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Efficient Appliances for People & the Planet

The Missing Piece of Energy Access:

Why 15% of Energy Infrastructure Investment Must Go to Appliances

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AUTHORS

Bishal Thapa
Sam Grant
Ari Reeves

CONTRIBUTORS

Siena Hacker, CLASP
Jeffrey Stottlemyer
Ian Muir, Catalyst Energy Advisors
Jennifer Ortiz, Catalyst Energy Advisors

CONTACT

Marina Baur
mbaur@clasp.ngo

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Kerry Nash

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Daisy Simmons

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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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ABBREVIATIONS AND ACRONYMS

C	Celsius
CO_2	Carbon dioxide
EV	Electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
Gt	Gigaton
GWh	Gigawatt hour
IEA	International Energy Agency
kWh	Kilowatt hour
LED	Light-emitting diode
LMIC	Low- and middle-income countries
LNG	Liquified natural gas
Mt	Megaton
MTF	Multi-Tier Framework for Energy Access
SDG	Sustainable Development Goal
TWh	Terawatt hour
UK	United Kingdom
USD	United States dollar
WICR	Walk-in cold room

Globally, hundreds of millions of people lack electricity. Most solutions focus on extending power supply infrastructure, but in marginalized areas, low electricity demand makes the expense of such infrastructure hard to justify. Increasing the use of energy-efficient appliances in these areas can attract electricity supply investments while delivering climate benefits. Achieving sufficient levels of appliance use to meet these goals would require allocating 15% of supply-side investments, or $38 billion USD, toward demand growth between now and 2030. The funding should focus largely on improving appliance affordability.

KEY FINDINGS

- Energy-efficient appliances are essential energy infrastructure, critical for achieving universal energy access and meeting climate mitigation and adaptation goals.
- Bringing modern energy to the 666 million people who lack it (most of whom live in Sub-Saharan Africa) requires expanding power infrastructure to places with low electricity consumption.
- Increasing appliance access across Africa could generate demand for 342 terawatt hours of electricity annually, creating a market worth approximately $50 billion USD that would catalyze accelerated power infrastructure development.
- Focusing on expanding markets for energy-efficient appliances (as opposed to standard, less-efficient appliances) would provide many benefits, including avoiding an estimated 2.6 gigatons of CO_2 equivalent emissions annually.

RECOMMENDATIONS

- The IEA estimates that at least $50 billion USD of public investment annually is needed until 2030 to achieve universal energy access. CLASP analysis shows that 10–15% of this amount—about $7.5 billion USD annually, or $38 billion USD in total—should be devoted to improving appliance access.
- Relevant decisionmakers should allocate 10–15% of power supply-side investments toward establishing sustainable electricity demand growth.
- Public institutions should target investments to overcoming market failures that limit appliance use—in particular, a lack of affordability and consumer confidence.
- All stakeholders should prioritize energy-efficient appliances over standard, less-efficient appliances.

CLASP analysis shows that achieving universal energy access will be more economically viable if approximately $38 billion USD is devoted to helping people in off- and weak-grid communities access energy-efficient appliances.

In the energy sector, appliances are often seen as an afterthought. In practice, however, they are the cornerstone of the energy system, providing a vital interface between energy and the people who need it.

Household appliances and business equipment powered by electricity (referred to collectively as “appliances”) are essential to improving people’s lives. They are critical determinants of economic growth, health, social wellbeing, and climate resilience.

Appliances also shape energy markets in fundamental, but often unappreciated, ways. Stronger understanding of their potential can accelerate efforts to meet two critical short-term targets for sustainable development and climate mitigation: achieving the United Nations’ Sustainable Development Goal 7 (SDG 7), which calls for universal energy access by 2030, and hitting the Paris Agreement target of net zero emissions by 2050.

The strong links between appliances and energy access are particularly relevant for governments seeking to bring electricity to the 666 million people who lacked it as of 2023. In recent decades, the global community has made rapid progress in expanding power supply infrastructure—that is, utility electric grids, mini-grids, and distributed solar—in underserved areas. Today, the areas that remain unconnected to power supply infrastructure are those that are hardest to reach and have the lowest ability to pay. Located primarily in Sub-Saharan Africa, these communities are typically perceived to have little economic activity. As a result, national governments forced to choose between many competing priorities often hesitate to extend power supply infrastructure there, fearing that the limited energy demand doesn’t justify the financial investment.

Appliances can play a key role in overcoming this challenge. Helping people in underserved areas access appliances can generate demand for modern energy services, signaling to power supply developers that sufficient demand for their product exists.

To achieve this, $38 billion USD in public investments need to target the market failures that reduce affordability and prevent universal appliance access in marginalized communities: low consumer confidence, insufficient policies, and a weak market ecosystem. Of these priorities, improving consumer confidence will require the most funding.

To maximize benefits for both people and planet, these efforts should focus on increasing access to high-quality, energy-efficient appliances.

Efficient appliances and equipment are essential for income generation, comfort, and health.

1. Energy-efficient appliances are essential energy infrastructure

This report presents a new approach for achieving universal electricity access faster and more sustainably. The central focus: improving access to energy-efficient appliances in places where current appliance ownership is low.

With this document, CLASP issues a call for not only universal energy access but full appliance access. Electricity on its own does not deliver economic activity and social wellbeing. Public investment is needed to expand and improve electricity supply, whether from the main utility grid, a mini-grid, or an off-grid distributed solar solution. Across all these different types of power supply infrastructure, public investment must also go to building appliance markets and accelerating ownership. Coupling appliances and energy supply and categorizing them as public infrastructure will accelerate access and expand the public good that modern energy services provide.

Improved access to appliances will increase electricity consumption while simultaneously powering economic growth, enhancing climate adaptation capacity, and supporting the transition to a net zero emissions pathway.

Understanding the challenge

At the halfway mark for the implementation of the United Nations' Sustainable Development Goals (SDGs) in 2023, 666 million people lacked access to electricity.[1] Another 1.6 billion are living in weak-grid areas with unreliable electricity.[2]

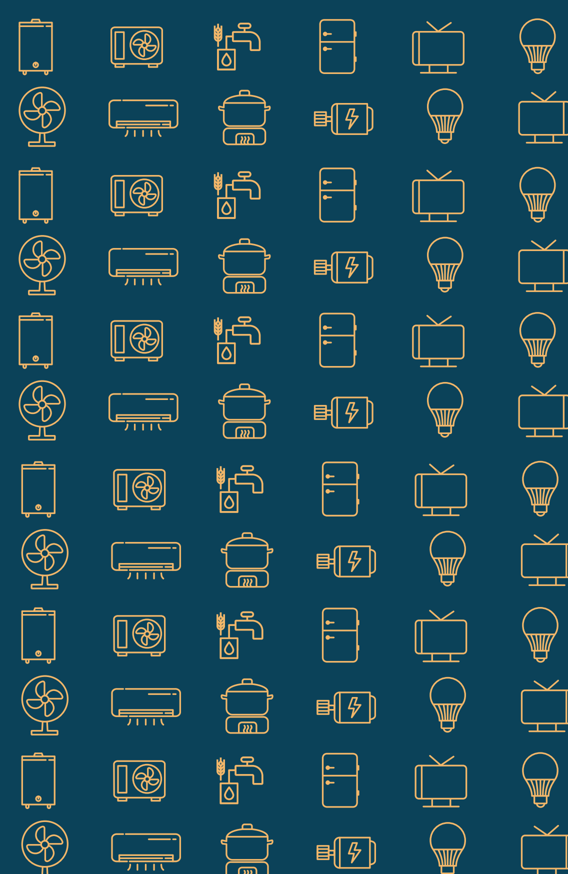
As a result, these communities face higher risk of food insecurity, heat stress, unrealized economic potential, and limited access to information, making them more vulnerable to climate change. To mitigate these risks, SDG 7 focuses on ensuring access to affordable, reliable, sustainable, and modern energy for all by 2030.

