EFFICIENCY FOR ACCESS

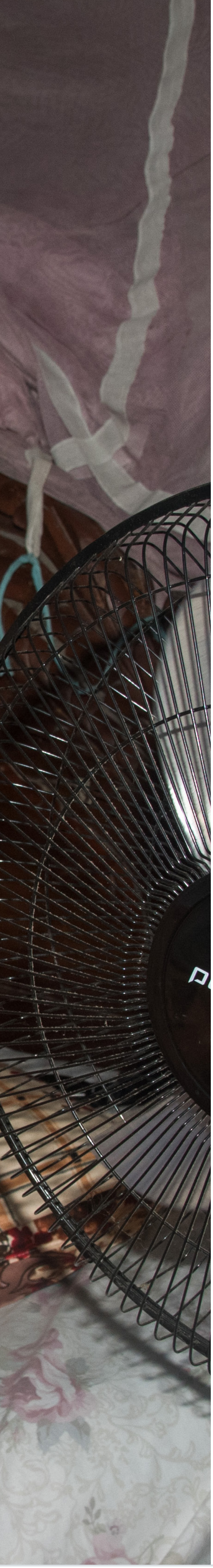
THE WORLD BANK

ALL ACCESS ELECTRIFICATION PATHWAYS

Analysis of the least-cost borne by the end-consumer in receiving higher energy services

JANUARY 2023

EFFICIENCY FOR ACCESS COALITION



Document Title: All Access Electrification Pathways

Acknowledgements

This report was written by CLASP Efficiency for Access team members, Nyamolo Abagi and Asif Hassan, with review from Makena Ireri and Ari Reeves.

The study was commissioned by CLASP and made possible by funding from the World Bank/ESMAP, with co-funding from UKaid through Efficiency for Access.

THE WORLD BANK

UKaid from the British people

INTRODUCTION

Energy access investment in support of SDG7 has focused largely on the provision of energy supply via grid extension or distributed renewables, while comparatively little attention has been paid to energy demand. As many solar home system (SHS) and mini grid developers, electric utilities, and investors can attest, supplying energy without a reliable expectation of demand can lead to serious revenue problems. Not only does a lack of demand mean a lack of profitability for energy suppliers and an inability to scale up to higher service levels, it also means that some consumers are not able to extract more than basic service from their home energy systems.

In response, a disjointed array of demand stimulation activities have cropped up, rightly focused on developing high-quality, energy-efficient appliances for both productive and consumptive use that meet important consumer energy service needs. Despite efforts by institutions such as the Efficiency for Access Coalition and Lighting Global towards standardization and promotion of affordability, quality, and efficiency, off- and weak grid appliance markets remain fragmented and underdeveloped. Consumer choices remain limited, and households who have invested in one energy supplier's technology platform typically have no clear or cost-effective path to scale up to higher tiers of energy service.

Without a consistent vision for how to deliver both the supply and demand side of SDG7 simultaneously, the result will be more technology islands, stranded assets, poor quality deployments, greater amounts of e-waste, and failures in consumer confidence; costs that will ultimately be borne by the world's most vulnerable consumers, well-meaning investors, and the environment.

OBJECTIVE

This research effort was intended to test the hypothesis that a more holistic approach to clean energy access – one that takes into account energy service delivery through affordable, energy-efficient, high-quality appliances AND energy supply through distributed renewable energy systems designed for future compatibility and interoperability – will open new "All Access Electrification Pathways" that off-grid and weak-grid consumers can follow through all possible routes to enhanced energy access. Standardising key aspects of the energy service value chain from the bottom up – starting with affordable, high-quality energy-efficient appliances and equipment – can minimise the public, private, and social costs of delivering SDG7, thereby enabling more effective conversion of private- and public-sector investments into improved, expanded, and sustainable energy access.

