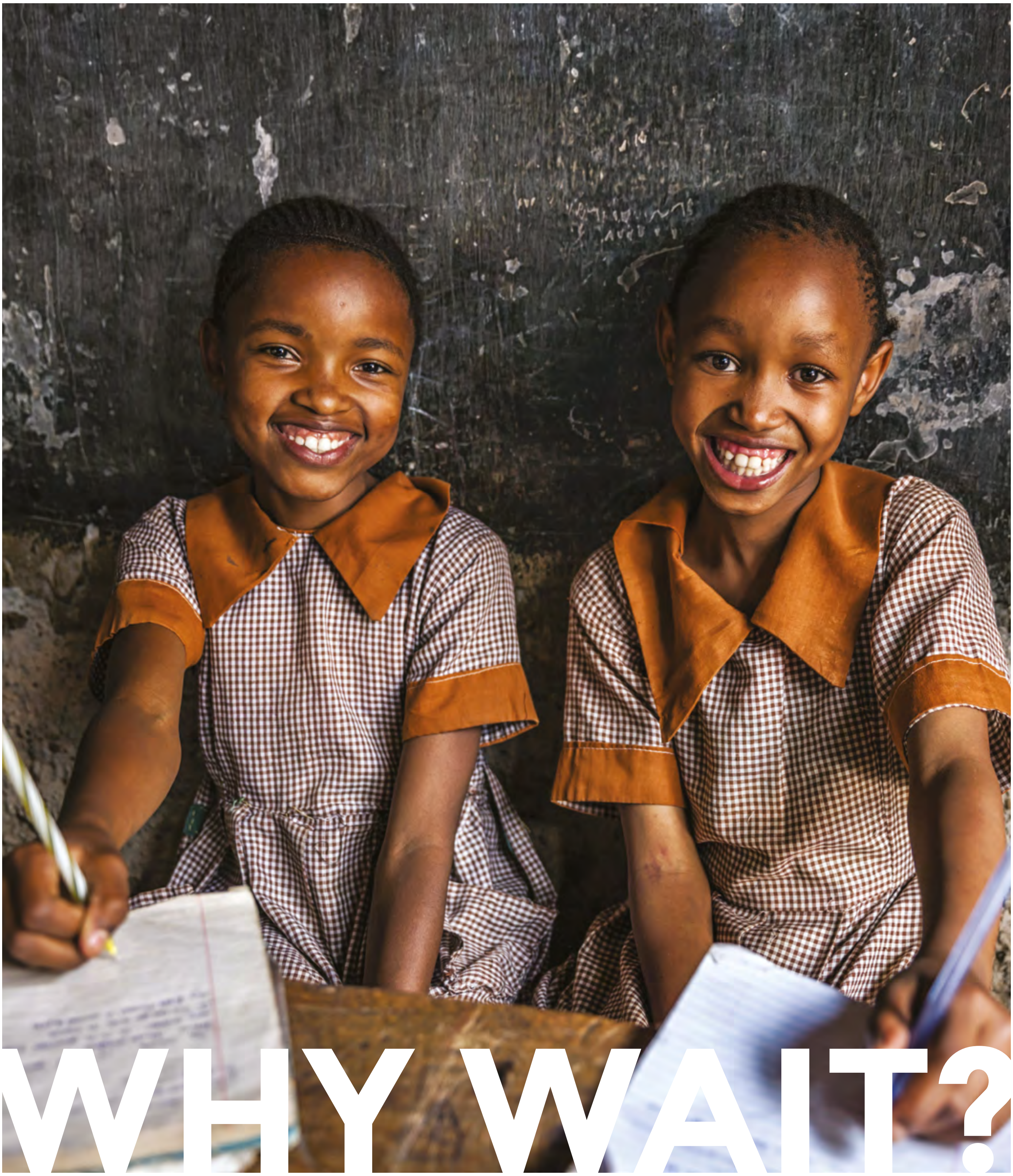

WHY WAIT?

SEIZING THE ENERGY ACCESS DIVIDEND

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FOREWORD

In recent years, as the world has focused on the size of the energy access gap and how to close it, it has been assumed that there are many benefits that would come with that access. It seems obvious that light in the evenings should help children study at home, contributing to a higher level of education. A health clinic that has reliable electricity would presumably provide better health services—and outcomes—to the community it serves. Burning less kerosene or animal dung or charcoal indoors to cook, because there is now a solar induction stove in the corner, should improve the family's health.

But despite how clear this seems, quantifying these gains—the dividends—to vulnerable populations from getting electricity access more quickly—or the missed opportunities of living without power for many more years, or even decades, remains challenging.

Sustainable Energy for All (SEforALL) and Power for All commissioned the Overseas Development Institute to provide a model framework that will help decision-makers evaluate the economic, social and environmental benefits that households and countries can expect through accelerated access to decentralized electricity, such as solar home systems and mini-grids. This first attempt to create a quantifiable approach helps provide a picture of these dividends based on the amount of energy service that is delivered across populations that are currently without power. It assigns economic, social and environmental values to the time it takes for households and businesses to obtain the benefits associated with access to energy.

Why Wait? Seizing the Energy Access Dividend, comes at a key juncture for countries that have agreed a goal of universal access to sustainable energy by 2030, but remain behind schedule in getting there. Finding affordable, reliable pathways to close the access gap on the schedules enshrined in the goals is now a priority. However, closing the access gap must compete with other development priorities. Understanding how energy access can support achieving multiple development goals and how affordable it can be is a critical piece of the decision-making puzzle that has been missing to date. We hope this initial framework will lead to bolder, more accelerated, national electrification plans.

By creating a quantifiable approach, this unique framework is a key first step in helping government leaders, planners and the international community assess the comparative advantages of energy products, services and systems in achieving the Sustainable Development Goal of universal access to sustainable energy by 2030—framed by appropriately valuing the time to access in the equation.

The report, which uses Bangladesh, Ethiopia, and Kenya as illustrative examples, estimates the dividends that could accrue by delivering power more quickly to under-served households in these countries. These benefits are significant for individuals, families and the broader society. However, they are lost forever when households must wait years—sometimes decades—for electricity service.

There's a growing body of evidence showing that electricity access can be provided more quickly and affordably when distributed renewable energy is integrated with centralized solutions. A Power for All report in 2016 showed that large-scale centralized projects can take many years to deliver service while home solar systems can be installed in less than a month.

The *Energizing Finance* collaborative research series that SEforALL released in September 2017 also shows that the amount of international and domestic finance committed to boosting household—level electricity access is far lower than what is needed and that a very small percentage of the funds committed flow to decentralized energy solutions in the countries with the largest energy access gaps.

Why Wait is a first report. The research and data can be made more comprehensive as we extend the work. However, in this first iteration the model framework shows positive benefits of delivering decentralized energy services earlier to those lacking electricity in Bangladesh, Ethiopia, and Kenya. The report indicates that households can save hundreds of dollars—equivalent to the average annual income of between 61,800 and 406,000 people depending on the country and timeframe to deliver universal access—by using solar for lighting and mobile phone-charging instead of kerosene and external phone-charging services. Another benefit from decentralized services is more time for studying—equivalent to the time spent in school each year of between 142,000 and 2 million students depending on the country and timeframe to deliver universal access. Black carbon emission reductions across these three countries—and scenarios for universal access—are significant and estimated at between 15 million and 330 million metric tons of carbon dioxide equivalent emissions.

These lost savings and study times equate to foregone investments in the potential contribution of children and families that no society can afford. This is powerful additional evidence for governments as they evaluate their electricity access strategies. They point to the gains from seizing opportunities to accelerate access in rural areas by scaling up decentralized services that can be delivered more quickly and affordably.

Why Wait helps refine the policy choices in front of decision makers. With this dividend framework in hand, we can ask, "What is stopping us from enacting policies and mobilizing investments into affordable energy services that can provide entire generations with wide-ranging, quantifiable benefits today?"

Technology, finance, economic understanding and now a dividend framework are coming together to make the goal of universal sustainable energy access achievable. This should stir political will to prioritize and push forward towards the goal. Together, we can go further, faster.

RACHEL KYTE
Chief Executive Officer of Sustainable Energy for All (SEforALL), and Special Representative of the UN Secretary-General for Sustainable Energy for All.

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EXECUTIVE SUMMARY

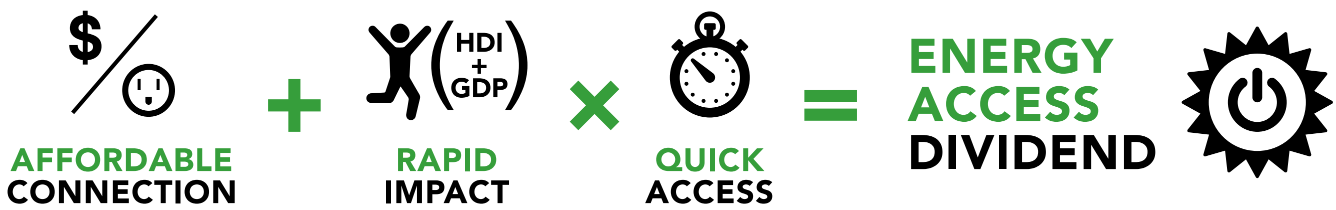
Universal access to modern energy services is a prerequisite for poverty eradication and an enabler of human and economic development. Across the world, one in every five people live without access to electricity (IEA and World Bank, 2017). Most of the 1.06 billion people lacking electricity access live in rural Sub-Saharan Africa and South Asia. Using current projections, 674 million people will still be without access to electricity in 2030, the target year for universal energy access under the Sustainable Development Goals (SDGs) (IEA, 2017). This prolonged energy access gap will profoundly compromise achievement of SDGs on poverty and inequality, education, public health, and climate change, among others.

The need to accelerate access to electricity raises important questions about how best to do this and the arguments that could be made to accelerate access in the face of potentially competing priorities. For example, what would be lost, in terms of human and economic development, if progress were slower than it needs to be. The recent rapid uptake of distributed renewable energy systems, the drop in technology prices and the higher efficiency of appliances have increased the range of viable electricity options and the speed at which electricity access can be provided. Different technologies provide varying levels, or Tiers, of electricity services as well as economic, social and environmental benefits.

This research paper, *Why Wait? Seizing the Energy Access Dividend*, explores the concept of an energy access dividend that assigns economic, social and environmental value to the time it takes for households, businesses and communities to obtain the benefits associated with electricity access. Such a dividend would allow decision-makers to quantify the benefits of delivering electricity access faster through decentralized electricity solutions rather than through more conventional, centralized grid-based approaches. These conventional approaches are proven to be more time consuming and expensive.

The Energy Access Dividend is a function of the costs of connections, their affordability to different population

FIGURE ES.1 ESTIMATING THE ENERGY ACCESS DIVIDEND



groups, the development impacts of electricity use for various levels of access, and the timing of access (Figure ES.1).

Why Wait? presents a first-of-its-kind approach to developing a framework to understand and quantify the Energy Access Dividend, assess the data and evidence base to support its application at a household and national level, and pilot it in a simplified manner through three country assessments.

This report includes Energy Access Dividend estimates for Bangladesh, Ethiopia and Kenya to demonstrate for government and financial decision-makers how a dividend framework can be used. These three countries were selected due to their wide-ranging differences in terms of income levels, demographics and electrification rates. They also have significant populations without access to electricity.

It is hoped that integrating dividend projections into electrification, development and economic planning, and budgeting decisions, would encourage a sharper focus on decentralized energy solutions. Thus, providing faster, lower-cost access to electricity and accelerating achievement of improvements in people's lives and livelihoods, and national economies.

THE IMPACTS OF ELECTRICITY ACCESS

The multiple services that electricity can provide to households have a variety of direct and indirect impacts. Among these benefits are reduced expenditures for energy services (such as kerosene and mobile phone-charging costs) that can be replaced by direct electricity access; more time available due to electric lights and other appliances; improvements in education, health, and communications; enhanced productivity and income levels; and reduced carbon dioxide (CO_2) and black carbon pollution, which are harmful to public health and contribute to global warming.

This research describes electricity impact pathways and uses them to inform the design of the Energy Access Dividend framework. The capacity of the electricity supply determines the range of services available to households at each Tier of electricity service, as defined by the World Bank's Multi-Tier Framework (Bhatia and Angelou, 2015) (Box ES.1). Households with Tier 2 access, for example, can use general lighting, phone charging and efficient appliances such as televisions and fans. Households at Tier 3 have electricity available for more time and a greater variety of energy services and impacts than at Tiers 1 and 2, because it is possible to use more appliances for longer.

BOX ES.1 THE MULTI-TIER FRAMEWORK FOR MEASURING ELECTRICITY ACCESS

Not all residential energy access is the same. In the case of electricity, for example, some systems may only be available for certain hours of the day or produce only limited power. Recognizing the importance of understanding the different energy access service levels that exist, and how they impact socio-economic development, the World Bank developed the Multi-Tier Framework (MTF) for measuring energy access.

The MTF defines and measures electricity access based on a range of service levels that cover energy for household use, productive engagements and community facilities. It focuses on the quality of energy being accessed, ranging from Tier 1—representing a basic lighting or mobile charging service for a few hours each day—to Tier 5—representing at least 23 hours a day of grid supply. The MTF considers "the ability to obtain energy that is adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy, and safe for all required energy applications across households, productive engagements, and community facilities" from a range of energy service technologies (Bhatia and Angelou, 2015).