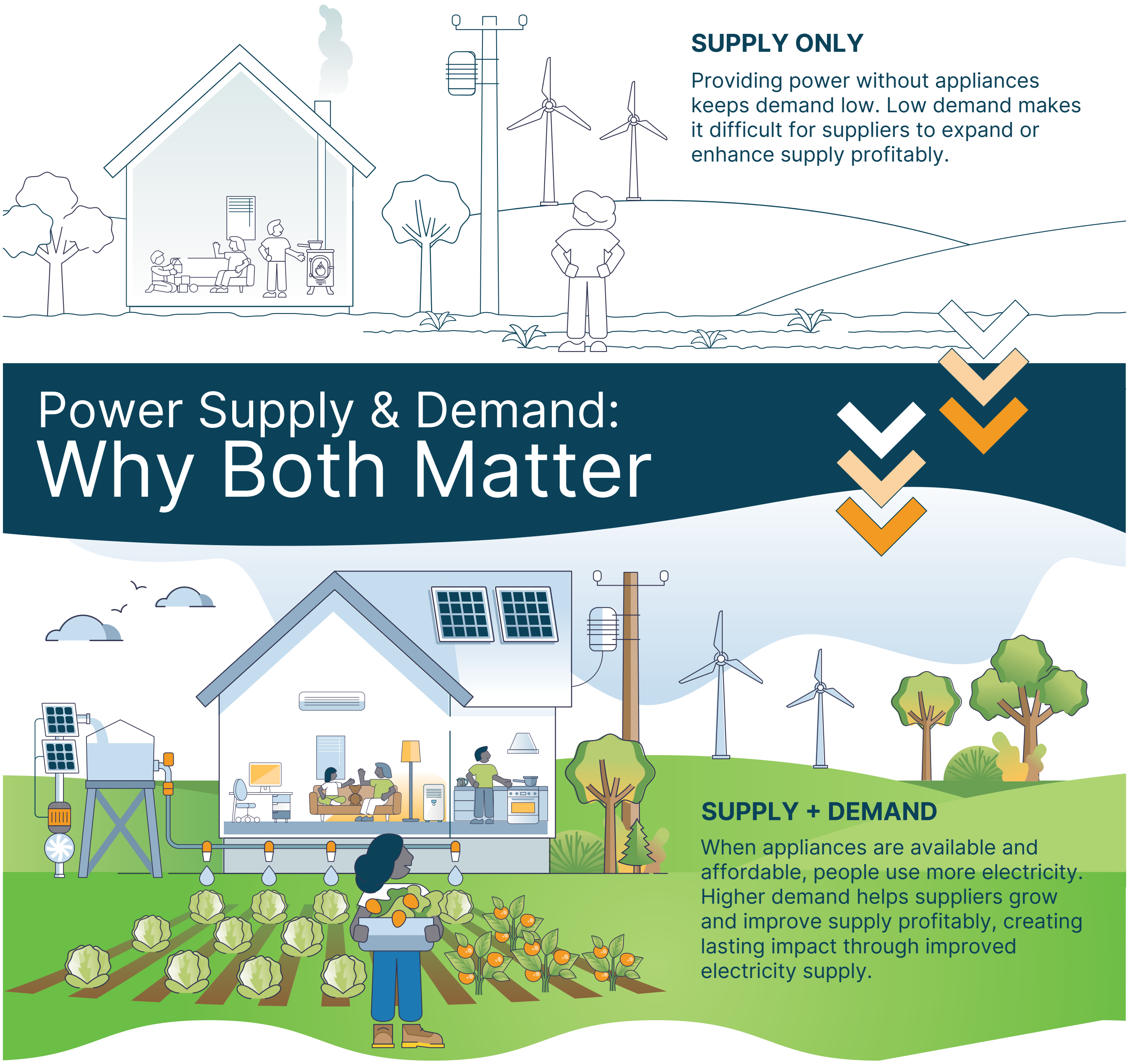
To date, efforts to deliver reliable electricity access have largely focused on expanding and strengthening power supply infrastructure in underserved areas. Governments have typically assumed that appliances would soon flow naturally into newly electrified communities, bringing with them critical services like cooling and electric cooking. However, supply expansion efforts are often hamstrung by the lack of electricity demand and economic activity in those areas, making it difficult to justify the financial investment needed to build more power infrastructure.

As a result, efforts to achieve universal energy access through power supply infrastructure expansion (i.e., supply-side solutions) must be supplemented with new approaches that boost electricity demand and unlock economic growth (i.e., demand-side solutions). Improved access to appliances in weak- and off-grid areas would significantly improve the economic viability and financial sustainability of expanding power supply infrastructure.

CLASP uses *appliances* as a catch-all term for a broad range of devices that convert energy into services that improve people's lives.

For this paper, CLASP focuses on two categories of appliances: business equipment and household appliances. We recognize that this is a simplified classification, since many devices can be used in homes, businesses, and other settings. For example, lighting is used in homes and businesses, as well as on roadways and in institutions like schools and hospitals. However, these two categories offer a strong framework for analyzing current gaps in access and the funding needed to close them.





Reasons for optimism

Governments and energy markets can perform at the scale required to ensure universal electricity access by 2030

Delivering universal electricity access by 2030 will require a significant increase in the current pace of expansion. With 666 million people lacking electricity access in 2023, over 100 million additional people, on average, will need to acquire new power connections every year through to the end of this decade. This will mean almost tripling

the annual average rate of increase in electricity access through the end of the decade relative to 2021–2022 levels.[3]

Despite the enormity of the challenge, governments and energy markets have proven that they can mobilize resources at the scale required to achieve universal electricity access. Not factoring in transmission and distribution costs, electricity generation infrastructure is already growing faster than the level required to deliver universal electricity access by 2030.

From 2013 to 2022, annual global grid electricity generation increased by 5,827 terawatt hours (TWh). Just 0.15% of this energy would be enough to provide at least 200 watt-hours (Wh) daily per household to the 666 million people still without electricity—enough for basic energy services like lighting and use of an efficient fan (Multi-Tier Framework [MTF] Tier 2).[i] Only 6% of 5,827 TWh could provide a reliable supply of electricity for at least 23 hours daily to people currently without access (MTF Tier 5). Approximately 15% of that same amount of energy would be sufficient to provide the 1.6 billion people in weak-grid areas with a reliable supply for at least 23 hours daily.[4]

Across the continent of Africa, where approximately 85% of the people without access to electricity live, annual grid electricity generation grew by 178 TWh from 2013 to 2022, an annual average growth rate of 2.5%.[5] Just 4% of this growth would be sufficient to provide a basic electricity supply of at least eight hours daily for every African who currently lacks access (MTF Tier 3).

i The Multi-Tier Framework for Energy Access was introduced by the World Bank in 2015 to provide a more nuanced way to define and measure access to energy that goes beyond the binary ‘connected’ or ‘not-connected.’ To learn more, see Beyond Connections: Energy Access Redefined.

Cost reductions and advancements in distributed renewable energy and storage technologies are also helping address the distribution and transmission cost barriers faced by remote communities.

Despite these advances, some areas are still not being served. Improved access to appliances could change this, driving higher electricity consumption and providing the economic and financial justification to expand power supply infrastructure into the hardest-to-reach areas.

With additional efforts, governments could fully erase the electricity access gap by 2030

In the decade between 2012 and 2022, approximately 338 million people (or roughly 35% of those without access in 2012) benefited from new electricity connections. Three-quarters of that increase in access occurred in Asia. India alone closed the electricity gap for 245 million people—and did so while continuing to improve the technical and financial performance of state-owned power companies. Parts of Sub-Saharan Africa also saw notable progress on improving energy access, with several countries in the region among the top 20 best-performing nations globally.[6] Countries such as Ghana, Kenya, and Rwanda are on course to achieve full access by 2030.[7]

Despite these successes, the pace of progress must accelerate to secure universal electricity access by 2030. The accumulated evidence and learnings from the gains thus far, including from several African countries, indicate that accelerated routes to universal reliable electricity access are possible. Improved access to energy-efficient appliances could serve as a stepping stone toward higher economic growth, improved livelihoods, and increased social wellbeing.

Energy markets are already mobilizing far more resources than would be required to achieve universal electricity access by 2030

The cost of achieving universal access to electricity by 2030 (i.e., fulfilling SDG 7.1.1) is estimated to be around $45 billion USD per year,[8] whereas the cost of universal clean cooking is $8 billion USD per year, which is less than

A solar-powered water pump in use: a standalone system delivering electricity where the grid doesn't reach.

2% of overall annual global spending on clean energy.[ii]

In Africa, home to the largest share of the population without access to electricity, governments and global companies already spend enough on energy to close the access gap. Currently, Africa commands 50% of global floating liquified natural gas (LNG) capacity[9] and is expected to add 12 new LNG terminals by 2027.[10]

The continent is in the middle of a 20-year energy investment cycle in upstream oil and gas that will see it invest approximately $800 billion USD annually, on average, between 2010 and 2030, according to Wood Mackenzie, a global energy consultancy.[11]

The scale of investments required for achieving universal electricity access is not unprecedented for most energy markets, even in Africa, where access gaps are high. More energy investments need to flow into enabling the expansion of the power supply infrastructure. Improved access to appliances can create room for new investment opportunities and provide the economic viability and financial sustainability for the expansion of power supply infrastructure.