Standardising key aspects of the energy service value chain from the bottom up—starting with affordable, high-quality energy-efficient appliances and equipment—can minimise the public, private, and social costs of delivering SDG7

METHODOLOGY

This document presents the findings of a Life Cycle Cost (LCC) analysis used as an indicator of the total cost of energy services borne by a consumer over a 10-year period. LCC is a method of assessing the total cost of asset ownership that factors in the costs of acquiring, owning, and disposing of the asset. The LCC formula used in the MS Excel-based analytical model[1] considers:

- Initial capital expense - upfront appliance purchast cost, electricity connection fees, cost of storage and PV as applies to the energy supply source. Our baseline analysis assumes that the consumer is purchasing the most efficient appliances available in the market.
- Operating expenses - primarily electricity tariff costs for grid and mini-grid consumers. For ease of analysis, interest charged on credit purchases (which is how majority of sales are likely to happen) is not factored in.
- Replacement and service costs - based on assumptions of the lifetime of components, and/or technology incompatibility or obsolescence.

It should be noted that the generation costs for mini-grids and grid extension costs are not factored into the LCC analysis. It is assumed that these costs are reflected in the tariff costs, amortised over time, or subsidised by a government or development partner.

Table 1: LCC Analysis Methodology

CONSUMER ARCHETYPE	COUNTRY	SCENARIO
Labour Migrant	Bangladesh	Base

SHS SYSTEM COMPONENT	RATING	NUMBER OF UNITS	RUN TIME (HOURS/DAY)	COST (USD)	LIFETIME (YEAR)	NOTES
50 Wp SHS				363		50 Wp SHS package includes 4 LED bulbs, 1 15" TV, and 2 mobile chargers
Battery (55/60 Ah)				50	5	
Charge Controller				10	10	
LED Bulb	3	4	6	20	10	
15" TV	10	1	3	106	5	
Mobile Charger	5	2	1	15	5	
Annual Operation and Maintenance				1.28		
Labour, Transportation, and Miscellaneous				15		

YEAR	REAL COSTS (IN $)	
0	$363	Formula: Year 0 (up-front cost of the PV system)
1	$1.28	Formula: Annual Operation and Maintenance Cost
2	$1.28	Formula: Annual Operation and Maintenance Cost
3	$1.28	Formula: Annual Operation and Maintenance Cost
4	$1.28	Formula: Annual Operation and Maintenance Cost
5	$1.28	Formula: Annual Operation and Maintenance Cost
6	$187.28	Formula: Combination of TV Price, Mobile Charger Price, Battery Price, Annual O&M, & Labour Cost
7	$1.28	Formula: Annual Operation and Maintenance Cost
8	$1.28	Formula: Annual Operation and Maintenance Cost
9	$1.28	Formula: Annual Operation and Maintenance Cost
10	$1.28	Formula: Annual Operation and Maintenance Cost

1. All Access Electrification Pathways - LCC Analytical Model.xlxs

CONSUMER SEGMENTATION & ELECTRIFICATION PATHWAYS

Findings from extensive desk research indicate that in the next 10 years, un- and underserved consumers' energy needs will possibly be met by the following options:

Supply Side

- Modularised Solar Home Systems (SHS) - standalone PV systems that allow for expansion of PV and storage over time to power an increasing number of appliances
- Micro-grids with regulated and/or subsidised tariffs
- Grid extension characterised by low, medium and high reliability