FIGURE ES.2 THE NATIONAL ENERGY ACCESS DIVIDEND, GOVERNMENT TARGET SCENARIO

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Power capability	very low	low	medium	high	very high
Hours of electricity available each day	4 hours	4 hours	8 hours	16 hours	23 hours

Financial savings Total ($ million)	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Bangladesh	0	107	214	428	1,473
Ethiopia	9	67	50	67	134
Kenya	18	358	317	98	62

Hours of study Total (million hours)	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Bangladesh	0	200	400	801	2,602
Ethiopia	32	128	96	128	256
Kenya	87	935	829	256	162

CO_2 emissions (t)	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Bangladesh	0	287	573	1,147	3,727
Ethiopia	3	25	18	25	49
Kenya	46	990	878	271	172

Black carbon (million t CO_2e)	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Bangladesh	0	3	6	12	40
Ethiopia	0.05	0.30	0.30	0.30	1
Kenya	3	6	6	2	1

Scale: 0–1,600 0–3,000 0–4,000 0–40

Notes:

- *For Ethiopia, the Government Target Scenario is the dividend from achieving universal access by 2030, the SDG 7 target year, instead of 2031, which is the year universal access would be achieved if the rate of electrification required to deliver the government's planned level of electrification in 2020 is projected forward. This would bring forward universal access by one year.*
- *For Bangladesh and Kenya, the Government Target Scenario is the dividend from achieving universal access in 2030, the SDG 7 target year, instead of the government target year of 2021 and 2020, respectively. This shows the scale of benefits that would be forgone if access were delayed from current plans.*
- *The dividend estimate is determined, among other things, by the assumptions about the distribution of households across Tiers (Section 2.4). In the case of Bangladesh, the assumption reflects the government's intention to expand access primarily through grid connections and focus on larger solar off-grid systems.*

TABLE ES.1 DATA SUPPORTING ASSESSMENT OF HOUSEHOLD IMPACTS FROM GAINING ACCESS TO ELECTRICITY

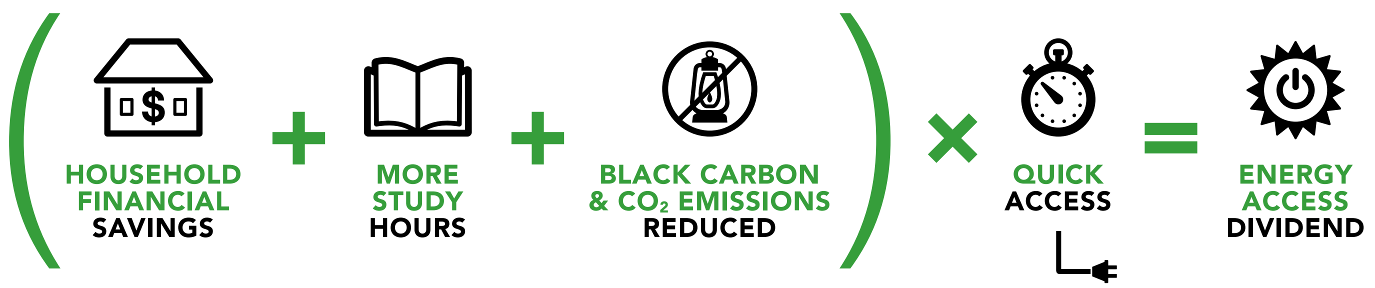
Indicators of household impacts from gaining access to electricity		Units	Availability of research evidence	Supports the achievement of the Sustainable Development Goals
1	Value of savings on household lighting expenditure	$	RELATIVELY STRONG	10 REDUCED INEQUALITIES
2	Use of savings (consumption, investment, savings)	$	GAP	
3	Health status (linked to reduced household air pollution)	DALYs	LIMITED	11 SUSTAINABLE CITIES AND COMMUNITIES
4	Hours spent studying at home	Hours	RELATIVELY STRONG	4 QUALITY EDUCATION; 5 GENDER EQUALITY; 8 DECENT WORK AND ECONOMIC GROWTH
5	Hours spent working to earn income (in-kind or cash)	Hours	LIMITED	
6	Hours spent on domestic/care work	Hours	LIMITED	
7	Value of savings on costs of phone charging	$	RELATIVELY STRONG	5 GENDER EQUALITY; 10 REDUCED INEQUALITIES
8	Access to mobile phone	Percent households	LIMITED	
9	Time required for essential communications	Hours	GAP	
10	Hours spent on leisure and using TV/ radio	Hours	LIMITED	4 QUALITY EDUCATION; 5 GENDER EQUALITY
11	Access to radio and television	Percent households	LIMITED	
12	Access to use of a refrigerator	Percent households	LIMITED	12 RESPONSIBLE CONSUMPTION AND PRODUCTION
Indicator of environmental impact				
13	Climate change (CO_2e) emissions	tCO_2e	RELATIVELY STRONG	13 CLIMATE ACTION

Progression from Tier 3 to Tier 4 or 5 does not necessarily increase the range of services available to a household but does increase the capacity of the electricity supply that is available for each service.

Twenty-one indicators were identified to measure the multiple impacts of electricity use for households, businesses, and community-based public services. A review of empirical evidence for these indicators confirmed that there is currently not enough information available on the impacts of electricity access on businesses and community-based public services to include these in the dividend calculation now. For households, there are information gaps for indicators such as appliance ownership and use, and health impacts attributable to lighting, which prevent their inclusion in the dividend estimates. However, there is sufficient data to proceed with the dividend estimates at the household level for several key household impacts: reductions in household expenditure for lighting and phone charging; increases in time spent studying at home; and reductions in emissions of carbon dioxide (CO_2) and black carbon pollution (Table ES.1).

For these household impacts, the evidence base allows quantifiable measurement but data varies across countries. In several cases, data and evidence of impacts in one country are limited to a small number of studies, which constrains what can be confidently included in an assessment of a country's dividend as well as cross-country analysis. The dividend estimates for Bangladesh, Ethiopia, and Kenya are therefore based on available, locally-relevant data for these three household impacts.

FIGURE ES.3 ESTIMATING THE DIVIDEND FOR HOUSEHOLDS IN THREE COUNTRY CASE STUDIES



A FRAMEWORK TO MEASURE THE ENERGY ACCESS DIVIDEND

This initial Energy Access Dividend framework focuses on direct, short-term, measurable micro-level impacts on households and the environment where empirical evidence is available. Although the impacts of electricity use are felt in the wider economy, these effects are uncertain and evidence is limited on indirect impacts. Therefore, these are omitted from the analysis together with the more intangible effects of access to electricity, such as well-being and personal security.

The framework estimates the dividend for a household in Bangladesh, Ethiopia and Kenya. Annual benefits of electricity access per household are then aggregated across all households without access on an annual basis over a defined time to arrive at a national dividend. The number of households without access to electricity is determined by the total population, average household size, and the rate of electrification.

The framework factors in time differences for delivering electricity access through alternative decentralized and centralized, grid-scale options. Table ES.2 shows the time periods considered in the analysis. Three different assumptions about electrification rates are used to help define expected time periods to deliver electricity access in each country: the government target rate for full electricity access; the rate required to achieve the 2030 universal energy access goal; and an historical rate, based on electrification rates between 2010 and 2014.

The Energy Access Dividend is estimated for two scenarios at the household and national level: access is delivered per the government target year where this occurs before 2030 ("Government Target"); and access is delivered in 2030 rather than a later year based on the historic electrification rate ("SDG 7 Target"). In each scenario, the dividend estimates the benefits based on the difference in years between these alternative electrification strategies, shown in Table ES.2.

The framework proposes an approach to explore the differential benefits of electricity access across the Tiers of energy service (Figure ES.3). This requires knowledge of the current and future distribution of households across Tiers. This distribution is estimated based on a review of available literature on Bangladesh, Ethiopia and Kenya. The distribution can be further refined as the World Bank's Multi-Tier Framework baseline surveys for several low-access countries are completed in 2018.

THE ENERGY ACCESS DIVIDEND FOR BANGLADESH

In 2014, nearly 77 million people in Bangladesh—38 percent of the population—did not have access to electricity (IEA and World Bank, 2017). The government's target to achieve universal access by 2021 will require a significant increase in electrification rates. The government's current emphasis is on delivering centralized grid-scale connections, enabling new connections at higher Tiers of access rather than lower-Tier household solar systems (generally Tiers 1 and 2), which can be delivered faster and at less cost.

The Energy Access Dividend in the Government Target Scenario is described here. It demonstrates the additional benefits that would accrue when universal access is reached in 2021 rather than the SDG 7 target year of 2030. The SDG 7 Target Scenario is described in Section 3.

The household Energy Access Dividend includes total (gross) expenditure savings from reductions in kerosene purchases and mobile phone charging of $217 and $252, depending on the Tier of electricity access. These savings are equivalent to 1.8 percent and 2.1 percent of average annual per capita income. The household dividend includes an additional benefit of 48 hours of home study per year. When considered cumulatively over 2021-30, the total additional home study time is equivalent to 27 percent of a school year for a household. Total CO_2 emission reductions per household over the nine-year period are estimated to be 514 kilograms (kg) and 617 kg, depen-

TABLE ES.2 TIME PERIODS INCLUDED IN THE ANALYSIS TO ESTIMATE THE ENERGY ACCESS DIVIDEND

	Bangladesh	Ethiopia	Kenya
Population (2014, millions)	161	99.4	46.1
Population with access to electricity (2014, %)	62	27	36
Target date for universal access to electricity			
Government target	2021	2031[(a)]	2020
SDG 7 target	2030	2030	2030
Target year based on an extrapolation of the historical rate of electrification over 2010–14	2036	2069	2030
Energy Access Dividend scenarios			
Government Target—Period benefits accrue from access in government, rather than later, SDG 7 target year (years)	9	1[(a)]	10
SDG 7 Target—Period benefits accrue from access delivered in 2030 (SDG target) rather than later year based on historical electrification rate (years)	6	39	n/a[(b)]

(a) For Ethiopia, the Government Target Scenario is the dividend from achieving universal access by 2030, the SDG target, instead of 2031, which is the year universal access would be achieved if the rate of electrification required to deliver the government's current planned level of electrification in 2020 is projected forward.

(b) In Kenya, the dividend is only calculated for the Government Target Scenario as the historical electrification rate achieves universal access in the same year as the SDG 7 target year of 2030.

ding on Tier of access. Annual black carbon reductions are 606 kg CO_2e and 727 kg CO_2e, equivalent to 49 percent and 59 percent of total annual per capita CO_2e emissions.

The national Energy Access Dividend, aggregated across all households receiving access over 2021-30 includes an estimated $2.2 billion in (gross) expenditure savings. This would be equivalent to about $247 million a year or the average annual income of around 185,600 people. The national dividend includes an estimated four billion additional hours of home study by students over nine years which is equivalent to the time that 278,000 students would spend in school over this period. CO_2 emission reductions total an estimated 5,734 metric tons and black carbon reductions of 60.8 million metric tons CO_2e over nine years. Annual black carbon emission reductions are equivalent to about 3.5 percent of Bangladesh's total CO_2e emissions in 2013.

THE ENERGY ACCESS DIVIDEND FOR ETHIOPIA

The Government of Ethiopia has a target to deliver access to connect 90 percent of towns and villages to the grid by 2020. The electrification rate to achieve this 2020 target has been extrapolated forward and indicates that universal access could be achieved in 2031 if progress were to continue at this rate. The benefits that would accrue in terms of financial savings, study time and emissions reduction if this electrification rate were accelerated so that universal access could be delivered in 2030—the SDG 7 target year—instead are presented here. This would bring forward universal access by 1-year. The SDG 7 Target Scenario is described in Section 4.

The household Energy Access Dividend includes total (gross) savings $4 at Tier 1 and $6 at Tiers 2 to 5. These annual expenditure savings are equivalent to 0.6 percent and 0.9 percent of average per capita income in 2016. Each household without electricity misses out on an estimated 77 hours of home study, equivalent to about 5 percent of a school year. CO_2 emission reductions are estimated to be 8 kg and 15 kg, depending on the Tier of access. Black carbon emission reductions are 110 kg CO_2e and 209 kg CO_2e a year depending on the Tier of access which is equivalent to between 7.3 percent and 13.8 percent of annual per capita CO_2e emissions in 2013.

The national Energy Access Dividend for the Government Target Scenario includes expenditure savings of $328 million (about 0.5 percent of total GNI in 2016). Annually, the dividend includes the equivalent of a school year for 1.4 percent of the school-age population. Annual emission reductions included in the dividend, CO_2 and black carbon, are equivalent to about 1.2 percent of Ethiopia's total annual CO_2e emissions in 2013.

THE ENERGY ACCESS DIVIDEND FOR KENYA

In 2014, 36 percent of the population in Kenya, 16.6 million people, had access to electricity. The government reports a significant increase in access since then and has a target for universal access by 2020. The proportion of the population with access to electricity was lower in rural areas (12.6 percent in 2014) than in urban areas (68.4 percent). The Government Target Scenario is described here, where universal access is delivered in 2020 rather than the SDG 7 target year of 2030.

The household Energy Access Dividend estimate includes expenditure savings of $7 to $12 per year, depending on the Tier of access. This is equivalent to 0.5 to 0.9 percent of annual per capita income in 2016. Research evidence suggests a study dividend for boys who will increase the time they study at home of an estimated 32.6 hours a year per household. This is equivalent to about 2 percent of a school year. CO_2 emission reductions are 17.3 kg to 34.5 kg a year per household across these scenarios. Black carbon reductions are between 1,125 kg CO_2e and 2,249 kg CO_2e, depending on Tier, which is equivalent to between two and three years of total per capita emissions of CO_2e in 2013.

