/day, 365 days/yr.
- E-cooking: Assumes an electric pressure cooker and an induction cooktop with total avg. daily electricity consumption of 2 kWh. Avoided emissions are expressed in kg of CO_2 equivalent per year.
- Walk-in Cold Rooms: Assumes a unit with avg. power consumption of 1.34 kW operated 24 hours/day, 200 days/yr. The price shown is the freight onboard (FOB) price rather than retail price.
- Water Pumps: Assumes a 220 W pump operating 6 hours/day, 200 days/yr.
- Milling Equipment: Assumes a 150-350 W system able to process approximately 200 kg produce/hr.

To calculate the CO_2 emissions avoided for lighting, fans, and refrigerators, CLASP compared the efficient appliance scenario described in the report to a counterfactual scenario in which inefficient appliances are adopted instead. Inefficient lighting and refrigerators are assumed to consume 50% more electricity than the efficient alternatives, and inefficient fans 100% more than the efficient alternatives. For these appliances, CLASP used two grid emissions factors to convert avoided electricity consumption into avoided CO_2 emissions: 0.314 kg CO_2/kWh for Africa and 0.466 kg CO_2/kWh for other regions. These factors are the population-weighted average of the default emissions factors used in Mepsy[1] for the 53 countries in Africa and 67 countries in other regions that are included in the analysis.

[1] Mepsy is an open-source tool. [Mepsy: The Appliance & Equipment Climate Impact Calculator - CLASP]

3 Data Sources

Data	Source	Year
Roll-up calculations		
Population	UN Department of Economic and Social Affairs - Population Division Data Portal	2024
Number of Households and Number of Persons per Household	UN Department of Economic and Social Affairs - Household Size and Composition Dataset	2022
Affordability		
Expenditure levels	World Bank Poverty and Inequality Platform	Various
Appliance retail costs	Actual FOB and retail pricing from various merchants	2024
Market-enabling subsidies	CLASP Consultant, Christopher Carlsen	2024
Penetration rate for household appliances (e-cooking, fans, and refrigerators)		
Annual sales	Euromonitor International	2024
Imports	COMTRADE	2023
GDP/capita	World Bank, GDP per capita (current US$)	2019-2023 average
Poverty Headcount	World Bank, Poverty Headcount ratio at $2, $2.50, $3, $3.5, $4, $5, $6, $7, $8, $9, and $10 a day	Latest available year 2004-2023
Reliability of supply and transparency of tariff index	World Bank, Getting Electricity	2023
Urbanization rate	World Bank, Urban population (% of total population)	2023
Share of electricity for domestic use	International Energy Agency, Data and statistics	2022
Electricity generation capacity/cap	International Energy Agency, Data and statistics	Latest available year 2011-2022
Electricity access rate	World Bank, SDG7 Tracking	2022
Electricity prices	Global Petrol Price, Electricity prices	2024

Lighting		
Total funding need	ESMAP - Off-grid Solar Market Trends Report	2024
Business equipment, including solar water pumps, mills, and walk-in cold rooms (WICR)		
Country-level addressable market for irrigation pumps and mills	CLASP - State of the Off-grid Appliance Market	2019
Retail costs of appliances & affordability	World Bank Lighting Global - The Market Opportunity for Productive Use Leverating Solar Energy (PULSE) in Sub-Saharan Africa	2019
Share of cash purchase for business equipment and affordability metrics for solar lanterns	ESMAP - Off-grid Solar Market Trends Report	2024
Demand for WICR	Efficiency for Access - Life Cycle Greenhouse Gas Emissions Assessment of Off- and Weak-Grid Refrigeration Technologies	2023