Diverse energy distribution approaches will power increased access

The power supply infrastructure needed to address the electricity gap includes a portfolio of distribution approaches: grid extension, mini-grids, and standalone distributed energy systems. These are typically employed in different settings. The grid is typically required for high-intensity electricity use and dense population centers, while mini-grids tend to support medium levels of electricity use where energy use is clustered around a small community that is not easily connected to a central grid. Standalone distributed energy systems are used for low levels of electricity use in more remote settings, generally in the form of solar home systems.

These distribution models have different cost structures and require different business models to operate effectively. In its 2025 SDG 7 progress report, the IEA indicated that grid expansion will account for at least half of the new connections needed across all different electricity use intensity scenarios.[12]

The ability to integrate multiple electricity supplies (e.g., grid, rooftop solar, and battery storage) with their end uses (e.g., electric vehicles, smart Internet of Things-enabled appliances, and demand response) will create flexibility and cost optimization. The higher the levels of electricity demand, the more likely that the grid supply could be expanded to meet that load cost effectively. Predictable minimum loads are needed to right-size all types of power grids and optimize capital expenditure with tariff revenue.

The lines between grid, mini-grid, and standalone distributed energy systems are blurring rapidly.

Even in advanced economies, power suppliers are integrating distributed energy systems to enhance resilience, lower costs, and transition to cleaner sources. In the United States, for instance, a power utility in Vermont, Green Mountain Power, integrated distributed solar and storage within its portfolio to launch a zero-outage initiative that also reduced power costs.[13]

Many places that are already grid-connected—including urban areas with reasonably high levels of reliability—include mini-grids and standalone distributed energy systems to complement grid supply, enhance reliability, and reduce costs. Coupled with digital innovations, modern power systems can now seamlessly integrate different supply options while aggregating and managing distributed systems. For example, Utilities 2.0, an energy access pilot program in Uganda, combined appliance finance and mini-grid development to strengthen the business case for the main utility to eventually expand to new communities. This integrated approach lowered the cost of expansion for the electric utility by 30%.[14]

A narrow focus on expanding power supply infrastructure is undermining progress on universal electricity access

To date, efforts to increase electricity access have primarily focused on expanding power supply infrastructure. Targets for energy access programs, for example, are specified in terms of power supply infrastructure, prioritizing gigawatts, kilowatt-hours, and number of connections. Estimates of the investment required to improve electricity access are similarly framed in terms of the cost of expanding supply infrastructure.

However, without appliances, electricity access is not transformative. Between 2000 and 2022, for instance, the percentage of Kenyans with access to electricity grew from 15% to 76%. Despite the increases in grid expansion and improved access, people's use of energy did not increase at the same rate. In fact, Kenya's average consumption dropped by 60% from 2008 to 2017, leading to slower-than-expected cost recovery for the utility.[15]

Financial sustainability challenges for power supply projects are not unique to Kenya. A World Bank report

ii Lower bound inferred from IEA, higher bound extrapolated from SDG 7 progress report estimate.

examining the financial health of electric utilities across Africa found that most utilities were not able to collect sufficient revenues to cover operating and capital expenditures during the period studied.[16] In India, research on microgrids has illustrated how demand uncertainty, including the fact that there isn't enough load throughout the day, often makes it difficult for electricity providers to plan cost-efficient supply solutions.[17]

A new body of research is demonstrating how increases in electricity consumption can reduce the cost of supply and make it economically viable.

An RMI field study drawing from field research of mini-grids in Africa illustrated that an increase in electricity consumption due to the use of business appliances "changed lives and transformed power system economics, reducing the cost of producing electricity by up to 50%."[18]

RMI's assessment discusses how investment to expand power supply infrastructure could be at risk without parallel effort aimed at increasing consumption. The next phase of the World Bank's Distributed Access through Renewable Energy Scale-Up (DARES) project aims to achieve a six-fold increase to 1,200 mini-grids in Nigeria over the next few years. RMI concludes that $400 million in planned capital expenditure grants under the program could be at risk without adequate investments in expanding electricity consumption to financially sustain the mini-grids.[19]

Another organization, Energy 4 Impact, conducted field research and analysis in Africa that showed that making credit available for business appliances led to much higher electricity use, which contributed to improvements in the business models and financial viability of mini-grid operators.[20]

PRACTICAL IMPLEMENTATION

Several global initiatives, such as the World Bank's M300 program, are beginning to recognize the importance of generating demand, seeking to enhance the deployment of business equipment and electrification of public institutions.[21] Such efforts remain limited, however, and their impact on mobilizing government action, resources, or the market ecosystem has been marginal. Only $65 million USD was raised for funding for equipment in 2022, estimates SDG 7's progress report, which is low compared to the sector's need.[22]

EVALUATION METHODOLOGIES

New methods for evaluating energy access—in particular, the Modern Energy Minimum—are recognizing the importance of electricity to not only meet basic needs but also advance economic development.

The Modern Energy Minimum presents an ambitious new target to define annual electricity needs as 300 kWh at the household level plus at least 700 kWh per capita in the wider economy.[23] This method uses residential and non-residential energy electricity consumption to illustrate that electricity must drive economic growth and meet broader development goals.

Lack of electricity demand slows investment needed for universal energy access

Underinvestment in appliances undermines progress

The push to achieve universal energy access is an opportunity to create the basis for economic growth and higher incomes in areas currently lacking reliable grid power. Appliances drive electricity consumption and increase demand, which enables economic growth. Consumption and demand are critically needed in equal measures to justify the expansion of power supply infrastructure. However, billions of people worldwide remain without access to appliances, in effect removing the key driver of universal access to reliable electricity.

DRIVERS OF ECONOMIC GROWTH AND HUMAN WELLBEING

Appliances underpin many aspects of modern life, and access to them is a crucial determinant of economic wellbeing, health, and quality of life.

Appliances are also critical to increasing resilience in the face of climate shocks and helping to lower emissions while mitigating environmentally damaging activities like deforestation.[24] For example, irrigation can bolster food security in times of drought, while electric cooking equipment can reduce the need to collect firewood for fuel.

Improved access to appliances spurs economic activity in two ways.

1. *Households and enterprises use appliances for*

Shop owner with a solar refrigerator that enables her to reduce food waste and generate higher income.

economically productive activities that create the basis for economic growth and enable higher incomes.

Walk-in cold rooms, water pumps, and milling machines are used directly in small and microenterprises to increase productivity. Water pumps, for example, provide reliable irrigation services and have demonstrated the potential to increase yields by two to threefold, depending on crops and climate.[25]

Appliances such as refrigerators are also used by small businesses to generate more income (through the sale of cold drinks and perishable items, for example). A survey of solar off-grid refrigerator customers in Kenya, Tanzania, and Uganda found that 45% of customers were interested in using their fridge to generate more income, including the 18% of customers who purchased their refrigerator to sell cold drinks.[26]

2. *The production, sale, and purchase of appliances spurs economic activity, establishes new markets, and leads to higher GDP growth.*

CLASP estimates that closing the appliances ownership gap will expand the markets for those products to some $61 billion (the estimated retail value of annual sales) and induce significant additional investments in manufacturing, retail, financing, services, and related ecosystems.[27]

Large access gaps in appliances remain

Tens of billions of appliances are in use today, generating approximately 35% of global energy demand.[28] (The remaining 65% of demand is from industrial process heat, transportation, and other end uses outside of residential and commercial buildings.)

Despite the importance of appliances and their large share of energy use, several billion people still lack access to essential appliances. Many households and businesses lack access to the appliances they need because they can't afford them or can't find them in their area, or because they lack access to electricity.