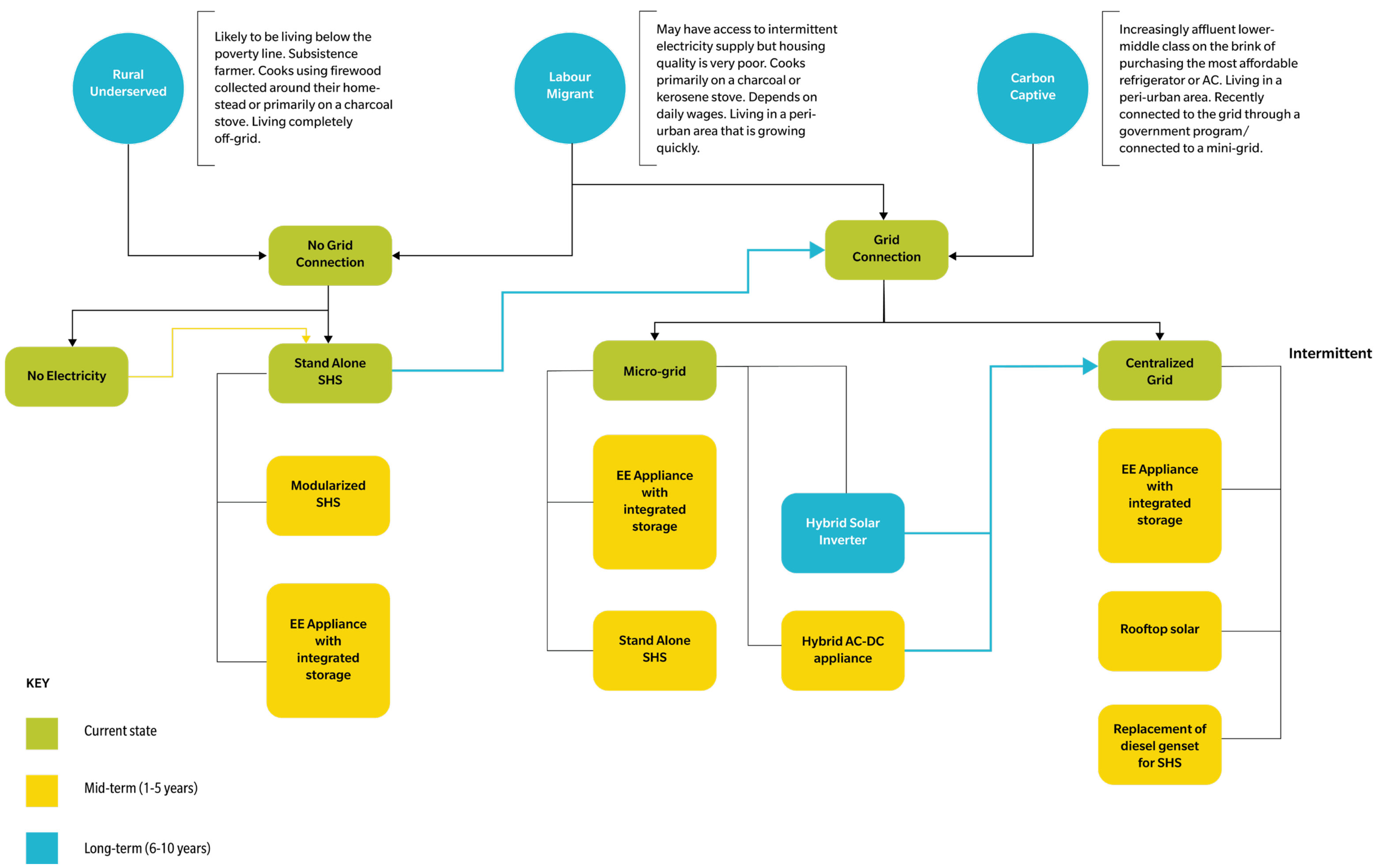
Demand Side

- Energy efficient appliances, including appliances with integrated battery storage
- Hybrid AC-DC Appliances (HAD) that can be powered by both AC and DC power sources

Our research began by identifying three consumer groups (or archetypes) as shown in Figure 1:

- Rural underserved - completely off-grid consumers likely to be living below the poverty line. They primarily practice subsistence farming. Their source of cooking fuel is firewood collected around their homestead or primarily cook on a charcoal stove.
- Labour migrant - economic migrants commonly living in an informal settlement in a peri-urban area that is growing quickly. Their housing quality is very poor and they cook primarily on a charcoal or kerosene stove. They depend on daily wages and may have access to intermittent electricity supply.
- Carbon captive - increasingly affluent lower-middle class living in a peri-urban area on the brink of purchasing the most affordable refrigerator or AC. They recently got connected to the national central grid through a government programme or are connected to a mini-grid.

Figure 1: Consumer segmentation and electrification pathways



It is assumed that over 10 years, as some form of economic development happens in their community, the consumer will have access to new or alternative energy supply options. The consumer however does not have a choice in their energy supply source as these investments depend on externalities beyond their control i.e., grid extension may happen if in accord with the government's electrification plan and the availability of development finance, a mini-grid may be installed by a private investor backed by impact investment capital etc.