The national Energy Access Dividend includes an estimated $853.7 million in foregone (gross) expenditure savings over the ten-year period. Annually, this is equivalent to 0.1 percent of Kenya's GNI in 2016. The dividend includes 2.27 million hours of foregone study at home (by boys), over the ten-year period. The foregone hours of study at home are equivalent annually to the time that 142,000 students would spend in school. The emission reductions total 2,356 metric tons CO_2, and 15.3 million metric tons CO_2e black carbon emissions, over ten years. The CO_2 emissions equal the per capita annual CO_2 emissions of over 357 Kenyans, while the annual black carbon emissions are equivalent to 4.5 percent of Kenya's total greenhouse gas emissions in 2013.

THE DIVIDEND AND AGENDA 2030

Energy Access Dividend estimates show that delayed access to electricity for large numbers of households will delay any direct or indirect contribution to the SDGs, and potentially constrain the achievement of several SDG targets by 2030.

The scale of the estimated dividend for Bangladesh, Ethiopia and Kenya is significant. Savings on expenditures for lighting and phone charging—equivalent to between 0.1 percent and 1 percent of GNI in Bangladesh and Kenya for the Government Target Scenario—potentially increase households' disposable income, thus allowing spending on other goods and services. This contributes to the goal to "end poverty in all its forms" (SDG 1) and to "reduce inequality" (SDG 10), both directly and indirectly. Higher expenditure on goods and services contribute positively to other SDGs, such as, "ending hunger" (SDG 2) or ensuring "healthy lives" (SDG 3).

Additional time spent studying at home contributes to the goal of "inclusive and equitable education" (SDG 4).

Overall, the dividend includes additional study time equivalent to a year's study by 0.1 percent to 1 percent of the total school-age population in Bangladesh and Kenya Government Target Scenario. Moreover, electric lighting will help eliminate educational differences attributable to a lack of electricity access, and thus "ensure equal opportunity and reduced inequalities in educational outcomes" (SDG target 10.3).

Reductions in CO_2 and black carbon emissions—the latter equivalent to 3.5 to 4.5 percent of total annual greenhouse gas emissions in Bangladesh and Kenya Government Target Scenario—contribute to the climate change goals (SDG 13) and pollution-reducing objectives under the Paris Climate Agreement. The reduction in kerosene consumption, and its complete substitution at higher Tiers of access also reduces household air pollution (HAP). While the research evidence on the effects of reduced HAP from lighting is limited, lower particulate emissions have a positive effect on health and can reduce the incidence of acute respiratory infections, which contributes to the "healthy lives" goal (SDG 3).

The quantitative evidence about links between the effects of access to electricity and other SDGs is either inconclusive or unavailable, however some research suggests that access to electricity can have a positive effect on productivity and employment in home-based businesses. This would contribute to poverty eradication (SDG 1) and economic growth, employment and decent work (SDG 8). Further increases in leisure time and use of appliances for entertainment can improve wellbeing and social cohesion. Increased use of television and radio, enabled by access to electricity, can also improve access to information and knowledge, with indirect effects on health, education and productivity.

CONCLUSIONS

It is possible to quantify the dividends of faster energy access. The research provides a structured model framework that enables policy makers to understand and quantify the dividends that accrue from accelerated access to decentralized renewable energy, supporting a policy discussion that goes beyond anecdotes to empirical evidence. It demonstrates it is possible to establish a systematic relationship between access to electricity, the associated development benefits and the time it takes to deliver these benefits through faster, lower-cost deployment of decentralized rather than grid-based electricity solutions.

The benefits of faster energy access can be mapped to other sustainable development outcomes. The research provides a first, objective insight on how to measure the benefits that accrue with accelerated access to decentralized energy services for households in rural and hard-to-reach locations, and how these can contribute to the delivery of other development goals. It maps the impact pathways between energy and the SDGs. It demonstrates the availability of data to quantify the links between delivering universal energy access and SDG 1, to end poverty; SDG 4, to ensure inclusive and quality education for all; SDG 10, to reduce inequality; and SDG 13, to take urgent action to combat climate change and its impacts.

This research provides a unique insight into what we know and do not know about the development benefits that result from energy access. The research maps the development impacts of energy access across different Tiers of energy service, proposes indicators for their measurement, and explores the availability of data for these indicators through a comprehensive review of peer-reviewed and grey literature. It provides a unique insight into the breadth and depth of the evidence—as well as its limitations and gaps—along with indications of the benefits that can be expected for lower Tiers of energy access. It highlights the limitations in data for productive and public community-based uses of energy, and the lack of evidence to disaggregate benefits for higher Tiers of energy service (Tiers 3 to 5). It demonstrates that there is sufficient evidence to quantify financial savings, climate change, and education benefits for lower Tiers of access.

The research shows that benefits are significant for individual consumers and society when energy services are delivered faster. Households with Tier 1 access have measurable benefits from electric lighting and phone charging services compared with households having no access at all. These include reduced energy expenditures and additional hours of home study, as well as unmeasured benefits such as reduced HAP and better access to information. There are also environmental benefits such as reduced CO_2 and black carbon emissions. Access to Tier 2 services are similar, but even larger since dependence on kerosene lighting is almost eliminated. Under Tiers 3, 4 and 5, the benefits are at least equivalent to those of Tier 2, but there may be additional benefits depending on the ownership of appliances. Electricity supply capacity at these tiers is higher, thus enabling broader use of appliances and other electrical equipment for productive activities. This framework provides an order of magnitude estimate of the Energy Access Dividend for Bangladesh, Ethiopia, and Kenya under two universal electricity access scenarios: first, access is provided in line with existing national plans; second, access is delivered by 2030. This shows that benefits are measurable and significant for households and society.

The dividend framework provides decision-makers with an approach to systematically consider the opportunity cost of choosing alternative electrification strategies in national electrification, development and budgetary planning processes. The lost opportunity to households who are years away from electricity access can now be quantified, calculated and added to the decision-making process. Not only is the accelerated delivery of electricity an issue of equity, this first estimate on the Energy Access Dividend for households demonstrates that there are economic and national benefits when the urgency of access is addressed.

The Energy Access Dividend framework suggests that policy-makers should consider alternative values for three key parameters when they are deciding national electrification strategies:

- the year that universal access to electricity is targeted.
- the Tier of access to be achieved by those currently without electricity.
- the annual benefits that will accrue by providing earlier access.

The last of these can be estimated following the approach outlined in this report. With increased focus by financiers and researchers on enhancing data collection and availability it will be possible to expand on this first step towards comprehensive and statistically robust estimates of the Energy Access Dividend. Future work should include:

- providing guidance on how to adapt the framework for the national context and integrating it as an electrification and budget planning tool.
- extending the number of country estimates.
- filling key gaps in data and evidence, such as electricity for productive uses and public community-based services, disaggregation of benefits across Tiers of access, and consistent energy data collection through regular household surveys.
- extending the framework to quantify the Energy Access Dividend from faster access to clean fuels and technologies for cooking.

ABBREVIATIONS

%	Percentage
$	US Dollar
AIM	Access Investment Model
CDM	Clean Development Mechanism
DALYs	Disability Adjusted Life Years
DHS	Demographic and Health Survey
EAD	Energy Access Dividend
GDP	Gross Domestic Product
GNI	Gross National Income
GOGLA	Global Off-Grid Lighting Association
GTF	Global Tracking Framework
GTP	Growth and Transformation Plan
HAP	Household air pollution
ICSU	International Council for Science
ICTs	Information and communications technologies
IEA	International Energy Agency
kWh	Kilowatt-hours, amount of electricity used over time
LEAP	Long-range Energy Alternatives Planning System
LSMS	Living Standards Measurement Study
LULUCF	Land-use, land-use change and forestry
MTF	Multi-Tier Framework
ODI	Overseas Development Institute
REA	Rural Electrification Authority (Kenya)
REN21	Renewable Energy Policy Network for the 21st Century
PV	Photovoltaic
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
SHS	Solar home systems
TA	Technical Assistance
W, kW	Watts, kilowatts
WHO	World Health Organization

GLOSSARY

Benefit foregone: the benefit of access to electricity that is lost when access to electricity takes longer to deliver by centralized grid-based solutions than decentralized electricity solutions.

Black carbon: fine particulate matter made of pure carbon, which is formed through incomplete combustion of hydrocarbons and biomass. It contributes to global warming by absorbing sunlight and interacting with clouds.

Electricity access: the availability of an electricity supply to a household, at any Tier of access.

Energy Access Dividend: the economic, social and environmental benefits of delivering access to electricity faster through decentralized electricity solutions rather than conventional grid-based electrification.

Energy service: the service that electricity enables to be delivered to the consumer, including lighting, heating, cooling, communications, and motive power.

Expenditure quintile: One of five equal groups containing 20 percent of the total population, divided according to the level of household expenditure.

High-impact countries: the 20 countries with the highest absolute gaps in access to electricity measured by population, as identified in the 2017 Global Tracking Framework (IEA and the World Bank, 2017), the latest available data at the time this research was commissioned. For electricity access the countries are: Angola, Bangladesh, Burkina Faso, Chad, Congo (DR), Ethiopia, India, Kenya, Korea (DPR), Madagascar, Malawi, Mali, Mozambique, Myanmar, Niger, Nigeria, South Sudan, Sudan, Tanzania, and Uganda.

Household Energy Access Dividend: the economic, social and environmental benefits to individual households of faster access to electricity through decentralized electricity solutions compared to conventional grid-based electrification.

Impact pathway: the route from consumption of electricity to development impact, via energy services received and their effects on social and economic behavior and outcomes, including to the environment.

Income quintile: One of five equal groups containing 20 percent of the total population, divided according to the level of household income.

Multi-Tier Framework: to measure the quality of the energy supply provided, household relevant energy access benefits are allocated to five "Tiers"—from Tier 1 ("very low level of access") to Tier 5 ("very high level of access"), based on the Multi-Tier Framework developed by the World Bank and supported by SEforALL (Bhatia and Angelou, 2015).

National Energy Access Dividend: the aggregate economic, social, and environmental benefits for a country of faster access to electricity through decentralized electricity solutions compared to conventional grid-based electrification.

Opportunity cost: the loss of the potential benefit from an alternative choice to the one taken.

Propensity Score Matching: A statistical technique used to reduce bias due to unobserved factors when direct comparisons are made between, say, households with and without solar home systems. A propensity score is the probability that a unit (such as a household) with certain characteristics will be assigned to the treatment group, as opposed to the control group.

Tier of access to electricity: the level of access to electricity, as defined by the Multi-Tier Framework in terms of capacity, hours of service and qualitative attributes. There are five Tiers of access, from Tier 1, the lowest, to Tier 5, the highest.

1. INTRODUCTION

Including the goal to "ensure access to affordable, reliable, sustainable and modern energy for all" in the 2030 Agenda for Sustainable Development establishes the vast importance of access to modern energy services for human development and economic growth.

Since its launch in 2011, Sustainable Energy for All (SEforALL) has emphasized that universal access to modern energy services is both a prerequisite for poverty eradication and a fundamental enabler of broader economic development (SEforALL, 2016). Adoption of the United Nations Sustainable Development Goals (SDGs) in 2015, with sustainable energy as the seventh goal (SDG 7), brought expectations that progress towards universal access to modern energy services will be realized in a matter of years—by 2030.

Yet, across the world, one person in five still lives without access to electricity (IEA and World Bank, 2017). This disadvantages them in several ways. It limits their opportunities to improve productivity and earn higher incomes; constrains their education; compromises their health and health care; and limits opportunities to obtain information. Although access to electricity is not a sufficient condition for poverty reduction, it is widely regarded as a necessary condition.

Most of the 1.06 billion people without access to electricity live in Sub-Saharan Africa and South Asia. In Sub-Saharan Africa, over 600 million people lack access to electricity, and in South Asia over 340 million (World Bank 2017b). Over 80 percent of the population without electricity live in rural areas, where average incomes are lower. They rely on kerosene, candles, and battery torches for essential lighting. Access to electricity is strongly correlated with incomes, at household and national levels. People living in poverty are more likely to lack access to electricity than those with higher incomes. Countries with a high incidence of poverty are more likely to have lower levels of access to electricity (World Bank, 2017b).

Current forecasts indicate 674 million people will remain without access in 2030, the SDG target year for universal energy access (IEA, 2017). The average rate of electrification needs to accelerate to achieve the 2030 target. However, progress on access to electricity is uneven across regions and countries. The challenge is especially pronounced in much of Sub-Saharan Africa, where progress on electrification is not keeping pace with population growth. Those gaining access will primarily be urban dwellers (World Bank, 2017b), while rural areas, where most of the energy impoverished reside, risk being left behind.

The ripples from these trends are profound. This is because slow progress on access to modern energy services (SDG 7) means slow progress on other SDGs. Access to energy is critical for poverty eradication (SDG 1), ending hunger (SDG 2), improving health and wellbeing for all (SDG 3), access to drinking water (SDG 6), and industrial development (SDG 8) (ICSU, 2017). Because energy is an enabler of social and economic activity, delay in universal access to modern energy services risks delaying progress towards all SDGs.