CLASP evaluated the ownership gaps for four household

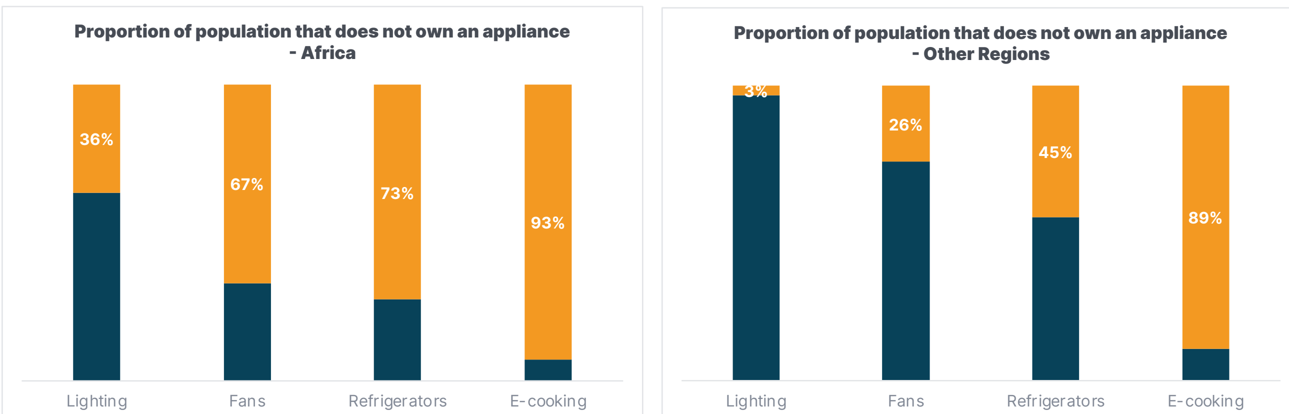
Access to electric cooking appliances can reduce harmful smoke, improve health, and ease daily labor often carried by women and girls.

appliances (lighting, refrigerators, fans, and electric cooking technologies [electric pressure cookers and induction cooktops]) and three types of business equipment (water pumps, walk-in cold rooms, and milling equipment).[iii] The results are shown in Figure 1 and Figure 2.

Our analysis considered household appliance access separately for African countries, which together account for 85% of the population without access to electricity, and for all other low- and middle-income (LMIC) countries except China and Turkey. For business equipment access gaps, we limited the geographic scope to Africa.

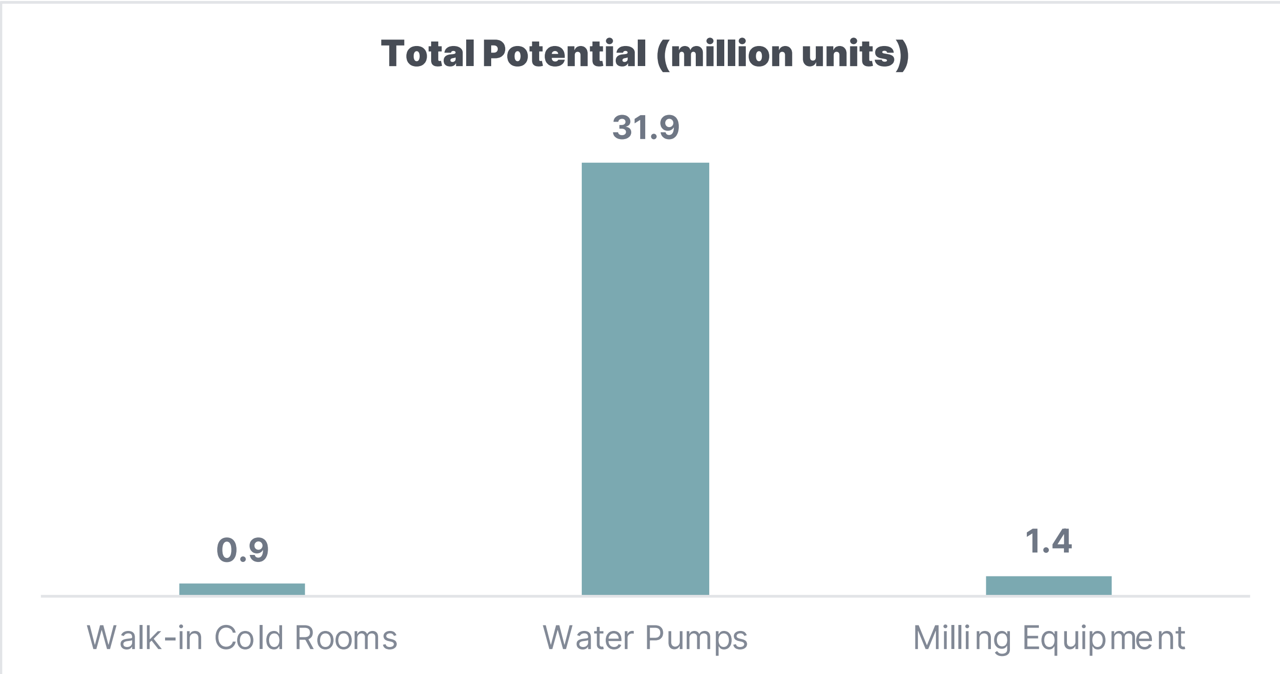
iii As noted in the third section of this report, CLASP recognizes that this simplified categorization ignores that these products can be used in both the home and a business. For example, lighting is needed in the home and to extend working hours for small businesses, while e-cooking equipment can be used for income generation.

FIGURE 1 Household appliance access gaps



Based on a total population of 1,506 million people in Africa and 3,659 million people in other regions. (Source: CLASP analysis)

FIGURE 2 *Total potential for business equipment in Africa*



Total potential includes no walk-in cold rooms, no milling equipment, and an estimated 0.16 million water pumps already in use in 2024. For walk-in cold rooms, the analysis includes only the 47 countries of Sub-Saharan Africa. (Source: CLASP analysis)

CLASP estimates that more than half of the population in Africa lacks access to fans, refrigerators, and e-cooking appliances.

The gap in access to appliances is even more severe for marginalized communities. Around the world, female-headed households are less likely to have access to appliances.[29] Similarly, households that include people with disabilities are also less likely to have electricity[30] access. Globally, 90% of refugees lack electricity access.[31]

The appliances we target for improved access also represent technologies at various stages of technical maturity and market development. Each addresses specific challenges posed by climate change and energy poverty.

CLASP recognizes that household appliances can be used in small businesses to derive income. Our analysis, however, segments walk-in cold rooms, water pumps, and milling appliances as business equipment since they are more closely linked to agriculture, from which many people in weak- and off-grid areas derive their livelihoods.[32] At the same time, we acknowledge that other types of business equipment could also contribute to electric load growth and economic development across Africa and elsewhere. We also acknowledge that appliances in the home drive domestic productivity that is unpaid and often unrecognized.

APPLIANCES DRIVE ELECTRICITY DEMAND

Appliances are the key drivers of electricity use. Closing the appliance access gaps in LMICs would result in additional annual electricity use of 1,012 TWh, with one third of that new demand in Africa. See Table 1 and Table 2.

TABLE 1 Increase in electricity demand from fully closing appliance access gaps

	Households with new access (million)		Electricity consumption per household (kWh/yr)	Additional electricity use (GWh/yr)	
Household appliance	**Africa**	**Other Regions**	**All Regions**	**Africa**	**Other Regions**
Lighting	127	26	43	5,442	1,112
Fans	235	220	88	20,584	19,233
Refrigerators	255	379	250	63,630	94,860
E-cooking	325	761	730	237,505	555,479
Total			**1,110**	**327,161**	**670,684**

Additional electricity use is the product of households with new access and electricity consumption per household. (Source: CLASP analysis)

TABLE 2 Increase in electricity demand from fully closing business equipment access gaps in Africa

	Households served by new equipment (million)	Electricity consumption per household served (kWh/yr)	Additional electricity use (GWh/yr)
Business equipment	**Africa**	**Africa**	**Africa**
Walk-in cold rooms	86	64	5,514
Water pumps	32	264	8,377
Milling equipment	144	5	702
Total		**333**	**14,594**

Additional electricity use is the product of households served by new equipment and electricity consumption per household served. The analysis assumes 100 households are served by each walk-in cold room and mill while one household is served by each water pump. (Source: CLASP analysis)

Closing appliance access gaps for households and smallholder farmers in countries with low rates of electricity access would place them at approximately the equivalent of Tier 4 under the Multi-Tier Framework for Energy Access (MTF), which measures the amount and quality of electricity available to a household. This would improve load demand certainty necessary for utilities, mini-grid developers, and distributed solar companies to expand electricity access faster, at lower cost, and more sustainably.

APPLIANCES SUITED FOR ALL SUPPLY ENVIRONMENTS

CLASP selected the seven appliance types analyzed in this report due to their high energy use and potential to benefit individuals and economies. Our selection was also influenced by their ability to be adapted for use in weak-grid, on-grid, and off-grid environments with minimal effort.