Constrained primarily by cost, the consumer will need to make a choice of which energy services to acquire and how to power the appliances needed to deliver those services. Our research focuses on the consumer's energy service journey mapped by the following four scenarios:

- Base: For each of the consumer groups identified above, the consumer's energy service journey begins with a home package that consists of four light bulbs, phone charging capability for two phones, and a small TV for entertainment and information needs.
- Segment: In this scenario, the consumer opts to continue using existing appliances with their current energy source till the appliances reach their end of life. The new energy source is used to separately power new energy services. For example, if the consumer was using a standalone SHS for lighting and mobile phone charging, when the grid finally arrives in their community, the consumer decides to continue to use the SHS to meet their lighting and phone charging needs. The new grid connection is then used for new energy services e.g., cooling or heating.
- Upgrade - In making this choice, the consumer decides to replace existing appliances that can only be powered by the legacy power source and purchase new products that are compatible with the new energy supply. For example, if the consumer started with a 12V SHS powering low-voltage DC appliances, when the consumer gets connected to an AC mini grid, they choose to replace their SHS system and accompanying DC appliances with new AC-powered appliances that can be powered by the mini grid.
- Interoperable - In this scenario, the consumer has access to both AC and DC energy sources and the consumer's appliances can be powered by either power source. The consumer has a more flexible choice in deciding when and which appliance to power with either power source.

LIFE CYCLE ANALYSIS: LABOUR MIGRANT

Most of the world's fastest growing cities are in Asia and Africa. It is estimated that between 2018 and 2050, Africa's urban population will triple and that of Asia increase by 61% (UN,2018). The growth of urban population will be driven by two primary factors: firstly, rural to urban migration, secondly, the expansion of cities. While there are many factors that drive rural to urban migration, the leading pull factors are perceived higher incomes, better infrastructure, education, and health. Consequently, the unplanned proliferation of rural migrants to urban areas often leads to high rates of unemployment, poor sanitation, increased crime rates, a shortage of basic amenities, and myriad of other related socio-economic challenges. In parallel, as economic growth increases, cities will expand or become more urbanized. As such, in the absence of effective urban planning and better socio-economic policies to meet the demands of the growing population, the expanding cities are at risk of facing similar challenges as those posed when a city experiences an influx of rural to urban migrants.

Our analysis focusses on energy service provision for potential labour migrants (one of the three consumer archetypes previously identified) in Bangladesh. Bangladesh is the world's 8th most populous country with an urban population of over 21M. The nation's capital Dhaka is expected to continue growing at an average rate of 3.5% per year.[2] While Bangladesh has made large strides in reducing the number of people living below the poverty line, the gap in electrification between rural and urban areas remains high. SHS installations in rural areas are largely attributed to IDCOL's SHS program that, as of 2019, had financed 4.13 million installations.[3] In recent years, the country's Sustainable and Renewable Energy Development Authority (SREDA) has been focussed on increasing its grid connected PV capacity. In 2018, it reported additions of 27.34 MW of grid-connected PV in comparison to 26.32 MW of standalone PV projects.[4]

Grid reliability is a major challenge in urban areas in Bangladesh. Consumers experience regular power cuts due to the imbalance between energy supply and increasing demand. Given the challenges with grid reliability, the government's interest in expanding the country's PV capacity, and the continued expansion of Dhaka, our analysis focuses on energy source transition of a labour migrant in Bangladesh. To set the scene, the migrant, seeking greener pastures, moves into a peri-urban community that is primarily off-grid and purchases a small SHS (year 1). Their new community is growing very quickly and has been identified as a viable site for mini grid development.

2. Source: https://worldpopulationreview.com/world-cities/dhaka-population
3. Source: https://idcol.org/home/solar
4. Source: https://www.pv-magazine.com/2020/01/06/grid-connected-solar-outpacing-remote-installations-in-bangladesh/

ANALYSIS OF DIFFERENT SCENARIOS

Our LCC analysis for the labour migrant is further defined by the following scenarios as illustrated in Figure 2:

- Base: The consumer starts as a low consumption consumer with basic energy needs that are met with a SHS appliance package. Rated at 50Wp, the SHS package includes 4 LED bulbs for lighting, phone charging (2 mobile charges a day), and one small 15" TV for information and entertainment. All the appliances are DC powered.