The need to increase the rate of improvement in access to electricity raises questions about how electrification is to be achieved and what might be lost—in terms of human and economic development—by continuing slow progress. Conventional electrification strategies, based on investment in centralized power plants and transmission lines, is not advancing fast enough in some countries to keep up with population growth (World Bank, 2017b). It favors those closest to existing infrastructure, and the lead-time for new infrastructure can be many years (Power Africa, 2016). Such strategies may also not be the least-cost option to extend services to new, completely unserved locations. By contrast, less capital-intensive distributed electricity systems, such as solar home systems and mini-grids, have expanded rapidly in countries such as Bangladesh, Ethiopia, and Kenya. Between 2010 and 2016, about 23.5 million off-grid solar systems were sold worldwide, with a 41 percent increase between 2015 and 2016 (REN21, 2017). Although decentralized electricity systems can be a more economical way to provide access to electricity in remote, thinly populated districts, they are often not included in national electrification plans, and are not an investment priority (Box 1.1).

Decentralized systems increase the range of viable options to provide access to electricity, but each option does not necessarily provide the same level of service. Decentralized systems vary widely in their capacity to generate electricity—from a few watts to many kilowatts, from a few minutes to many hours. Therefore, they vary in the services they enable. The binary measurement of access to electricity (access versus no access), which has been the main metric to assess progress towards universal access (IEA and World Bank, 2017), does not capture these differences in the level of service. Nor does it capture the quality of the supply of electricity.

However, the Multi-Tier Framework (MTF) (Bhatia and Angelou, 2015), developed under the auspices of SEforALL, measures access across five Tiers of electricity service: from Tier 1, the lowest, to Tier 5, the highest. As well as measuring the capacity of access to electricity (in watts and watt-hours), the MTF measures access in terms of qualitative attributes, including availability, reliability, affordability, and legality. It provides a means to help understand the differences in the effects of access to electricity at different Tiers or levels of service. This allows assessment of alternative electricity access options.

BOX 1.1 FINANCE FLOWS TO DECENTRALIZED ENERGY SOLUTIONS

Investment in electricity access is falling far short of the levels required to meet the Sustainable Development Goal 7 of providing universal access to affordable, reliable, sustainable and modern energy for all by 2030. Recent analysis undertaken as part of SEforALL's Energizing Finance research series finds that public and private, international and domestic finance commitments for electricity in the 20 high-impact countries averaged $19.4 billion a year over 2013–14. This falls well below the estimated $52 billion needed annually to meet the 2030 objective of universal electrification (SEforALL, 2015 and IEA, 2017). About $6 billion a year in commitments went to increase residential electricity access for medium or high levels of electricity service, primarily at Tier 3 or above.

While an estimated 72 percent of electricity delivered through decentralized solutions, such as mini-grid and off-grid technologies, supported residential uses, only one percent of total trackable finance for electricity committed in 2013–14 across the high-impact countries or roughly $200 million per year in finance commitments were for decentralized energy solutions. This fact is alarming, given that decentralized solutions—alongside centralized energy services—offer enormous promise to provide basic electricity services quickly and at significantly lower costs to rural communities that face the biggest energy access gap. (SEforALL et al., 2017)

1.1 FRAMING THE ENERGY ACCESS DIVIDEND

Policy-makers face a range of critical questions when designing electricity access solutions for consumers who are without services today, particularly those that are in rural and hard-to-reach areas. Considerations include how to approach electrification planning and embrace grid-based and decentralized solutions, what level of energy service should be prioritized for which consumer groups, and how to address concerns about affordability.

The concept of an Energy Access Dividend is to assign economic, social and environmental value to the time it takes for households and businesses to obtain the benefits associated with access to energy (Box 1.2). By creating a quantifiable approach, the Energy Access Dividend is a first step in helping planners, governments and financiers assess the comparative advantages of energy products, services and systems in achieving the development goals of SDG 7—framed by appropriately valuing the time to deliver access. The dividend concept derives from understanding that access to electricity at different Tiers can have differing impacts on social and economic development, and that the rate of providing access to electricity varies between alternative options.

Large-scale energy infrastructure projects can take many years to deliver access, while solar home systems (SHS) can be installed in a few months (Power for All, 2016). The dividend is an estimate of the economic, social and environmental benefits that would be lost, or foregone, by governments choosing to provide access through slower options when faster delivery options are available. Taking this dividend into account in electrification planning and investment decisions, can encourage actions that will hasten electrification rates and bring forward achievement of the universal access goal.

The Energy Access Dividend captures two main concepts. The first relates to *timing*. If Tiers 1 to 2 of energy access can be delivered more quickly through decentralized solutions than Tiers 3 to 5 through a centralized grid, then development benefits will be realized faster. The second relates to the *relative benefits* of low-Tier energy access compared to higher-Tier access. The Energy Access Dividend will be high when low-Tier access can be rapidly deployed through decentralized solutions in situations where good quality grid connections remain a distant prospect.

This report presents for the first time an approach and methodology for a framework to estimate the Energy Access Dividend for different Tiers of electricity service. Its purpose is to demonstrate how a dividend can be estimated,

BOX 1.2 EVOLUTION OF THE ENERGY ACCESS DIVIDEND CONCEPT

The Energy Access Dividend evolved from the concept of the "Energy Access Opportunity Cost", presented in the May 2016 Power for All Call to Action "Decentralized Renewable Energy: The Fast Track to Universal Energy Access" as well as consultations SEforALL held in 2016 in preparing their Strategic Framework for Results (2016–21—Further, Faster Together. The Energy Access Opportunity Cost concept is based on the need to account for the missed opportunities of individuals and nations of not having energy access. More specifically, decisions on which pathways to choose for energy access must include potential gains in health, education, income, and productivity that are not realized when energy access is delayed. The time element and cost differences become multipliers on the underlying "opportunity cost" of large scale projects, as decentralized renewable energy delivers human development and GDP impacts faster and at lower cost to more people in more places (Power for All, 2016).

and then used to help inform decision-making on electrification and funding strategies. The analysis uses three countries—Bangladesh, Ethiopia and Kenya—to illustrate the dividend methodology. Although the data available were by no means comprehensive, the analysis shows that quantification across a small number of indicators in these three countries can still be informative. The dividend estimates in this report—which focus on financial savings, educational benefits, and climate change effects—are significant for social and economic development. Future refinements of the methodology, combined with increased availability of relevant data, will enhance this understanding.

1.2 INTENDED AUDIENCE

This report is geared towards national policy and finance decision-makers and international development partners that are planning, designing, or investing in energy access solutions. By providing decision-makers with an integrated framework through which to assess the benefits at different Tiers of access, the research can help them identify and prioritize pathways to provide electricity access at an accelerated pace. This report is also an introduction to policy, finance and development partners in sectors that are accelerated through early access to energy, such as education, health, rural development, to enable their prioritization of early energy access.

1.3 REPORT STRUCTURE

The framework and methodology to estimate the Energy Access Dividend are presented in Section 2. Energy Access Dividend estimates for Bangladesh, Ethiopia and Kenya are presented in the next three sections. Section 6 discusses similarities and differences between the country estimates, the scale of the dividend, and its links to the Sustainable Development Goals. Conclusions and recommendations for policy-makers, financiers and researchers are provided in Section 7.

2. METHODOLOGY

2.1 APPROACH TO DEVELOPING THE FRAMEWORK

As a first step towards understanding the Energy Access Dividend, the research followed the following steps (Figure 2.1):

- Develop an analytical framework to objectively map different levels of electricity service to the development benefits that result and provide a quantified estimate of the energy access Dividend.

- Review data and evidence to assess if it is possible to measure development benefits that result from electricity access across the Tiers of energy service defined in the Multi-Tier Framework. Explore what is known about the benefits to households, consumers and for productive uses. Identify any limitations or gaps in available data and evidence.

- Pilot the framework in a country context, in a simplified and illustrative way, to test its usefulness for energy planning and decision-making.

- Define next steps to refine and extend the framework for the Energy Access Dividend and support its application in a national context.

2.2 FRAMEWORK TO MEASURE THE DIVIDEND

The Energy Access Dividend is a function of the costs of energy access, their affordability to different population groups, the development impacts of electricity use at different Tiers of access, and the timing of access. Estimation of the Energy Access Dividend depends on the availability of empirical evidence for each of these factors.

2.2.1 IMPACTS OF ELECTRICITY ACCESS

At the heart of the Energy Access Dividend are the impacts of electricity access and use on economic, social, and environmental outcomes. The dividend is the sum of the additional benefits of access to electricity when access is provided sooner than it otherwise would be. If access is provided by options that can deliver electricity almost immediately (for example, over a matter of months for solar home systems), instead of options that have long lead time (of several years, or more, for large-scale transmission and distribution infrastructure), a dividend is realized. If options with long lead times are chosen to deliver access to electricity, the benefits of electricity are unavailable over that period. In other words, the Energy Access Dividend is equivalent to the opportunity cost, in terms of benefits foregone of waiting for other forms of electricity, which take a longer time to deliver.

The impacts of electricity use are felt in the wider economy (macro-level impacts) and by individual consumers (micro-level impacts) (Pueyo et al, 2013). The Energy Access Dividend framework focuses on micro-level impacts, although theoretically it could include macro-impacts. However, impacts of electricity access and use on a country's productivity, incomes and economic growth are uncertain and difficult to predict. The relationship between electricity consumption and economic growth

FIGURE 2.1 STEPS TO DEVELOP THE FRAMEWORK AND DIVIDEND ESTIMATES

1 Develop Analytical Framework

- What benefits accrue when households, businesses, and communities get access to energy?
- What is known about how these benefits change as access moves from Tier 1 to Tier 5?
- How do these benefits support the delivery of the Sustainable Development Goals?
- Develop impact pathways to describe how energy access delivers development impacts—the "Energy Access Dividend framework".

2 Check Data & Evidence

- Review peer-reviewed and grey literature on economic, social, and environmental benefits associated with electricity access.
- Assess where there is robust data and evidence to quantify the benefits identified in the Energy Access Dividend framework.

3 Test Framework

- Develop a simplified analytical model to pilot the framework using available data in three countries (Bangladesh, Ethiopia and Kenya).
- Estimate the dividend for two scenarios: (i) meet SDG 7 target, and (ii) meet national universal access target.
- Quantify the Energy Access Dividend for households, and at the national level, for each scenario.
- Assess if benefits are measurable and meaningful.

4 Define Next Steps

- Provide guidance on how to adapt the framework for the national context and integrate it into energy, development, and economic planning.
- Extend the framework to quantify benefits associated with clean fuels and technologies for cooking.
- Extend the country Epilots to cover the twenty high-impact countries for electricity access.
- Propose research to fill the gaps in data and evidence.

is bi-directional, i.e., economic growth causes increased electricity consumption, and the latter contributes to economic growth (Economic Consulting Associates, 2014; World Bank, 2017b).

The indirect and second order effects of micro-level impacts, such as savings on energy expenditure, can be linked to macro-economic impacts such as employment creation induced by additional expenditure on goods and services made possible by savings on energy expenditure. This initial framework for the Energy Access Dividend focuses on direct, short-term, and measurable micro-level impacts including energy expenditure savings and additional time for study. This approach allows the framework to reflect and highlight the multi-dimensional impacts of electricity access and use, which would not necessarily be revealed by an assessment of macro-level and indirect impacts.

The initial framework also reflects wider, macro-level impacts on the environment from changes in greenhouse gas and black carbon emissions, which result from the adoption of electric lighting. The emission reductions at the micro-level can be readily aggregated, and there is sufficient evidence to provide robust estimates (See Section 2.3).

2.2.2 CATEGORIES OF ELECTRICITY CONSUMER

For micro-level impacts, three categories of electricity consumer can be identified: households, businesses, and public community-based facilities. The distinction between households and businesses may be indistinct in the case of micro- and home-based enterprises. However, in principle, within the household, it is possible to distinguish between productive (economic or income-generating) and consumption uses of electricity.

Sections 2.2 and 2.3 show the impact pathways for electricity use at the household level. Indicators of electricity use by businesses have been well described (Mayer-Tasch et al., 2013) but detailed data and research evidence about impacts following changes in access to electricity are unavailable for many countries (Annex 2). Similarly, data on electricity use by community-based public facilities—such as schools, health facilities, and government offices—is not available in sufficient detail to be included in these initial estimates of the Energy Access Dividend (Annex 2). The dividend estimates for Bangladesh, Ethiopia and Kenya therefore focus solely on the dividends for households.

2.2.3 ESTIMATING THE ENERGY ACCESS DIVIDEND FOR HOUSEHOLDS

The overall approach to estimating the Energy Access Dividend is to first estimate the annual benefits of access to electricity per household. These benefits are equivalent to the benefits foregone by households when they do not have access to electricity. The benefits foregone per household are then aggregated across all households without access, and across the years that they lack access, to provide a national level estimate of the dividend.

Estimates for the Energy Access Dividend are determined by three factors:

1. The number of households without access to electricity.

2. The benefits of access to electricity.

3. The number of years a household is without electricity.

The number of households without access to electricity is a function of the total population, average household size, and the rate of electrification. The Energy Access Dividend estimates for Bangladesh, Ethiopia, and Kenya use World Bank population forecasts,[1] and therefore take population growth into account. The average household size is the national average from the most recent population census. The baseline rates of electrification are from the Global Tracking Framework 2017 (IEA and World Bank, 2017), with alternative assumptions for future rates of electrification.

Five categories of household benefit or impact of access to electricity can be identified from a review of the literature (e.g., World Bank, 2008; Pueyo et al., 2013; Bonan et al., 2014; Pueyo and Hanna, 2015; Lemaire, 2016):

- Savings on expenditures for energy services substituted by electricity, e.g., kerosene, candles, dry cell batteries, and battery and phone-charging fees.

- Changes in time use made possible by electric lights or appliances, including time spent on studying, working, and leisure.