Areas lacking grid access or with poor grid reliability

A solar water pump can ensure reliable water access for farmers and improve food security. At the same time, efficient off-grid appliances like these can help attract investment in local power infrastructure.

are often categorized as grid, off-grid, or served by a mini-grid. However, this delineation is artificial from an electricity consumption point of view. As shown in SDG 7's progress report, which is based on data from 15 countries, households have many different levels of consumption within each of these supply environments. Some have no grid connection, or very low electricity consumption, even in places where the grid is available, while others have moderate levels of electricity use despite living in off-grid areas.[33]

Expanding access to appliances will induce power supply infrastructure to expand across all areas. In some cases, it may provide economic justification to extend the grid. In other cases, it may draw in more distributed mini-grids or increase the availability of standalone distributed solar energy systems. Increase in electricity consumption from improved access to appliances provides the economic justification for the expansion of power supply infrastructure.

Efficiency is vital

Critically, communities without electricity need access not only to appliances, but to energy-efficient appliances. Efficient appliances are perfectly situated at the nexus of people and planet and can simultaneously deliver on the goals of achieving universal energy access, improving climate adaptation, and furthering climate mitigation.

Efficiency improves access by lowering the cost of ownership. The expense of purchasing and operating appliances presents a major barrier for many low- and middle-income consumers. By running on less energy, efficient appliances typically save consumers money on their utility bills if the appliances are connected to the grid, making them a viable option for more people. For off-grid communities, efficient appliances require smaller distributed power systems.

CLASP research has found that in nations with a high risk

Efficient appliances benefit everyone: They save consumers money, help suppliers meet demand, and reduce climate impacts.

of extreme heat and low access to cooling appliances (e.g., India, Indonesia, and Nigeria), doubling global air conditioner efficiency could reduce the overall lifecycle costs of these systems by 43%. This would provide $210 billion USD in annual net customer benefits by mid-century and expand access to an additional 13% of the population—most of them lower- and middle-income households—in those three countries.[34]

In addition to saving consumers money and making air conditioning financially viable for more people, doubling efficiency would also bring considerable public health benefits. This solution could prevent more than 22,000 premature deaths each year across India, Indonesia, and Nigeria.[35] As global temperatures rise, cooling is becoming even more important for reducing death and illness.

Efficient appliances also provide many other vital climate adaptation benefits. Rising temperatures and increasing instances of extreme weather raise the risk of food insecurity due to drought, extreme heat, and other challenges in the agriculture sector. Appliances can be used to help farmers adapt to a warming world and bolster food security.

In addition to protecting communities from climate impacts, appliance efficiency is an important tool for preventing the worst effects of global warming. To limit global temperature increase to 1.5°C, the world must achieve a 43% reduction in greenhouse gas emissions by 2030,[36] which is 17 times higher than the current emissions reduction projections.[37] CLASP has found that the appliance sector is responsible for nearly 40% of global energy-related Co_2 emissions. Appliance efficiency can substantially reduce these emissions, in addition to enabling end-use electrification and grid decarbonization. It also decouples energy growth from emissions growth, allowing energy and climate needs to be simultaneously fulfilled.[38]

Lastly, energy-efficient appliances benefit energy suppliers. (This is true whether this supply runs through a main grid, a mini-grid, or a distributed energy system.) Efficient appliances enable energy suppliers to maximize the amount of consumer demand for energy services they can meet with a given amount of energy supply. This ability is critical for managing load growth sustainably and maintaining profitability.

2. Public investments can address appliance market failures

Market failures prevent underserved people from accessing critical appliances

Global appliance markets are mature, with an established, well-functioning ecosystem and integrated international supply chains. The global market for home appliances alone is valued at around $800 billion and is projected to exceed $1 trillion within the next few years.[39]

However, these markets do not spill over into underserved communities, even for appliances that could easily transfer into environments with an unreliable electricity supply. Not enough investments are going into promoting appliances for use in off-grid environments or expanding ownership of existing off-grid products.

Appliance markets for underserved communities face a common set of market failures in weak- and off-grid areas. These products remain out of reach in these communities because markets are nascent, early-stage, or, in some cases, nonexistent.

Market failures limiting access to appliances in underserved communities are typically observed in three different ways, through a common set of underlying factors: lack of credible policy, absence of consumer confidence, and a weak market ecosystem.

Lack of credible policy

Government policies are critical prerequisites to directing investments and engaging markets on universal energy access. Credible policies serve as important signals that give markets confidence to invest in these areas, grow markets, crowd in new players, and spark innovation. (Examples of public investment are explained later in the report.)

Despite this, many governments have yet to identify clear policy intent and targets for achieving universal electricity access. For example, almost 80% of African countries still lack clear targets to achieve universal electricity access by 2030.[40]

Governments must also go beyond policy, however. To be credible, policies must be backed by funding and political commitment. Implementation of those policies must provide market players with confidence that energy access is a priority and that meaningful change is underway.

This lack of credible policy to address electricity access seeps into the markets for appliances in underserved communities. These areas are not regarded as national priorities or economic growth centers and therefore fail to draw market players to supply power or appliances.

Recent initiatives are supporting governments to establish important reforms and quantify the investment needs from public and private sources toward meeting that goal. For example, the newly launched Mission 300 aims to connect 300 million Africans with electricity by 2030. The program is focusing not only on connections to electricity, but also on how that electricity will be used to improve lives. As of June 2025, 12 countries had signed Mission 300's National Energy Compact, which lists specific policy actions that governments will undertake to integrate energy access within their broader energy sector plans.[41]

Absence of consumer confidence

Many consumers do not yet have confidence in the appliances available in weak- or off-grid areas. For example, ownership of four solar appliances useful to consumers in weak- and-off-grid areas has achieved less than 2% of the estimated market potential, according to CLASP research.[42] The lack of consumer confidence may reflect concerns about the performance, durability, efficacy, after-sales services, or warranty of the products. The absence of credible policy and the lack of a robust market ecosystem also combine to undermine consumer confidence in available appliances.

In most cases, consumers will defer or avoid purchases of appliances if they don't have enough confidence in the benefit those appliances will provide. Often their decisions to avoid purchases are attributed to the fact that they cannot afford the products. It is equally likely that consumers are avoiding purchases not because the product is expensive or that it wouldn't provide them with adequate returns; rather, they may perceive the risks of the product's failure or its underperformance to be too high.[43]

Consumer confidence in appliances is critical to establishing the demand for those appliances. Only the actualization of this demand through improved access to appliances will provide the market ecosystem with the confidence needed to crowd in investments, innovation, and new participants.

Achieving consumer confidence requires appliance companies to adopt sales approaches tailored to off-grid areas, where dispersed populations acquire new products through word of mouth and in-person demonstrations.

Market players are essential in expanding consumer choice, unlocking investment, and helping transform under-served areas into vibrant appliance markets.

Weak market ecosystem

Weak- and off-grid areas often lack a critical mass of appliance and equipment markets serving residents. The relative scarcity of market players means that consumers lack product choices and markets are unable to crowd in investments, consumer credit, and innovation at the scale required.

The absence of credible government policies, perceptions about the lack of consumer demand, and lack of consumer affordability all contribute to a weak market ecosystem. Another key barrier is a lack of technical capacity and adequate skills in the local workforce. Consequently, the markets remain highly reliant on grants and public finance, which thus far haven't been large and consistent enough to transform these segments into vibrant demand centers.

Public investments are needed to address market failures for improved access to appliances

Market failures limiting access to appliances will not disappear on their own. Overcoming them will require broad, sustained interventions matched by significant increases in public investments. Governments must play the leading role, establishing energy access as a key priority and forging an ecosystem that draws in market players, financial institutions, and customers.

Interventions aimed at increasing access to appliances must specifically address the market failures outlined in Table 3.

TABLE 3 Addressing market failures for appliances

	Credible policy	Consumer confidence	Market ecosystem
Observed appliance and equipment market failures	Governments lack credible policy and clear goals and targets	Consumers lack confidence in products	Market players aren't numerous enough
Underlying factors for market failures	Not regarded as a priority by government	High risks of poor product durability, performance, efficacy, warranty; non-existent after-sale service	Uncertainty about consumer demand for appliances weakens the business proposition
Impacts of market failures	• Low demand for appliances • Insufficient public and private investments in appliance access • Limited product diversity • Not enough innovation • No enhancements to the technical skills and capacity of the local workforce Together, these impacts stunt economic growth, which reinforces the lack of economic and financial viability of strengthening electricity supply infrastructure into weak- and off-grid areas		
Response strategies to address market failures	Drive government action to establish clear policies, goals, targets, and reform measures Back policies with strong implementation and commitment to generating adequate public finance to enable the transformation	Enhance product quality and standards, improve consumer awareness, crowd in consumer credit, and strengthen product performance and warranty guarantees	Support market ecosystem development with training, business incubation, supply chain development, and enabling the flow of private capital

These responses to market failures could be delivered through many different pathways. However, all pathways require public investments to succeed.