The migrant's household gets connected to an AC mini-grid in year 3. Our analysis assumes that over 10 years, with increasing incomes, the consumer's energy needs also increase. In year 3, and likely with credit support, the consumer purchases a small radio and pedestal fan. In year 4, they purchase an electric pressure cooker, and in year 5, a small refrigerator. The consumer thus has 3 possible pathways to follow to optimize for cost and energy service delivery:

Energy source transition with additional appliances

1. Upgrade - Given the limitations to the size and number of devices that can be powered by a 50Wp SHS, in this scenario, the consumer chooses to transition fully to the AC mini grid. The user fully retires their SHS and purchases new AC appliances that can be powered by the mini-grid.

Energy source mix and appliance stacking:

2. Segment - In this scenario, the consumer decides to continue to power their low-voltage appliances--lighting, phone charging, TV--with their 50Wp SHS and uses their mini-grid connection for additional services--cooking, refrigeration.

3. Interoperable - Our final scenario looks at an interoperable option where the consumer starts their energy service journey with interoperable basic appliances--lighting, phone charging, TVs. In year 3, the consumer adds an AC/DC pedestal fan. E-cooking is still most viable on AC power and hence the consumer purchases an AC EPC in year 4. In year 5, the consumer completes their energy service package with a highly-efficient standalone AC/DC refrigerator.

Figure 2: Life Cycle Cost Analysis summary for labour migrant with transition to mini-grid with unsubsidised tariff

ENERGY SOURCE	YEAR 1-2	YEAR 3	YEAR 4	YEAR 5-10	LCC
Base		User begins energy journey with a small DC SHS to meet basic lighting, phone charging, and information/entertainment needs. In year 3, the user gets connected to a mini-grid. In deciding the most cost-effective way to get increased energy services, the user has three choices as explored below.			
Upgrade	User completely switches to mini-grid in year 3 to power all appliances.				$4492
Segment	Base appliances powered by solar for 10 years. New appliances powered by mini-grid.				$4501
Interoperable	User switches to mini-grid in year 3 but purchases an efficient AC/DC fridge powered by a standalone SHS				$4428

DISCUSSION

Our analysis shows that the interoperable pathway is the most cost effective for consumers in the long-term. Given the grid reliability issues in Bangladesh, the use of 50Wp SHS as a back-up is commonplace. This demand for back-up systems has led SHS suppliers like Super Star Group (SSG) and Rahimafrooz Renewable Energy Limited (RREL) to provide a "free" adapter to their customers so they can power their DC appliances with the AC grid. Acting as a convertor, the adapter takes in 220V AC and converts it to DC power for the appliances connected to its output ports, consequently achieving interoperability. While these systems were designed with a grid connected user in mind, this demand driven product improvement feature when adopted in an off-grid context (as described in the interoperable scenario above), offers the consumer the clearest pathway to integrate with a changing energy supply source.

Because our analysis utilises highly efficient appliances, the real cost driver for the end consumer is the mini-grid tariff. Currently in Bangladesh, the difference between the levelized cost of electricity for mini-grid consumers is much higher than the regulated tariff for grid consumers; at USD 0.38/kWh, the average mini grid tariff is 7.6X greater than the average national grid tariff (USD 0.05/kWh). Given that the higher tier appliances – cooking, cooling, demand 42.8X times more energy than is needed for basic energy services (1713 kWh vs 40kWh respectively), in whichever energy mix, the cost of the tariff greatly impacts the consumer's monthly energy bill.

Although subsidies have supported the expansion of national power grid systems around the world, the use of public money to finance solar mini-grids is less common. These subsidies are particularly important as mini-grids are often serving less affluent consumers. We further explore a scenario where a capital cost subsidy brings down the average mini-grid tariff from USD 0.38/kWh to USD 0.10/kWh.

While the capital cost subsidy does not bring the mini-grid tariff to parity with the grid, this reduction in the average cost/kWh reduces the overall cost for the end-consumer by about 50% across all scenarios as seen in Figure 3.

Our analysis shows that the interoperable pathway is the most cost effective for consumers in the long-term. Interoperability offers the consumer the clearest pathway to integrate with a changing energy supply source.