[1] *World Development Indicator: SP.POP.TOTL.*

- Social impacts, including educational benefits, health benefits, entertainment, and better access to information and knowledge.

- Productivity and incomes, from home-based activities, businesses, or employment outside the home.

- Reductions in greenhouse gas and particle emissions from kerosene and candles.

The framework to estimate the dividend is based on the benefits that a household receives annually from access to electricity, across these five categories. The indicators identified to measure these benefits are discussed in Section 2.3.

The Energy Access Dividend should reflect the differential benefits of access across Tiers 1 through 5, as defined by the MTF. As well as estimating the annual benefit to a household of access at each Tier, the framework aggregates benefits across households to estimate the national dividend. For this aggregation, a forecast of the distribution of households across Tiers is required. Unfortunately, such forecasts were unavailable for the analysis, as any data about access to electricity by Tier is rare.[2] Therefore, the Energy Access Dividend estimates for Bangladesh, Ethiopia, and Kenya, assume distribution rates across Tiers of access. The assumptions are discussed in Section 2.5.

The framework should also distinguish between the benefits of access to electricity to populations in rural and urban settings, and between income groups (quintiles or deciles). However, segmentation of the Energy Access Dividend across population and social groups depends on the availability of data about electricity use by different groups, which are unavailable in many countries.

Finally, the framework includes a factor to reflect the difference in time between the delivery of access to electricity by alternative options. This difference in time, measured in years, is multiplied by the aggregate annual benefit of access to electricity, to provide the estimate of the national Energy Access Dividend. In the absence of detailed analysis of when households in each location will be, or are likely to be, electrified through different options, the estimates in this report assume the number of years. dividend estimates are described in Sections 3 to 5.

2.2.4 SUMMARY OF APPROACH IN THIS INITIAL ANALYSIS

The framework for the Energy Access Dividend provides an estimate of the dividend for a household and an aggregate dividend for a country. These estimates are based on population data, available evidence of the multiple benefits of access to electricity, and assumptions about the distribution of access to electricity across Tiers of access (as defined by the MTF) and the number of years between access delivered by alternative options.

To demonstrate the approach, the Energy Access Dividend is estimated for three countries: Bangladesh, Ethiopia, and Kenya. These countries represent different country contexts (regions, average income levels, demographics, rates of electrification). They are all high-impact countries, as defined in the Global Tracking Framework (IEA and World Bank, 2017) and currently have significant populations without access to electricity. Bangladesh, Ethiopia, and Kenya are also included in the analysis in parallel studies looking at financial flows for energy access in 20 high-impact countries (SEforALL et al., 2017; SEforALL, 2017); and from reviews of the literature, country-specific information about the impacts of electricity was known to be available.

The remainder of this Methodology section describes the identification of indicators for the multiple benefits of access to electricity through impact pathway analysis, and the evidence base for each indicator, which allows a quantitative estimate of the Energy Access Dividend. As-

[2] *The World Bank MTF baseline surveys currently underway in several countries will begin to redress this information gap.*

sumptions for the distribution of households across Tiers of access and the periods (years) for the dividend estimate are also presented.

2.3 IMPACT PATHWAYS FOR ELECTRICITY ACCESS

Development of the Energy Access Dividend framework begins with an understanding of how electricity access and use impacts on the economy, society, development and the environment. Electricity provides a variety of services for households: lighting, cooking, and water heating, space heating, cooling, information and communications, and motive power (Practical Action, 2010). These services have a variety of direct and indirect impacts on economic and social development. Some impacts are qualitative and therefore difficult to measure. Some impacts may be felt in the short-term, and others only felt after a period of years.

The variety of impacts from the use of electricity, as identified in systematic reviews of the literature, is shown in Table 2.1. Pueyo et al. (2013) focus on the impact of additional generation capacity, while Pueyo and Hanna (2015) focus on the poverty reduction impacts of different levels of access, including negative impacts.

The different pathways of impacts from electricity use inform the design of the framework for the Energy Access Dividend. The framework needs to differentiate impacts at

TABLE 2.1 TYPES OF IMPACT IDENTIFIED IN THE LITERATURE

Impact of additional generation capacity Pueyo et al. (2013)	**Impact on poverty reduction Pueyo and Hanna (2015)**
Improved livelihoods	Higher income
Increased land value	Higher wages
Energy poverty	Increased employment
Environmental benefits	Creation of new enterprises
Safety	Higher investment
Social benefits	Lower production cost
Improved social services	Better product/service quality
Gender equality	Extension of operating hours
Employment	More consumers attracted
Health	Increased production
Energy cost savings	Higher revenues
Household productivity	Higher productivity
Communication and access to information	Crowding out effects
Increased incomes	Increased debt
Improved quality of life	Inequity
Education	Less employment
	Lower wages
	Longer working hours for women

different Tiers of access, but there is very limited research evidence about these differences. Almost half of the impact studies identified by Pueyo and Hanna (2015) did not allow identification of Tiers of access, while Lemaire (2016) found only four studies (out of 104) that discuss impacts from solar home systems of different capacities.[3]

The capacity of the electricity supply at each Tier of access, in watts or kilowatt-hours, allows identification of the range of services that could be available to households. These are shown in Table 2.2. The pathways to impacts of these services for Tiers 1, 2, and 3 are depicted in Figure 2.2. The energy services made possible by access to electricity at each Tier are shown in the second column of Figure 2.2. The effects that these services have on households are in the third column, and the impacts on

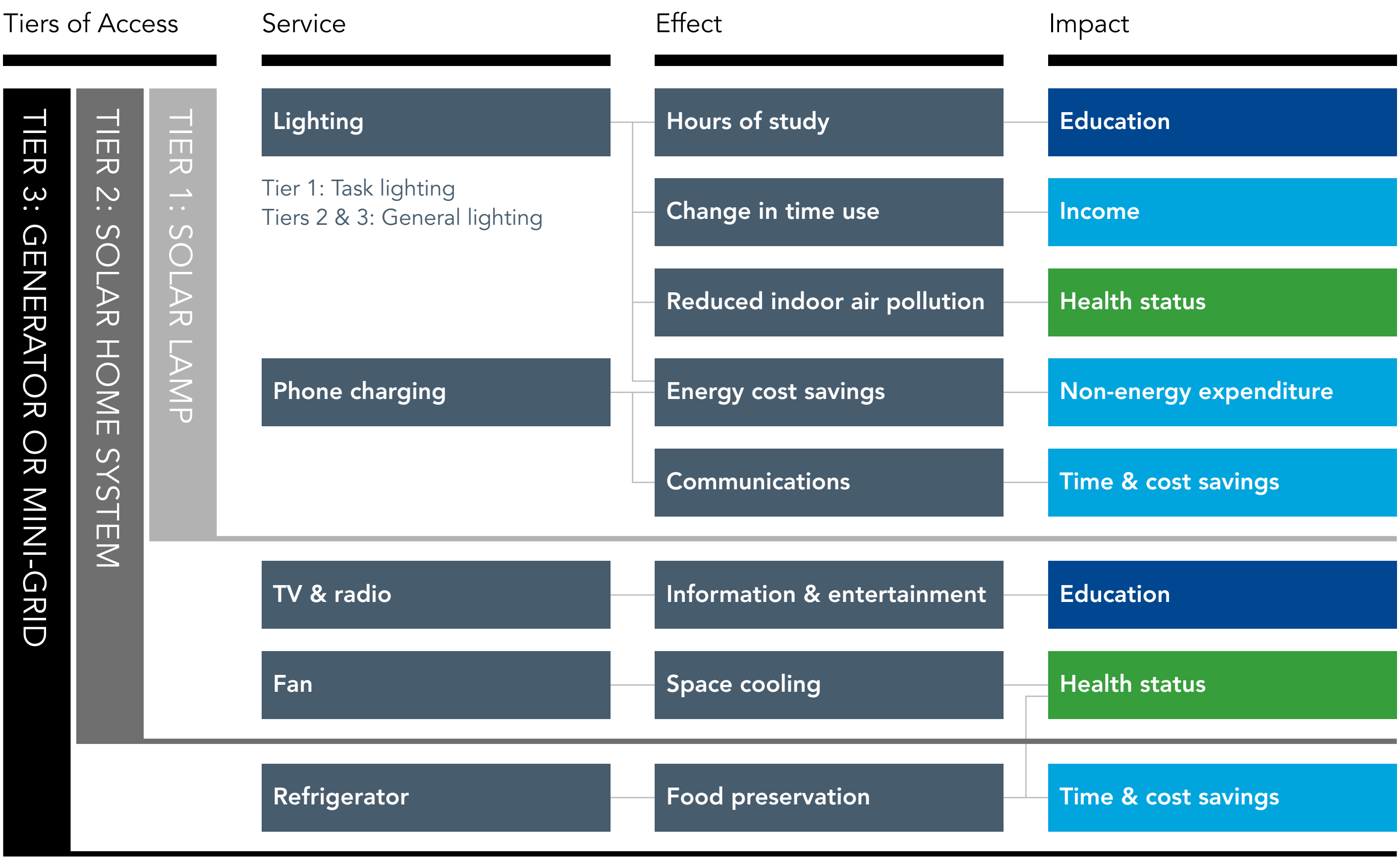
TABLE 2.2 CAPACITY AND SERVICES POSSIBLE AT DIFFERENT TIERS OF ACCESS

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Power capacity	< 3 W	3–49 W	50–199 W	200–799 W	0.8–1.9 kW	≥ 2 kW
Daily consumption capacity	< 12 Wh	12–199 Wh	0.2–0.9 kWh	1.0–3.3 kWh	3.4–8.1 kWh	≥ 8.2 kWh
Annual consumption capacity	< 4.5 kWh	4.5–72 kWh	73–364 kWh	365–1,249 kWh	1,250–2,999 kWh	≥ 3,000 kWh
Services provided		• Task lighting • Phone charging	• General lighting • Phone charging • Television • Fan	• General lighting • Phone charging • Television • Fan • Medium-power appliances	• General lighting • Phone charging • Television • Fan • Medium- and high-power appliances	• General lighting • Phone charging • Television • Fan • Medium-, high- and very-high power appliances
Appliances		• Task lights • Phone charger • Radio	• Multi-point general lighting • Phone charger • Radio • Television • Computer • Fan	• Multi-point general lighting • Phone charger • Radio • Television • Computer and printer • Fan • Air cooler • Refrigerator • Food processor • Rice cooker	• Multi-point general lighting • Phone charger • Radio • Television • Computer and printer • Fan • Air cooler • Refrigerator • Food processor • Rice cooker • Iron • Hair dryer • Toaster • Microwave	• Multi-point general lighting • Phone charger • Radio • Television • Computer and printer • Fan • Air cooler • Refrigerator • Food processor • Rice cooker • Iron • Hair dryer • Toaster • Microwave • Air conditioner • Water heater • Electric cooker

Sources: Bhatia and Angelou, 2015; ADB, 2015.

[3] *Use of the Multi-Tier Framework (Bhatia and Angelou, 2015) is recent, and many studies included in literature reviews pre-date its development.*

FIGURE 2.2 IMPACTS OF ELECTRICITY USE AT DIFFERENT TIERS OF ACCESS



social and economic development are in the fourth column.

As shown in Table 2.2 and Figure 2.2, households with Tier 3 access have greater variety of energy services and impacts. Higher capacity electricity connections at Tier 3, for example, allow the use of more appliances and provide higher capacity for services than is available at lower Tiers (e.g., general lighting instead of task lighting). Progression from Tier 3 to Tier 4 or 5 does not necessarily increase the range of services, but the capacity available for each service increases.

The impact pathway analysis provides the basis for the identification of indicators to measure impacts, and thus estimate the Energy Access Dividend quantitatively.

TABLE 2.3 POTENTIAL INDICATORS FOR INCLUSION IN THE ENERGY ACCESS DIVIDEND FRAMEWORK

	Indicators of household impacts from gaining access to electricity	Units	Availability of research evidence	Supports the achievement of SDG	Supports measurement of SDG indicator
1	Value of savings on household lighting expenditure	$	RELATIVELY STRONG	SDG 10—Reduce inequality within and among countries.	10.1.1—Growth rates of household expenditure or income per capita among the bottom 40 percent of the population and the total population. 10.2.1 – Proportion of people living below 50 per cent of median income, by age, sex and persons with disabilities.
2	Use of savings (consumption, investment, savings)	$	GAP		
3	Health status (linked to reduced household air pollution)	DALYs	LIMITED	SDG 11—Make cities and human settlements inclusive, safe, resilient and sustainable.	11.6.2—Annual mean levels of fine particulate matter (e.g., PM2.5 and PM10) in cities (population weighted).
4	Hours spent studying at home	Hours	RELATIVELY STRONG	SDG 4—Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. SDG 5—Achieve gender equality and empower all women and girls. SDG 8—Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.	4.1.1—Proportion of children and young people: (a) in grades 2/3; (b) at the end of primary; and (c) at the end of lower secondary achieving at least a minimum proficiency level in (i) reading and (ii) mathematics, by sex. 4.6.1—Percentage of population in a given age group achieving at least a fixed level of proficiency in functional (a) literacy and (b) numeracy skills, by sex. 5.6.1—Proportion of women aged 15–49 years who make their own informed decisions regarding sexual relations, contraceptive use and reproductive health care. 8.5.1—Average hourly earnings of female and male employees, by occupation, age and persons with disabilities.
5	Hours spent working to earn income (in kind or cash)	Hours	LIMITED		
6	Hours spent on domestic/care work	Hours	LIMITED		

Indicators of household impacts from gaining access to energy	Units	Availability of research evidence	Supports the achievement of SDG	Supports measurement of SDG indicator
7 Value of savings on costs of phone charging	$	RELATIVELY STRONG	SDG 5—Achieve gender equality and empower all women and girls. SDG 10—Reduce inequality within and among countries.	5.6.1—Proportion of women aged 15–49 years who make their own informed decisions regarding sexual relations, contraceptive use and reproductive health care. 10.1.1—Growth rates of household expenditure or income per capita among the bottom 40 per cent of the population and the total population. 10.2.1—Proportion of people living below 50 per cent of median income, by age, sex and persons with disabilities.
8 Access to mobile phone	Percent households	LIMITED		
9 Time required for essential communications	Hours	GAP		
10 Hours spent on leisure and using TV/radio	Hours	LIMITED	SDG 4—Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. SDG 5—Achieve gender equality and empower all women and girls.	4.1.1—Proportion of children and young people: (a) in grades 2/3; (b) at the end of primary; and (c) at the end of lower secondary achieving at least a minimum proficiency level in (i) reading and (ii) mathematics, by sex. 4.4.1—Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill. 5.4.1—Proportion of time spent on unpaid domestic and care work, by sex, age and location. 5.6.1—Proportion of women aged 15–49 years who make their own informed decisions regarding sexual relations, contraceptive use and reproductive health care.
11 Access to radio and television	Percent households	LIMITED		
12 Access to use of a refrigerator	Percent households	LIMITED	SDG 12—Ensure sustainable consumption and production patterns.	12.3.1—Global food loss index.
Indicator of environmental impact				
13 Climate change (CO_2e) emissions	tCO_2e	RELATIVELY STRONG	SDG 13—Take urgent action to combat climate change and its impacts.	13.2.1—Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the adverse impacts of climate change, and foster climate resilience and low greenhouse gas emissions development in a manner that does not threaten food production (including a national adaptation plan, nationally determined contribution, national communication, biennial update report or other).