Many governments have utilized public investments to improve energy access, increase adoption of climate-friendly technologies, and seed broader market transformations. They have used a wide range of different instruments to achieve these goals. For example, direct subsidies that reduce the upfront or ongoing operating cost for consumers are common. Governments have also routinely provided fiscal incentives such as grants, tax breaks, other forms of direct payments based on production, interest cost subsidies, debt guarantees, risk-bearing equity, and other hybrid instruments.[44]

The case studies below demonstrate how governments have utilized public investments to address underlying market failures and galvanize broader transformation in the appliance sector.

- **Ambitious policies in India.** Over the last decade, India has been the greatest success story in improving access to electricity. Between 2014 and 2018, it provided electricity connections to 135 million additional people—a figure that accounts for 60% of the global increase in access in that period.[45] This success highlights how credible policy coupled with public investments can secure transformative gains.

  In 2014, the government of India committed to achieving universal household access to electricity by 2018. It matched that goal with a long-term plan to provide $4 billion USD in central government grants and leverage another 15% to 40% from distribution utilities and financial institutions.[46] The implementation strategy included an interactive digital dashboard to track progress as well as a national program to expand and enhance electricity distribution networks.[47]

  India's supply-side pathway to universal electricity access benefited from parallel efforts to scale adoption of LED lightbulbs. In 2015, India launched the Unnat Jyoti by Affordable LEDs for All program, aimed at transitioning all households to LED use. The program set minimum performance standards for LED manufacturers and used iterative bulk purchasing over several years to drive down costs for consumers. By reducing the cost of owning and operating lighting, the program increased demand for electricity, which in turn helped accelerate rural electrification, transformed India's lighting market to LEDs, and enabled the country to emerge as one of the largest global suppliers of the product.[48]

- **Energy-efficient air conditioning in China.** In 2012, China launched a $2.2 billion USD program to subsidize consumer purchases of energy-efficient air conditioners and computers. This program is an illustration of how public investments and efficiency policies were deployed to enable market transformation and drive consumer choices. Ongoing consumer subsidies, coupled with an aggressive update in 2019 to the country's minimum energy performance standards for air conditioners, unlocked massive growth in air conditioner sales while increasing the market share of the most energy-efficient models from 19% to 56% just two years after the new standards took effect.[49]

- **Electric vehicles (EVs) in the UK.** Between 2010 and 2022, the UK government offered a "plug-in grant" to lower the cost of purchasing an EV for consumers. At the conclusion of the grant program, the government had disbursed $1.9 billion USD in subsidies to consumers to support the purchase of more than 500,000 electric vehicles. Subsidization of the electric vehicle market continues in the UK, with more than $230 million USD in public funds allocated for public charging stations and various other incentive and rebate schemes.[50] Electric vehicles have the potential to drive significant load increases across electricity grids interested in sustainable expansion. Second-life EV batteries could also support cost reduction for mini-grids and distributed energy solution providers.

Public investments and targeted subsidies can also be used to drive broader social and environmental impacts for vulnerable communities. A growing body of research demonstrates the potential for such investments and subsidies to help accomplish specific development outcomes, such as:

- Accelerating adoption of new agricultural technologies that increase yields and modernize smallholder farming systems[51, 52]
- Expanding access to critical transportation infrastructure among lower socioeconomic demographics, strengthening their position in the labor market and increasing overall quality of life[53]
- Extending health insurance coverage to underserved and unbanked populations, driving population-level health improvements[54]
- Increasing access to and uptake of distributed solar energy solutions in off-grid areas[55, 56]

Collectively, this body of research affirms the broader benefits of such public investments and targeted subsidy programs to increase access to appliances as a pathway to universal electricity access.

A mini-grid-powered water pump in action in India, showcasing how ambitious policies and public investments can expand electricity access, drive adoption of modern appliances, and transform communities.

3. Closing appliance ownership gaps requires $38 billion USD of public investments

Analytical framework for estimating public investment needs

Public investments are necessary to correct the market failures that limit access to appliances in off- and weak-grid areas. They must enable governments to formulate credible policies, generate customer confidence in appliances, and expand the market ecosystem to draw in scale-up capital, additional participants, new products, and innovation. These investments need to be financed with grants or extremely low-cost capital with a high-risk appetite.

Addressing these market failures will crowd in additional public and private investments that enable the appliance and equipment markets to mature and scale. Mature appliance markets will create a virtuous cycle where increased electricity demand improves the return on electricity supply infrastructure, attracting more infrastructure.

While there is research outlining investment needs to drive energy-efficient purchasing decisions, little precedent exists for quantifying the public investments needed to address the market failures responsible for the gaps in appliance access. This section presents an estimate of the public investments needed to close appliance ownership gaps and build the pathway to universal electricity access. We discuss CLASP's findings from the detailed modeling that was conducted to estimate the funding requirements for the seven focus appliances. Our analysis draws from a variety of publicly available datasets and existing research and is informed by field research and program experiences from CLASP and other organizations.

Methodology

CLASP's analytical model[iv] estimates the funding required to increase appliance and equipment access by an additional 20% of households in the target geographies, up to a maximum penetration rate of 75% by 2030, whichever threshold is met first.[v] The model assumes a tipping point at a 20% penetration level, after which markets will be able to crowd in required investments and scale to their full potential without further public intervention.

The assumption of 20% penetration as the tipping point represents a best guess due to a lack of evidence from analogous market transformations in the energy and consumer goods sectors. This tipping point will likely vary across countries depending on the broader political, social, and economic environment. Additional public investments aiming to overcome deeper market failures in hard-to-reach and vulnerable communities may be required. From this perspective, the estimates of the required public investments represent an estimate of the minimum financial need.

CLASP's analytical model draws on a combination of historical market data, industry reports, and expert insights to estimate public investment needs and forecast market growth. It incorporates appliance cost trajectories, household income distributions, and prior subsidy program outcomes to project the level of support required to address market failures. The full methodology, including key assumptions and data sources, is provided in the annex.

The results of the analysis are reported separately for Africa and other regions and exclude high-income countries, China, and Turkey. Approximately 85% of the population without electricity access lives in Sub-Saharan Africa,[57] and urgent action and support must be directed specifically to helping countries in this region rapidly close the gap.

Our estimates of the requirements for public investments are categorized into the three market failure segments outlined in the section above and illustrated in Table 4.

Activities listed in the table overleaf are intended to be highly illustrative. In practice, a wide range of activities and interventions involving a broad set of stakeholders could be designed to address the same market failures. There are multiple paths to tackling these market failures.

iv To develop this model, CLASP worked closely with Catalyst Energy Advisors, a boutique consulting firm that focuses on the energy access deficit in emerging markets.

v For the four types of home appliance, the model explores expanding access in all low- and-middle income countries (LMICs) other than China and Turkey. For water pumps and mills, the analysis includes only LMICs in Africa. For walk-in cold rooms (WICRs), the analysis includes only the 47 countries of Sub-Saharan Africa.