Figure 3: LCC for Bangladesh labour migrant with subsidised mini-grid tariff

ENERGY SOURCE	YEAR 1-2	YEAR 3	YEAR 4	YEAR 5-10	LCC
Upgrade	User completely switches to mini-grid in year 3 to power all appliances.				$1956
Segment	Base appliances powered by solar for 10 years. New appliances powered by mini-grid.				$2035
Interoperable	User switches to mini-grid in year 3 but purchases an efficient AC/DC fridge				$2078

It should however be noted that in this revised analysis, the interoperable scenario now becomes the most expensive pathway. The cost is primarily driven by the upfront cost of the standalone AC/DC fridge. While this highly efficient fridge consumes less energy than a similar sized AC refrigerator (ratings of 182 Wh/day and 415 Wh/day respectively), the upfront purchase cost of the AC/DC fridge is 2X that of the less efficient AC fridge (USD 461 for AC/DC fridge vs USD 230 for AC refrigerator) as it includes the cost of built in PV and storage capacity to enable it to run autonomously. This presents an opportunity for further evaluation to quantify the longer-term climate and environmental benefits of highly efficient solar appliances. Furthermore, while there isn't a significant difference in the LCCs for all scenarios, it is evident that for low-consumption users, solar appliances can deliver the same level of energy service as traditional AC appliances at a cost that is not vastly different in the long-term.

CONCLUSION

Our research considered different electrification pathways for a rural to peri-urban migrant in Bangladesh and evaluated the least cost pathway for the consumer during their transition from an off-grid setting to a mini-grid system. Our analysis developed a series of demand-led scenarios starting from basic energy consumption and gradually increasing appliance loads for higher levels of energy services. Pegged on the Life Cycle Cost (LCC) methodology, as an indicator of the total cost borne by the consumer for energy services over a period of 10 years, our analysis reveals that in the long-term interoperability is the least-cost electrification pathway for consumers of this archetype.

Our analysis integrated data from efficient appliances identified through various Efficiency for Access (EforA) programs. This is not always the case for underserved customers, who often buy locally available appliances that are generally less energy efficient than those tested by EforA. Furthermore, in Sub-Saharan Africa, unlike Bangladesh, SHS meeting basic energy needs are often sold as low-voltage DC appliances with no provisions for interoperability. As such, in energy transition scenarios, these consumers will be left with stranded assets, warranting additional evaluation of a possible least-cost electrification pathway in a context where interoperability is not built into product design.

For achievement of universal energy access, the grid of the future will need to comprise an increased deployment of small-scale generation and distribution systems working in parallel to the traditional AC grid and decentralized mini grid. These systems will need to be managed by intelligent software agents that are better suited to demand responsiveness. To further minimize the total cost of energy, all relevant stakeholders will need to be engaged in the planning, design and delivery process. For instance, policy makers need to use evidence-based data to inform capital investments for grid densification and stimulate the market for private sector investments in decentralized systems. Product manufacturers need to deepen their understanding of consumers and iterate on technology improvements. In parallel, market facilitators can direct consumers to data that enables them to make informed choices on energy spend decisions.

While limited in scope, this analysis is aimed at forming a foundation by which further analysis can take place. Given discrete energy source choices, the findings present an opportunity to evaluate how policy and technology efficiencies can lower overall costs and allow for wider energy service provision. A sensitivity analysis can be further conducted on the analytical model to evaluate:

- The effectiveness of tariff and/or appliance subsidies
- Effect of appliances subsidies that bring down the upfront purchase cost of highly efficient appliances
- The ideal energy generation mixes
- Amorisation of the cost of grid/mini-grid infrastructure development vs. SHS deployment
- Opportunity for cost savings while using appliances with built-in storage or modularised SHS that grow with consumer's needs
- Opportunities for further technology efficiency improvements and its impact on the total cost of purchase and lifetime cost of service

For achievement of universal energy access, the grid of the future will need to comprise an increased deployment of small-scale generation and distribution systems working in parallel to the traditional AC grid and decentralized mini grid.

EFFICIENCY
FOR
ACCESS

CONTACT US

efficiencyforaccess.org

info@efficiencyforaccess.org

@EforA_Coalition

CREDITS: All photos are stock or property of the Efficiency for Access Coalition