2.4 ELECTRICITY ACCESS IMPACT INDICATORS

Development of the Energy Access Dividend framework begins with the identification of a set of indicators to reflect the different kinds of impact identified. A set of 13 potential indicators of household impacts was identified from a preliminary review of the evidence and analysis of impact pathways. These are listed in Table 2.3, which also shows the SDG indicators most relevant to each. A brief description of the data and research evidence for each potential indicator follows. Annex 2, reviews the impact indicators for electricity access for businesses and community-based public services.

INDICATOR 1—VALUE OF SAVINGS ON HOUSEHOLD LIGHTING EXPENDITURE

Reviews of the literature identify reductions in household expenditure on lighting as one of the main effects of access to electricity (Pueyo et al., 2013; Bonan, 2014; Lemaire, 2016). Electricity is used for lighting across all Tiers of access. Recent impact studies focus on the effects of access to off-grid solar lamps and solar home systems (e.g., Lemaire, 2016; Rom et al., 2017), but the effects on expenditure for lighting may not be very different for centralized, grid-based access (Khandker et al., 2012). Most households without electricity access use kerosene for lighting, and many use battery torches or candles, often in conjunction with kerosene (Lighting Asia, 2014). However, kerosene tends to account for most of the expenditure on lighting in households without electricity (Bacon et al., 2010). The Energy Access Dividend, therefore, focuses on the reduction in expenditure on kerosene that results from its substitution by electric lighting.

Evidence from impact studies allows this reduction to be estimated (see Sections 3 to 5). Impact studies use Propensity Score Matching techniques to compare expenditure on kerosene in households with and without access to electricity (usually with or without a solar lamp or solar home system), or compare kerosene consumption in households before and after adoption of electric lighting. Some studies focus on financial expenditure (e.g., Rom et al., 2017), which is subject to variation in the price of kerosene, while others focus on quantities (liters) of kerosene consumed (e.g., Samad et al., 2013). The evidence indicates that Tier 1 access to electricity, providing task lighting, is unlikely to substitute completely for kerosene lighting. However, at Tiers 2 through 5, general lighting is possible, and expenditure on kerosene lighting can be almost eliminated.

The cost of electric lighting should be considered to estimate the net benefit of changes in expenditure on lighting. For households, the costs of access to electricity vary within and between countries, and across Tiers of access. For solar lamps, reductions in kerosene expenditure may allow a payback period of one or two years, after which there are net savings (d.light, 2015). For solar home systems or connection costs to a centralized grid, the payback period may be longer or there may not be a net reduction in lighting expenditure. However, the direct financial comparison between electric and kerosene lighting does not consider the qualitative difference in lighting. When the comparison is made in terms of lumens, or lumen hours, the cost of electric lighting can be several times lower than kerosene (Lemaire, 2016).

INDICATOR 2—USE OF SAVINGS

Several studies suggest that household expenditure on non-energy goods and services increases after access to a solar light or solar home system (e.g., Van de Walle et al., 2013; Khandker et al., 2013; Samad et al., 2013). This appears to be largely driven by savings on expenditure for non-electric lighting, and there is limited evidence of an effect on incomes through additional time on productive activity or productivity improvements.

While it is reasonable to assume that net savings on lighting expenditure are used for consumption expenditure, the absence of detailed evidence about changes in consumption of specific goods and services prevents any

benefits from this being included in the Energy Access Dividend estimate.

INDICATOR 3—HEALTH STATUS

Household access to electricity is expected to reduce illness in two ways. First, reduced household air pollution (HAP) due to reduced consumption of kerosene for lighting, and second, improved availability of health information through radio and television. The substitution of electric lights for kerosene lamps also reduces the incidence of accidental burns. Another route for health benefits, from access to electricity at health facilities, is considered under public, community-based facilities, in the following discussion.

Empirical evidence of the effect of access to electricity on household air pollution (HAP) is limited. In El Salvador, Barron (2014) found a 63 percent reduction, leading to a reduction in acute respiratory infections. A recent study in Kenya, which focused on personal exposure to particulate matter after the adoption of solar lamps, found a 61 percent reduction in the main living space of households and a 79 percent reduction in the rooms of school students (Lam et al., 2017).

While the evidence allows estimates of reductions in particulate emissions to be made, translating this into health impacts is made difficult by the absence of research. One estimate of the health effects of kerosene lamps is an increase in under-five mortality of 2.2 per 1,000 people (World Bank, 2008). Ideally, the health benefits would be measured using the World Health Organization's metric of Disability Adjusted Life Years (DALYs). However, data on burden of disease and DALYs related to HAP do not distinguish between pollution from cooking fuel and lighting fuel, or between solid and liquid fuels.

Similarly, the absence of sufficient evidence about the effect of access to electricity and the use of electric lighting on accidents in the home, and on access to health information, prevents these benefits from being included in estimates of the Energy Access Dividend.

INDICATOR 4—HOURS SPENT STUDYING AT HOME

There is evidence from research in several countries to indicate that access to electric lighting increases the amount of time students spend studying at home.[4] This is perceived to be one of the main benefits of electricity by households without access. Impact studies compare the time that students spend studying at home in households with and without access to electricity, or compare the time students study in households before and after adoption of electric lighting. They find net increases in time spent studying at home, taking account of studying that is switched from daytime hours.

The change in time spent on home study varies across households and countries, and it may vary between social groups. Khandker et al. (2009) found the effect was limited to wealthier households. There can also be gender disparities. In Kenya, for example, in one study, boys studied about half an hour longer than before in households that acquired a solar lamp, while for girls there was no difference (Rom et al., 2017). In Ethiopia, male and female students in about half of the households with a solar home system spent 15-20 percent more time studying at home than in households without electric light (Barnes et al., 2016).

Evidence that the increase in time studying at home improves educational performance is limited, and cannot be generalized across countries. The effect may be subject to local context (i.e., other factors in the education system). In Bangladesh, no effect on exam results was found in households that acquired solar home systems (Kudo

[4] *Including Barnes et al., 2009; Banerjee et al., 2011; Kumar and Rauniyar, 2011; Khandker et al. 2012; Samad et al. 2013; Asaduzzaman, 2013; Azimoh, 2015; Lemaire, 2016; and, Rom et al., 2017.*

et al., 2016); a correlation with grade improvements has been found in Kenya (Hassan and Lucchino, 2014); and in Honduras, there was a reduction in educational attainment following electrification (Squires, 2015).

For the Energy Access Dividend, estimates of additional time spent studying at home are based on evidence from research about the change in the number of hours a day that boy and girl students spend studying at home. The number of students per household is based on the average number of male and female children in the 5–14 age group, from the most recent population census (Table 2.4). The estimates assume that students study at home only on school days, and that there are 200 school days in a year (assuming eight hours per day).

INDICATOR 5—HOURS SPENT WORKING TO EARN INCOME

Research findings on the impact of access to electricity on household economic activity are varied. Several studies indicate that access to electricity at Tiers 1 and 2 has little or no effect on the time spent in productive activity within the household (Brossman, 2013; d.light, 2015; Rom et al., 2017). In Kenya, men were found by one study to reduce the time they spend on productive activities, in favor of increased leisure (Rom et al., 2017). While in Nepal and India, access to electricity results in women spending double the time on income-generating activities (Rao et al., 2016). Women in Peruvian households with solar panels spent less time in productive activities outside their homes than women in households without panels (Arraiz, 2015; in Lemaire, 2016).

There is also limited evidence that following access to electricity, women may increase participation in the labor force, i.e., seek wage employment outside the home (Dinkelman, 2008). However, it is difficult to quantify and relate this effect to Tiers of access.

With access to electricity at Tier 3, there is the potential for low-power appliances to be used in productive activities in the home. In Indonesia, for example, 90 percent of women interviewed for one study reduced the amount of time they spent on agricultural activities by using electrical appliances, for rasping coconuts or chopping chilies instead of doing this work manually (EnDev, 2015). Households with access at Tiers 3, 4, and 5 may purchase appliances to make use of electricity in ways that change the way they spend their time or increase their productivity. Estimates of the Energy Access Dividend in this report assume that there is no significant effect on time spent within the household to earn income, at Tiers 1 and 2. Evidence of an effect at Tiers 3, 4, and 5, is limited and cannot be generalized.

INDICATOR 6—HOURS SPENT ON DOMESTIC/CARE WORK

Access to electric lighting could enable domestic/care

TABLE 2.4 AVERAGE HOUSEHOLD SIZE AND NUMBER OF CHILDREN PER HOUSEHOLD AGED 5–14

	Bangladesh	Ethiopia	Kenya
Year of most recent census	2011	2007	2009
Average household size (number of people)	4.35	4.70	4.30
Boys per household aged 5–14	0.532	0.734	0.615
Girls per household aged 5–14	0.506	0.693	0.596

Sources: BBS, 2015; CSA, 2010; KNBS, 2016.

work to be undertaken after dark, extending the time available for this work or allowing the reallocation of women's time during the day. In Kenya, Rom et al. (2017) found that, on average, women spent 5.1 hours a day on domestic chores, while men spent 1.7 hours a day. This did not change with access to electricity. In India and Nepal, the time women spent on domestic work did not differ significantly between households with and without access to electricity (Rao et al., 2016). Research in the Philippines found that women spent one hour less on domestic work following electrification (World Bank, 2002).

Although access to electricity allows household members to extend their day by one or two hours, some of this additional time may be spent on leisure (see Indicator 10). Rather than change the total amount of time on domestic or care work, the effect of electric lighting may represent a reallocation of women's time during the day. Most women appreciate being able to distribute their household chores more freely throughout the day (EnDev, 2015).

With access at Tiers 3, 4, and 5, which enables the use of appliances for domestic work—the time required for it may be reduced. However, little evidence is available to allow it to be included in estimates of the Energy Access Dividend.

INDICATOR 7—VALUE OF SAVINGS ON COSTS OF PHONE CHARGING

Many households without access to electricity have mobile phones. They recharge their phone batteries at shops and kiosks, or at the homes of relatives or neighbors that have an electricity connection. In some places, they must travel several kilometers to market centers to recharge their phones. In East Africa, for instance, the financial savings when a household gains access to electricity and a phone charger in the home are $0.21–0.31 a month (d.light, 2015; Rom et al., 2017).

These savings are at all Tiers of access. However, the number of mobile phones per household can increase as income increases (James, 2016), and additional savings may be found when a household gains access to electricity at Tiers 4 and 5. Although the information to estimate differential savings across Tiers of access is unavailable, Energy Access Dividend estimates include savings for one mobile phone per household, considering the proportion of households incurring phone-charging costs before access to electricity.

INDICATOR 8—ACCESS TO MOBILE PHONE

Easier and lower-cost phone charging may result in an increase in mobile phone ownership, or the number of subscribers. However, mobile phone ownership in some countries is now almost universal and the effect may only be an increase in the number of phones per household. Access to electricity may not make a significant difference to the proportion of the population owning a mobile phone. There is insufficient household information available for this effect to be included in the Energy Access Dividend estimates.

INDICATOR 9—TIME REQUIRED FOR ESSENTIAL COMMUNICATIONS

This indicator was identified to measure savings in the time and/or cost of essential communications (e.g., for travel) that are made possible by improved access to mobile phones. In Uganda, for example, d.light (2015) estimated these costs to be $0.13 a week. However, with this single exception, the literature does not consider this possible benefit from access to electricity and, due to lack of evidence, it cannot be included in the Energy Access Dividend estimates.

Household access to electricity reduces the time and financial cost of recharging phone batteries. This can result in more frequent battery charging and more frequent use of mobile phones. Collings (2011) noted that the use of mobile phones, measured in paid-for airtime, increased when phone charging became easier and cheaper. An indicator on frequency of mobile phone use may be an appropriate indicator for future dividend estimates.