TABLE 4 *Addressing market failure for appliances*

	Establish credible policy	Strengthen the market ecosystem	Build consumer confidence in appliances
Public investment goals	Identify access to appliances as well as universal access to electricity as key national priorities Create an enabling environment with credible policies, goals, targets, and financing plan	Enhance financial sustainability for markets Improve technical capacity and skills Crowd in additional investments, financial products, market players, and product innovation	Enhance consumer affordability by reducing consumers' risk of ownership Create demand certainty for appliances
Illustrative funded activities	Provide technical assistance for policy and planning, quality standards and assurance, and consumer awareness	Increase availability of high-risk capital for start-up and early-stage scale Reduce the cost of capital through interest subsidies or guarantees Fund technical and business innovation as well as accelerated commercialization	Offer customer subsidies for appliances Provide guarantees for customer credit, product performance, and warranty
Expected beneficiaries	Governments and implementation partners	Market players, financial institutions, and intermediaries	Consumers and financial institutions or intermediaries

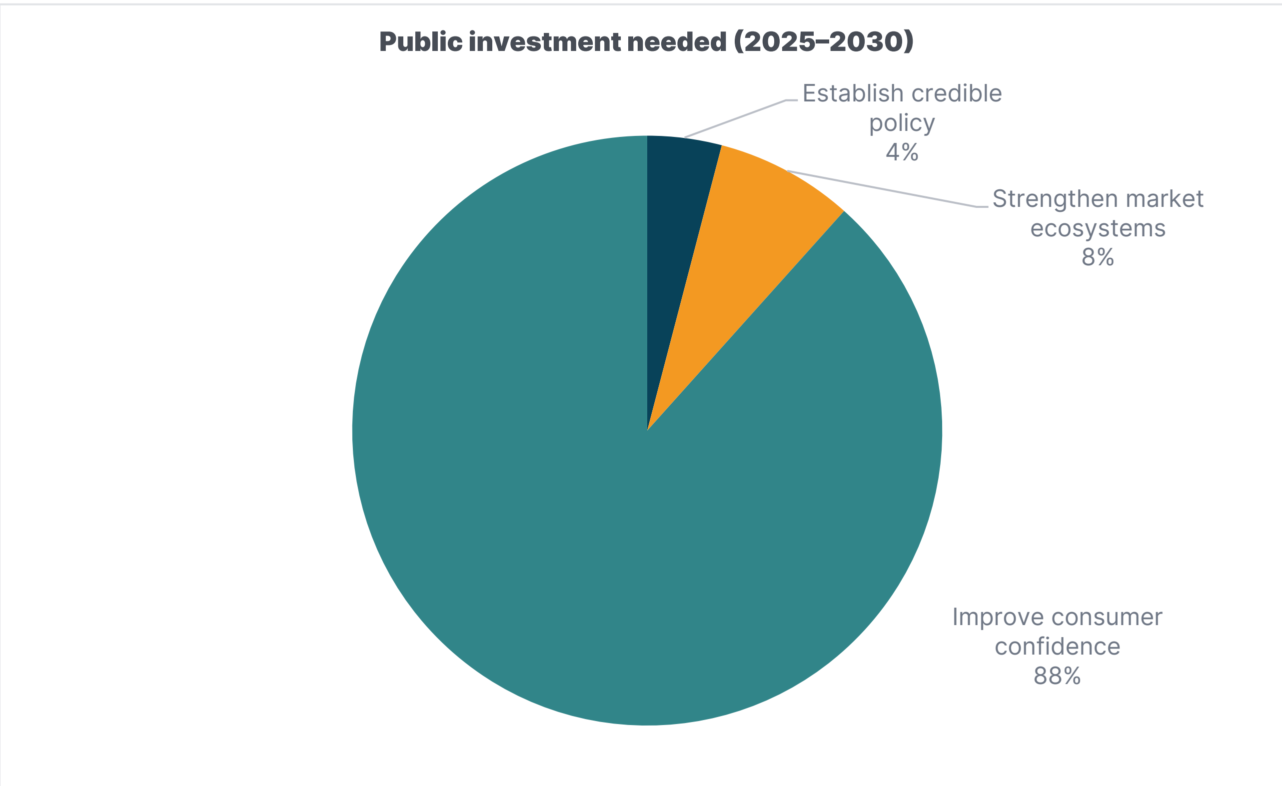
Estimated public investment needs

Total public investments of approximately $38 billion are required between 2025 and 2030 to address the market failures discussed above and close the access gaps for the seven types of appliances identified earlier. Of this total, $15.3 billion, or 41%, must go to support African countries, while the remainder should be invested in other regions. Figure 3 shows how the total public investment needed breaks down across the three categories of market failures.

The largest share of public investment—approximately 88% of the $38 billion USD—will be needed to enhance consumer confidence in appliances. Consumer confidence is the critical driver to helping markets mature because it provides the key signals for certainty in demand and consumer willingness to pay.

Product prices are unlikely to decline significantly prior to 2030 without intervention. Consumer confidence and demand certainty help drive scale, and it is through those

FIGURE 3 Public investment needed by type of subsidy



economies of scale that product prices will ultimately decline. Programs have often used consumer subsidies to generate consumer confidence and build demand certainty, which can then help to reduce the product's upfront costs and risks.

Directing public investment toward consumers ensures appropriate targeting. It allows funds to be used directly to benefit people in underserved, poor, and vulnerable communities that are often the hardest to reach. It capitalizes on end-user demand in those communities to draw appliance markets directly into these areas rather than wait for markets to expand from higher-income areas. It utilizes increased electricity consumption to induce the expansion of power supply infrastructure directly into these underserved areas instead of waiting for it to slowly trickle down from places where power supply is already abundant.

Public investments focused on improving consumer confidence help establish the economic base that is best suited for those communities by giving people greater agency, enabling them to purchase the appliances they most need. Markets then respond to consumer choices and the resulting demand rather than simply redirecting products from other geographies that may not even be relevant.

Table 5 and Table 6 show the amount of public investment needed for each appliance type, the number of units that would be acquired as a result, the implied subsidy per unit of the product, and the average retail price of the product before the subsidies or incentives become available.

TABLE 5 Public investment needed to expand access to home appliances

	Public investment ($ million)		Units acquired (million)		Implied subsidy or incentive ($ per unit)		Retail price ($)
Household Appliance	**Africa**	**Other Regions**	**Africa**	**Other Regions**	**Africa**	**Other Regions**	**All Regions**
Lighting	1,747	358	100	21	17	17	203
Fans	1,579	786	95	126	17	6	27
Refrigerators	6,126	11,177	77	171	80	66	140
E-cooking	5,102	9,856	78	210	65	47	119
Total	**14,554**	**22,177**	**351**	**527**	**42**	**42**	**-**

"Implied subsidy or incentive" is public investment divided by units acquired. Retail price is before subsidies or incentives become available. The retail price shown here for lighting is representative of a high-quality VeraSol-certified solar home system in the 11–20 watt-peak range, which includes the power system and light points. The inclusion of the lights and distributed power system drives up the subsidy requirement needed. This is justified by acknowledging that distributed solar systems will be the least-cost approach to providing this critical energy service. See the methodology annex for more detail. (Source: CLASP analysis)

TABLE 6 Public investment needed to expand access to business equipment in Africa

	Public investment ($ million)	Units acquired (million)	Implied subsidy or incentive ($ per unit)	Retail price ($)
Equipment	**Africa**	**Africa**	**Africa**	**Africa**
Walk-in cold rooms	246	0.17	1,449	16,023
Water pumps	313	6.22	50	650
Milling equipment	208	0.29	727	1,625
Total	**767**	**6.67**	**115**	-

Implied subsidy is public investment divided by units acquired. The price shown for walk-in cold rooms is freight on board starting price, not retail price. See the methodology annex for more detail. (Source: CLASP analysis)

The total public investment required to tackle market failures for business equipment is much lower than for household appliances. This is in large part because we do not apply direct consumer (end-user) subsidy to business equipment, e.g. walk-in cold rooms (WICR), water pumps, and milling equipment. Recognizing that subsidized equipment lowers the business risk of acquiring the asset, we assume the income generated from the equipment should be able to pay down the upfront purchase cost over time. Business equipment may also need other fiscal incentives such as credit, an improved ecosystem for after-sales service, and performance and warranty guarantees.

Household appliances require public investments of $36.7 billion to either achieve a 20% increase in penetration or to reach a 75% penetration rate, whichever target is met first. (This is a conservative estimate, as small and medium enterprises also use many of these appliances. Our analysis, however, attributed use of these appliances only to households.) Of the total public investment needed to improve household appliance access globally, $14.6 billion, or 40% of the need, is in Africa. The rest, we estimate, will go to other countries. For business equipment, achieving 20% of the potential for WICRs, mills, and water pumps across Africa will require an estimated $0.8 billion in public investments.

Appliance ownership, electricity consumption, and financial flows in a full appliance access scenario

Public investments to address the market failures on appliances in underserved communities will drive broader systemic changes and secure universal electricity access. While the benefits of appliance and equipment ownership are broad, this report drills down on how appliance and equipment use can accelerate electricity supply.

- First, public investments will enable the appliance markets to mature, crowding in additional financial flows.
- Second, mature markets will improve access to appliances, closing the ownership gap for these products.
- Third, increased appliance use will result in higher electricity consumption, providing economic viability and financial sustainability to expand power supply infrastructure into weak- and off-grid areas.