INDICATOR 10—HOURS SPENT ON LEISURE AND USING TELEVISION/RADIO

Some studies of the impact of access to electricity consider changes in the amount of time spent on leisure activities (Lemaire, 2016), which is related to the amount of time spent watching television. Radio listening receives less attention. In Kenya, Rom et al. (2017) found that men spend twice as much time on leisure as women (2.2 hours a day, compared with 1.1 hours). Men's leisure time increases to 3 hours a day when the household has access to electricity, but women's leisure time is unchanged (Rom et al., 2017). In India and Nepal, Rao et al. (2016) found no difference in the amount of time women spend watching television when the household has access to electricity.

Demographic and Health Survey (DHS) household data for Kenya include the proportion of women and men who watch television at least once a week, by rural/urban location and by wealth quintile (KNBS, 2015). Although the published survey data do not include disaggregation by (binary) access to electricity, this should be possible from the raw data. However, this data is not included in the DHS surveys of all countries, limiting its appropriateness for Energy Access Dividend estimates.

INDICATOR 11—ACCESS TO RADIO AND TELEVISION

Data on television and radio ownership are available from national surveys in most countries (e.g., the DHS in Kenya), but this may not be disaggregated by income or wealth quintile, or related to access to electricity. In Kenya, the data are available for households reliant on kerosene, solar and the grid for their lighting, and for high-income, medium-income, and low-income households. The proportion of households owning a television increases with access to electricity and the proportion is higher for grid-connected households than households with solar home systems[5] (Lee et al., 2016). Data from India show a similar pattern (Aklin, 2016). Although the annualized cost of a television could be used as a proxy for the value of the benefits to the household, the same level of detail about television ownership is unavailable in all countries. The indicator would only be appropriate for Energy Access Dividend estimates in countries where the disaggregated data are available.

INDICATOR 12—ACCESS TO USE OF A REFRIGERATOR

Improved food conservation using a refrigerator can benefit the health of household members and reduce the cost of food (by reducing food waste). The incidence of refrigerator ownership is much lower than for televisions. Lee et al. (2016) found in Kenya that 4 percent of households dependent on off-grid solar for their electricity owned a refrigerator, compared with 17 percent of grid-connected households. Ownership of refrigerators is higher amongst households in higher-income groups (Nzia, 2009), but the available data do not allow assessment of how ownership changes after access to electricity, by Tier of access, or over time. This limits the usefulness of the indicator for Energy Access Dividend estimates.

INDICATOR 13—CLIMATE CHANGE EMISSIONS

Mills (2003) showed that a kerosene lamp with a glass hood emits 98 kg of CO_2 per year. Simple wick lamps emit 33 kg CO_2/year. To overcome the variation in emissions that can be found in practice, the Energy Access Dividend estimate applies the standard conversion factor of 2.4 kg CO_2 per liter of kerosene, which is used by the Clean Development Mechanism (CDM, 2014).

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[5] Sixteen percent of households without electricity owned a television. This increased to 45 percent among households dependent on solar home systems for electricity, and 82 percent for grid-connected households (Lee et al., 2016).

Kerosene lighting also contributes to global warming through the emission of black carbon, which has a much greater warming effect than CO_2, per kilogram emitted. Globally, an estimated 270,000 metric tons of black carbon are emitted annually by kerosene lamps, equivalent to 240 million metric tons of CO_2 (Jacobson et al., 2013). Black carbon emissions vary between different kinds of kerosene lamps and the rate of burning fuel (Lam et al., 2012). To take account of this variation, the average quantity of black carbon emitted per liter is calculated from Tedsen (2013), who estimates emissions savings based on the mix of kerosene lamps found in each country. The black carbon emission factors used for the Energy Access Dividend estimates are presented in Table 2.5.

Reductions in greenhouse gas emissions following household access to electricity are directly related to reduced kerosene consumption. For households with solar lamps or solar home systems, these emissions are reduced (Tier 1) or eliminated (Tier 2 and 3). For households with mini-grid or grid-based connections (Tiers 3, 4, and 5), the estimated reduction should take account of the emission factor of the electricity supplied.

IMPACT INDICATORS OF THE HOUSEHOLD ENERGY ACCESS DIVIDEND

Through the review of evidence available for each potential household indicator, gaps in the availability of information for several indicators were identified which prevent their inclusion in the estimates. However, for some key impacts, the evidence base allows quantifiable measurement. These indicators are included in the Energy Access Dividend estimates presented in Sections 3 to 5. They are reductions in household expenditure (for lighting and phone charging), increases in time spent studying at home, and emissions of CO_2 and black carbon.

2.5 TIERS OF ELECTRICITY ACCESS

The benefits of gaining access to electricity for the first time depend on the level of service acquired. The categorization of levels of access follows the MTF, which defines Tiers of access based on the capacity of the electricity supply, the duration of the supply, the quantity of electricity consumed and qualitative attributes of the electricity supply (Bhatia and Angelou, 2015).

The benefits of access at each Tier are determined by the energy services allowed by the quantity and quality of electricity consumed at that Tier, as shown in Table 2.2. The quantity and variety of energy services made possible by access to electricity increases as the capacity of the electricity supply and the quantity of electricity consumed increase.

For the Energy Access Dividend, a Tier of access needs to be assigned to each household without access to be able to estimate the benefits it foregoes by not having access. Because data about the existing distribution of households across Tiers is very limited,[6] let alone fore-

TABLE 2.5 EMISSION FACTORS FOR BLACK CARBON FROM KEROSENE LIGHTING

	Bangladesh	Ethiopia	Kenya
Black carbon per liter kerosene (grams)	37.43	49.95	23.01
Black carbon CO_2e per liter kerosene (kilograms)	25.45	33.97	15.65

Source: Calculated from data in Tedsen (2013) and Clark (2013).

[6] *The results of the MTF baseline surveys for Bangladesh and Ethiopia were unavailable at the time of this writing. The preliminary findings for Kenya were reviewed (MOEP, 2017).*

casts of the Tier that each household will enjoy when it first gains access, assumptions are made on the proportion of households without access for each Tier (Table 2.6). This is based on a review of literature relevant to each country case study.

The share of new connections at each Tier of access between 2017 and 2030, in Bangladesh, Ethiopia, and Kenya are estimated in SEforALL et al. (2017).[7] These shares take account of government plans and priorities for electrification and estimates of the SEforALL Finance Committee for the expected delivery of access by different methods (SEforALL, 2015). These shares (Table 2.6) are applied as the Tier proportions assigned to the total number of households without access in any year.

It is further assumed that the proportion of households gaining access annually at each Tier is constant over the period of the Energy Access Dividend estimate. Analysis of how households progress from one Tier to another—and how economic growth and other factors influence this—is unavailable. However, SEforALL et al. (2017) estimate the share gaining access at each Tier for the whole period to 2030, consistent with a constant average share in each year.

2.6 TIME

The concept of the Energy Access Dividend is based on the premise that it takes considerably longer to provide access to electricity through extension of a national grid than through decentralized energy systems. The framework to assess the Energy Access Dividend needs to include a factor to reflect this difference in time, if possible, taking account of variations between alternative decentralized systems. The time difference can vary widely between households, depending on location and the options available to them. These options can vary over time as costs change and infrastructure is developed.

National electrification plans provide overall targets for extending access to the national grid and, in some cases, detailed information about when the grid will be extended to specific locations. Increasingly, these plans reflect a least-cost analysis of alternative means to provide access to electricity, to help determine priorities for investment in grid extension. However, it was beyond the scope of this analysis to undertake a detailed examination of the electrification plans of the three countries and their implications for the time factor.

For individual households, an assumption can be made about the period required to achieve access through different systems (e.g., solar home system, mini-grid, grid connection). To aggregate benefits foregone for all households without access, it is necessary to make further assumptions about the proportion that would gain access by each kind of system, and their respective rates of electrification.

Alternatively, the overall rate of electrification and the number of households that gain access before universal

TABLE 2.6 PROPORTION OF HOUSEHOLDS WITHOUT ACCESS AT EACH TIER

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Bangladesh	0 %	5 %	10 %	20 %	65 %
Ethiopia	5 %	20 %	15 %	20 %	40 %
Kenya	10 %	30 %	35 %	15 %	10 %

Source: Taken from SEforALL et al., 2017.

[7] *The delivery methods were grid (urban and rural), mini-grid, rural household systems, and solar lighting (SEforALL, 2015).*

access is achieved can be used to determine the time period for the Energy Access Dividend. First, the average time that a household is without access is calculated for three scenarios, or sets of assumptions, using (a) the rate required to achieve government electrification targets, (b) the rate needed to achieve universal access by 2030, the SDG target, and (c) a recent historical rate of electrification (2010–14). These are shown in Table 2.7.

The Energy Access Dividend was then estimated for two scenarios: access is delivered per the government target year where this is before 2030 ("Government Target"), and access is delivered in 2030 rather than a later year based on the historic electrification rate ("SDG 7 Target"). In each scenario, the dividend estimates are based on the difference in years between these alternative electrification strategies, shown in Table 2.7.

2.7 LIMITATIONS

The Energy Access Dividend concept assesses a multitude of impacts of access to electricity at the household level, which the pathways analysis shows can be varied. Ideally, estimation of the Dividend would be based on quantification of these impacts. Theoretically, this would be possible, provided the data are available and there is evidence to support attribution of impacts to access to electricity. However, the absence of data and research evidence limit what can be practically included in Energy Access Dividend estimates today.

Information is available to allow quantifiable estimates of the benefits of access to electricity for a small number of indicators. For other indicators, national totals and averages may be available, but the data are not disaggre-

TABLE 2.7 PERIODS INCLUDED IN ANALYSIS TO ESTIMATE DIVIDENDS

	Bangladesh	Ethiopia	Kenya
Population (2014, millions)	161	99.4	46.1
Population with access to electricity (2014, %)	38	27	36
Target date for universal access to electricity			
Government target	2021	2031[a]	2020
SDG 7 target	2030	2030	2030
Target year based on an extrapolation of the historical rate of electrification over 2010–14	2036	2069	2030
Energy Access Dividend scenarios			
Government Target—Period benefits accrue from access in government, rather than later, SDG 7 target year (years)	9	1[a]	10
SDG 7 Target—Period benefits accrue from access delivered in 2030 (SDG target) rather than later year based on historical electrification rate (years)	6	39	n/a[b]

(a) For Ethiopia, the Government Target Scenario is dividend from achieving universal access by 2030, the SDG target, instead of 2031, which is the year universal access would be achieved if the rate of electrification required to deliver the government's current planned level of electrification in 2020 is projected forward.

(b) In Kenya, the dividend is only calculated for the Government Target Scenario as the historical electrification rate delivers universal access in the same year as the SDG 7 target year of 2030.

gated enough—by Tier of access, income group, electricity consumption level, or energy service—to be included. For some indicators, evidence for the attribution of an impact to electricity access or use is unavailable (e.g., impact of a reduction in household kerosene consumption on health status).

The availability of data varies across countries and, where data are available, the values for an indicator can differ between countries. Thus, it is not feasible to generalize from the evidence available in one country to other countries. Country-specific estimates of the Energy Access Dividend are required. However, the research evidence about the impacts of access to electricity in individual countries is limited. Within the small number of studies that might be available for a single country, there may be variations in methodology, the number of households included in research, and when the research was conducted. These factors limit what can currently be confidently included in Energy Access Dividend estimates.

This approach to estimating the Energy Access Dividend focuses on quantifiable effects from access to electricity. It therefore omits the more intangible benefits of electricity reported in the literature, such as quality of life or well-being (SolarAid and SunnyMoney, 2015; Rom et al., 2017), socializing (Eckley et al., 2014), security (Orlandi et al., 2016), and inclusion in social progress (Winther and Wilhite, 2015). Assessment of these effects has largely been through surveys of perceptions, with small sample populations.

New data and research may allow future iterations of the Energy Access Dividend to include additional indicators. Table 2.8 summarizes the scope of the Energy Access Dividend framework and analysis.

TABLE 2.8 SCOPE OF THE FRAMEWORK AND ANALYSIS

What "Why Wait?" does do	What "Why Wait" does not do
• Focus on household benefits. • Focus on direct, short-term, measurable micro-level impacts, including: - Energy expenditure savings - Additional time for study • Focus on wider, macro-level impacts on the environment from changes in greenhouse gas and black carbon emissions. • Disaggregates the benefits that accrue from gaining access by level of service for Tiers 1, 2 and above. • Estimates the Energy Access Dividend for households, and at the national level for Bangladesh, Ethiopia and Kenya. • Assumes households gaining access to Tier 1 and 2 do so through decentralized renewable energy solutions.	• Focus on business and community facility benefits, due to a lack of data. • Focus on the macro-level impact of electricity use on national productivity, incomes and growth. • Focus on intangible benefits such as quality of life, socializing and security. • Distinguish between benefits to populations in rural and urban settings, and between income groups, due to data gaps. • Conduct an energy supply demand analysis as part of the Energy Access Dividend. • Provide cost benefit analysis of alternative electrification solutions.

3. BANGLADESH

3.1 CONTEXT

About 62 percent of Bangladesh's 160 million citizens had access to electricity in 2014 (IEA and World Bank, 2017), with about 15 million people, or about 9.2 percent, having gained access to electricity, over the 2010–14 period. However, about 60 million people—38 percent of the total population—lived without electricity.

In urban areas, 90 percent of the population had electricity. In rural areas, where almost two-thirds of the population live, just over half (51 percent) had access to electricity (IEA and World Bank, 2017).