TABLE 7 Direct and indirect beneficiaries of public investment

	Direct beneficiaries of public investment (million)			People with improved access once full access is achieved* (million)		
	Africa	**Other Regions**	**All Regions**	**Africa**	**Other Regions**	**All Regions**
Lighting	432	88	520	548	112	660
Fans	409	542	951	1,010	944	1,954
Refrigerators	331	734	1,065	1,094	1,632	2,726
E-cooking	335	903	1,238	1,399	3,272	4,671
Walk-in cold rooms	73	-	73	369	-	369
Water pumps	27	-	27	136	-	136
Milling equipment	123	-	123	621	-	621

**Includes direct beneficiaries of public investment plus others who gain access to the appliance, but not those with access in 2024. (Source: CLASP analysis)*

TABLE 8 Market and electricity demand growth resulting from public investment

			Africa	**Other Regions**	**All Regions**
Directly enabled by public investment	Total units sold 2026–2030 (million)	Appliances	351	527	878
		Equipment	7	-	7
		All types	**357**	**527**	**885**
	Annual public investment 2026–2030 ($ billion)	Appliances	2.9	4.4	7.3
		Equipment	0.2	-	0.2
		All types	**3.1**	**4.4**	**7.5**
	Electricity consumption in 2030 (TWh/yr)	Appliances	89	208	297
		Equipment	3	-	3
		All types	**92**	**208**	**300**
Results once full appliance access is achieved (full market)	Annual sales volume (million units)	Appliances	245	596	841
		Equipment	7	-	7
		All types	**252**	**596**	**847**
	Annual sales value ($ billion)	Appliances	16	39	55
		Equipment	5	-	5
		All types	**21**	**39**	**61**
	Annual electricity consumption (TWh/yr)	Appliances	389	945	1,334
		Equipment	15	-	15
		All types	**404**	**945**	**1,348**

In this table, 'Appliances' refers to household appliances and 'Equipment' refers to business equipment. (Source: CLASP analysis)

This section discusses the financial flows, increased ownership of appliances, and the growth in electricity consumption that would result from using public investments to address market failures. CLASP estimates that addressing the market failures and achieving full appliance access within the regions analyzed could:

- Expand appliance access to an additional 4.6 billion people, more than three times the number of beneficiaries targeted by public investments
- Expand annual sales volume to an estimated 847 million units per year
- Expand the total size of the appliance and equipment market to an estimated $61 billion in annual sales, with public investments of just $7.5 billion per year during the first five years
- Increase the amount of electricity consumed by appliances to more than 1,300 TWh per year
- These results are summarized in Table 7 and Table 8.

GROWTH IN ELECTRICITY CONSUMPTION

Improved access to appliances can significantly increase electricity consumption in weak- and off-grid areas. Assuming the recommended investments, our estimates suggest that the average household electricity consumption from household appliances alone would be 1,110 kWh annually, corresponding to Tier 4 of the MTF (see Table 1). In addition, achieving the full potential of business equipment would add an estimated 330 kWh annually per household served by this equipment (see Table 2). If household appliances and business equipment are combined, the resulting per-household electricity consumption would be 1,440 kWh annually per household, placing them at Tier 4 under the MTF.

In Africa, for example, improved access to appliances could add 342 TWh in annual electricity demand, which is equivalent to 38% of the 905 TWh of electricity generated across Africa in 2022.[58] Such levels of electricity consumption serve as strong inducements and offer powerful economic rationale for expanding and strengthening power supply infrastructure into off-grid areas and improving access in weak-grid areas. Similar impacts can also be expected in other regions that still have significant gaps in electricity access

Climate impacts of improved access to appliances

Improved access to energy-efficient appliances is at the nexus of energy access, climate adaptation, and climate mitigation. Closing the appliance and equipment gaps doesn't just aid the process of improving access to electricity—it could also help avoid emissions and place the planet on a low-carbon development trajectory. For example, a household can lower its greenhouse gas emissions by switching from polluting biomass cooking fuel to electricity generated from a green source.

The impacts of public investments that address appliance market failures will stretch well beyond underserved areas. Improvements in the enabling environment, improved consumer confidence, and stronger ecosystems will apply to appliance markets everywhere, even though the public investment expenditures may be targeted to weak- and off-grid areas.

We compared the full appliance access scenario presented in this report to a business-as-usual scenario in which full appliance access is eventually achieved with incumbent technologies rather than with efficient appliances. For lighting, fans, and refrigerators, we compared the annual energy consumption of efficient units to that of less-efficient units and then converted the difference in energy consumption into avoided emissions using standard grid emissions factors. For e-cooking, WICR, water pumps, and mills, we used recent estimates of the emissions avoided by choosing an efficient solar-powered unit versus the incumbent fossil-fueled technology.

The difference between the two scenarios is 2.6 Gt CO_2 equivalent emissions avoided annually, with 2.4 Gt of the total from e-cooking. E-cooking would be the largest driver of new electricity demand if it is deployed to its full potential. It accounts for such a large portion of the emissions avoided as it is assumed that households are transitioning away from using polluting biomass fuel. Table 9 shows how these numbers break down across products and regions. To put this number in perspective, 2.6 Gt is approximately 39% of the annual emissions reduction the appliance sector must deliver globally in 2040 (6.7 Gt CO_2 /yr) to be on a path to net zero emissions by 2050.[59]

TABLE 9 Emissions avoided by achieving full appliance access with efficient appliances

	Emissions avoided (Mt CO_2 equivalent/yr		
	Africa	**Other Regions**	**All Regions**
Lighting	2	8	11
Fans	10	35	44
Refrigerators	14	50	63
E-cooking	701	1,702	2,402
Walk-in cold rooms	4	-	4
Water pumps	70	-	70
Milling equipment	3	-	3
Total	**804**	**1,795**	**2,598**

Additional detail is contained in the methodology annex. (Source: CLASP analysis)

High-impact, low-distortionary public investment interventions are key

International funding is scarce for all low-income and developing countries, and particularly so for the Sub-Saharan African countries with high gaps in electricity access. Governments in these countries have many competing priorities, and public investments used in one sector have a clear opportunity cost in that they cannot be used in another. Given this, the effective and efficient use of capital is even more imperative, offering no room for leakage, inefficiency, or misappropriations. Smart designs for public investment programs have the greatest chance for success and lasting impact.

The design of public investment programs will vary across regions and countries. Nonetheless, key lessons and best practices from similar programs should guide and inspire the next generation of efforts to achieve universal access to reliable electricity.

Target underserved communities. The impacts of public investments on enhancing universal access to reliable electricity through increased appliance and equipment ownership hinges on how effectively beneficiaries are targeted. Programs that specifically target consumers in weak- and off-grid areas can address market failures more quickly and directly. Programs that target consumers located in areas with good power supply who may not have access to appliances will be less impactful in addressing electricity access.

Align with the scale of challenges. Market failures are difficult to address quickly; they need sustained commitments to ensure resource adequacy. One of the most important design principles for forward-looking public investment programs is to recognize the true scale of the challenge and right-size both investments and timelines.

In some instances, appliances will likely need financial support and incentives for extended timeframes (e.g., more than ten years). Unfortunately, concerns about market distortions and unrealistic expectations often prevent programs from functioning over such a timescale.

Incorporate competitiveness and flexibility. Even with long time horizons, competitiveness and flexibility must be embedded in the design and operations of public investment programs.

A common point of failure of past programs is that the design philosophy stems from overly rigid, proscriptive, and complex structures. This is especially common in the results-based framework, where subsidies or financial incentives available to participating companies, products, or customers remain in place for a prolonged period. Such designs can create distortions in markets by making the subsidy or financial incentive so entrenched that it reduces enterprises' competitiveness and reduces incentives for innovation. This type of long-duration program can depress customers' willingness to pay or foster reliance on the public investment expenditures.

Better alternatives exist. Competitive processes such as reverse auctions, in which companies request financial incentives based on their unique cost structure and experience, incentivize companies to request only as much subsidy as they need to accomplish specific commercial goals. These types of designs also ensure that funding levels are dynamic and can be reduced over time as market activities grow, transaction costs decline, and economies of scale emerge. Sunset clauses within the program that provide the sector with visibility on how long the public investments will remain in place will be extremely useful to creating certainty and galvanizing market responses.

Ensure transparency, monitoring, and safeguards. Public investments programs must be transparent, providing the ability to track where and to whom the funds are going. They must be accompanied by high standards for traceability and include processes that give all investors confidence that those expenditures are going to the right places. Public investment programs must also include strong monitoring, which makes it feasible to evaluate impact. Program design must have built-in safeguards that make it easier to recognize and limit unintended consequences rapidly.

Annex

The full methodology can be downloaded from the report landing page.

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