In 2010, fuel and lighting accounted, on average, for 5.6 percent of total household expenditure in Bangladesh. In urban areas, the proportion was higher (6.1 percent) than in rural areas (4.9 percent) (BBS, 2011). The proportion was also highest amongst the landless (7.0 percent).

There is limited information about the distribution of households in Bangladesh across the different Tiers of access to electricity, as defined by the MTF. A survey of 231 households by Groh et al. (2016) gives an approximate distribution, showing most households, with access to electricity, at Tier 2. The Poor People's Energy Outlook 2016 (Practical Action, 2016) surveyed over 4,400 households in four communities, finding all households with access at either Tier 1 or Tier 2.

Further indication of the distribution across Tiers is provided by national household surveys. The Demographic and Health Survey (DHS) 2014, for example, found 85 percent of those with electricity connected to the grid and 15 percent having access from solar home systems. Lighting Asia (2014) found a similar pattern. The average annual consumption of electricity by households in income quintiles ranges from 32 kWh for the lowest income group (i.e., equivalent to Tier 1) to 455 kWh a year for the highest income group (i.e., equivalent to Tier 3) (Asaduzzaman et al., 2010). Per capita residential electricity consumption was 107.4 kWh in 2014 (i.e., 472.75 kWh per household), which is equivalent to Tier 2 access.

Government electrification plans are now directed towards extending access to the grid and raising per capita electricity consumption (SEforALL et al., 2017). Off-grid systems, which have been successfully distributed to over four million households, will continue to be promoted for remote areas.

The Energy Access Dividend estimate therefore assumes the distribution for future Tiers of service as shown in Table 3.1.

The government target is universal access to electricity ("electricity for all") by 2021 (Planning Commission, 2012). This will require a significant increase in the rate of progress in electrification. A continuation of the rate achieved in recent years (2010-14) would not achieve universal access before 2036.

3.2 TIMEFRAME FOR ANALYSIS

The Energy Access Dividend estimates for Bangladesh are based on two scenarios. The Government Target Scenario

TABLE 3.1 DISTRIBUTION OF HOUSEHOLDS ACROSS TIERS OF ACCESS

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Percent of households	0 %	5 %	10 %	20 %	65 %

Source: SEforALL et al., 2017

where the aggregation of annual benefits is over a period of nine years. This period is the difference between the SDG target year (2030) and the government target year (2021). The Dividend therefore represents the benefits that would be lost for each year of delay in reaching the governments targets between 2021–30.

The Dividend is additionally calculated for the SDG 7 Target Scenario where annual benefits accrue over 6 years. This period represents the additional benefits gained by reaching universal access in 2030 compared to continuation of the historic rate of electrification that would close the access gap in 2036.

3.3 INDICATORS

This section provides a summary of the evidence available for each indicator in Bangladesh, including key assumptions used in estimating the Energy Access Dividend.

INDICATOR 1—VALUE OF SAVINGS ON HOUSEHOLD LIGHTING EXPENDITURE

The main source of lighting in households without electricity is kerosene. The poorest households are much more likely to use kerosene for lighting than households with high incomes (Bacon et al., 2010). Each Bangladeshi household without electricity consumes about three liters of kerosene a month (Lighting Asia, 2014). The evidence from several studies, summarized in Table 3.2, is that kerosene consumption drops considerably when a household adopts the use of a solar home system (SHS). The reduction is greater in households that adopt a larger SHS, but kerosene consumption is not necessarily completely substituted.

The estimate of the Energy Access Dividend assumes that households gaining Tier 1 access to electricity with solar lamps or small SHS reduce their consumption of kerosene by 2.5 liters a month. The reduction for households gai-

TABLE 3.2 CHANGE IN HOUSEHOLD KEROSENE CONSUMPTION ON ADOPTION OF A SHS

Source	Monthly kerosene consumption before SHS (liters)	Monthly kerosene consumption after SHS adoption (liters)	Change in monthly kerosene consumption (liters)	Monthly kerosene consumption of non-adopters (liters)
Komatsu et al. (2011): Manikganj households Kishoreganj households Comilla households	3.59 4.04 4.16	3.43 0.78 0.81	0.16 3.26 3.35	3.21 3.14 3.73
Samad et al. (2013)			1.00	3.00
Brossman (2013): Small SHS users SHS users	2.58 3.65	0.21 0.34	2.37 3.31	
Khandker et al. (2012)			0.92	2.84

ning Tier 2 access and above is assumed to be three liters a month.

The current retail price of kerosene is Taka 65 per liter.[8] Therefore, the monthly saving for households gaining access to electricity is Taka 162.50 ($2.03) for Tier 1 households and Taka 195.00 ($2.44) for households at Tier 2 and above. A constant 2016 price is used throughout the period covered by the dividend, and the value of future savings is not discounted.[9]

INDICATOR 4—HOURS SPENT STUDYING AT HOME

In Bangladesh, access to electricity increases the time spent studying at home, by both girls and boys (Khandker et al., 2009; Samad et al., 2013; Brossman, 2013). Khandker et al. (2009) found that this increase was confined to wealthier households (i.e., those with significant land holdings), while Brossman (2013) found the increase to be greater for students in the 11 to 15 year age group.

The increase in study time found by different studies (Table 3.3) ranges from six minutes a day to over half an hour a day.

For the Energy Access Dividend, a 15-minute per day increase for boys and a 20-minute per day increase for girls are assumed, across all access Tiers.

INDICATOR 7—VALUE OF SAVINGS ON COSTS OF PHONE CHARGING

Mobile phone ownership is widespread in Bangladesh. About 73 percent of all households owned a mobile phone in 2011 (Ahmed et al., 2013) and, by 2016, there were 82 mobile phone subscriptions for every 100 people (World Bank, 2017). However, mobile phone ownership varies by income group, with about half of the households in the lowest income quintile having a phone, compared with over 90 percent in the highest quintile (Ahmed et al., 2013).

Ownership of a mobile phone influences household decisions to adopt electricity (Komatsu et al., 2011). Brossman (2013) found that almost all users of large SHS and 94 percent of small SHS users owned a phone, compared with 78 percent of households without a SHS. The evidence suggests that the number of phones and the frequency of their use increases in households when there is access to electricity in the home.

Phone users in Bangladesh charge their phones two or three times a week. Households without electricity charge their phones at the marketplace or at the house of a friend or relative who has electricity (Komatsu et al., 2011). In rural areas, subscribers without electricity may have to travel several kilometers to charge their phone.

TABLE 3.3 NUMBER OF MINUTES A DAY OF ADDITIONAL STUDY TIME AFTER ACCESS TO ELECTRICITY

	Khandker et al. (2009)	Khandker et al. (2012)	Samad et al. (2013)	Brossman (2013)
Boys	16.3	22	8	6
Girls	20.5	13	7	35

[8] *See: http://www.bpc.gov.bd.*

[9] *The analysis focuses on the benefits of access to electricity and does attempt to assign monetary values to all the benefits. Discounting future consumption of benefits requires making additional assumptions about the social time preference of consumption and future rates of growth (Cropper, 2013).*

The cost of each recharge is around Taka 5.00 ($0.06) (Brossman, 2013; Lighting Asia, 2014; GSMA, 2011). Assuming two charges a week, monthly expenditure for phone charging is assumed to be Taka 40 ($0.50). It is also assumed that all households at each Tier have at least one mobile phone, but only half of those without electricity pay to recharge it.

INDICATOR 13—CLIMATE CHANGE EMISSIONS

Access to electricity results in a reduction in greenhouse gas emissions proportionate to the reduction in kerosene consumption. This is assumed to be 2.5 liters a month at Tier 1 access and 3 liters at Tiers 2 to 5. Each liter of kerosene used for lighting emits 2.4 kg of CO_2e. Therefore, annual reductions per household are 72 kg. CO_2e at Tier 1 and 86.4 kg CO_2e at other Tiers.

Black carbon reductions are estimated using a factor of 25.45 kg CO_2e per liter of kerosene (Tedsen, 2013; Clark, 2013), and annually per household are 763.5 kg CO_2e and 916.2 kg CO_2e, at Tiers 1 and Tiers 2 to 5, respectively.

3.4 ESTIMATING THE ENERGY ACCESS DIVIDEND IN BANGLADESH

A summary of the indicator assumptions used for estimating the dividend can be found in Table 3.4.

HOUSEHOLD ENERGY ACCESS DIVIDEND

Government Target Scenario

This scenario shows the benefits forgone for households in Bangladesh for each year of delay for the government target of 2021 up to the SDG 7 target of 2030 (Table 3.5). This includes (gross) expenditure savings foregone per household of waiting for a centralized grid-based connection of $217 for households at Tier 1 to $252 for households at Tiers 2 to 5 over 2021–30. These totals are equivalent to 16.3 percent and 18.8 percent of annual GNI per capita in 2016 (World Bank, 2017). Annually, the expenditure savings are equivalent to 1.8 percent and 2.1 percent of average per capita income, depending on the Tier of access.

In the average household, at all Tiers, 48 hours of study at home are foregone each year without access to electricity. Over the period 2021-30, if there is no electricity access 53.5 days of study are foregone per household. This is equivalent to about 3 percent of a school year each year.

The foregone CO_2 emissions reductions are estimated to be 514 kg and 617 kg per household, depending on the Tier of access. Annually, foregone CO_2 emission reductions are 57 kg and 69 kg, depending on Tier of access, which is equivalent to 4.6 percent and 5.6 percent of per capita annual greenhouse gas emissions.

TABLE 3.4 SUMMARY OF INDICATOR ASSUMPTIONS

Indicator	Bangladesh
Value of savings on household expenditure, per month	Tier 1: $2.03 Tiers 2–5: $2.44 Based on 2.5 liter reduction at Tier 1 and 3 liter reduction Tiers 2–5; Taka 65 ($0.81) per liter.
Hours spent studying at home	Boys: 15-minute increase per day Girls: 20-minute increase per day
Value of savings on costs of phone charging, per month	Tiers 1–5: $0.50
Climate change emissions, annual reduction	Based 2.5 liter reduction at Tier 2 and 3 liters at Tiers 2–5. CO_2: 2.4 kg/liter Black carbon: 25.45 kg CO_2e per liter

Black carbon emission reductions foregone per household in Bangladesh are estimated to be 606 kg CO_2e and 727 kg CO_2e a year, depending on the Tier of access, equivalent to 49 percent to 59 percent of total annual per capita CO_2e emissions.

SDG 7 Target Scenario

Under SDG 7 Target Scenario the estimate is for a six-year period, and represents the dividend from achieving universal access in 2030, the SDG target year, instead of the year when universal access is achieved under the historical rate of electrification, which is 2036 (Table 3.5). The household dividend under this scenario includes total financial savings over the six years of between \$76 and \$88 per household, depending on the Tier of access. Annually the financial savings are between \$12.67 and \$14.67, which is equivalent to 1 percent and 1.1 percent of annual GNI per capita in 2016.

The home study time dividend under the SDG 7 Target scenario totals 150 hours per household, at all Tiers of access over the six years. Annually this represents 25 hours, equivalent to 1.5 percent of a school year per household.

The emission reductions over the six-year period in the

TABLE 3.5 HOUSEHOLD ENERGY ACCESS DIVIDEND IN BANGLADESH

Household Dividend	Government Target Scenario		SDG 7 Target Scenario	
Period for which benefits accrue (years)		9		6
Dividend (Cumulative per household, over period)	**Tier 1**	**Tiers 2–5**	**Tier 1**	**Tiers 2–5**
Expenditure on lighting (\$)	174	209	61	73
Expenditure on phone charging (\$)	43	43	15	15
Total expenditure reduction (\$)	217	252	76	88
Hours of study: boys (hours)	190	190	67	67
Hours of study: girls (hours)	238	238	83	83
Total hours of study (hours)	428	428	150	150
CO_2 emission reduction (kg)	514	617	180	216
Black carbon emission reduction (kg CO_2e)	5,451	6,542	1,909	2,291
Dividend (Annual per household, over period)	**Tier 1**	**Tiers 2–5**	**Tier 1**	**Tiers 2–5**
Expenditure on lighting (\$/ year)	19.3	23.2	10.2	12.2
Expenditure on phone charging (\$/ year)	4.8	4.8	2.5	2.5
Total expenditure reduction (\$/ year)	24.1	28.0	12.7	14.7
Hours of study: boys (hours/ year)	21	21	11	11
Hours of study: girls (hours/ year)	26	26	14	14
Total hours of study (hours/ year)	48	48	25	25
CO_2 emission reduction (kg/ year)	57	69	30	36
Black carbon emission reduction (kg CO_2e/ year)	606	727	318	382

Source: Author's own analysis.

SDG 7 Target scenario include totals of 180 kg CO_2 and 216 kg CO_2, and black carbon reductions of 1,909 kg CO_2e and 2,291 kg CO_2e, depending on Tier of access. Annually, the CO_2 emission reduction is equivalent to between 2.4 percent and 2.9 percent of total per capita emissions (in 2013), and the black carbon reduction is equivalent to between 26 percent and 31 percent of per capita CO_2e emissions.

NATIONAL ENERGY ACCESS DIVIDEND

Government Target Scenario

The dividend includes total expenditure (gross) savings foregone by households of $2.2 billion if universal access to electricity is delayed by a period of nine years to 2030, compared to the government target of 2021. Annually the expenditure savings foregone would be $246.9 million, which is equivalent to the annual income of about 185,600 Bangladeshi citizens.[10]

A delay of nine years in providing universal access in Bangladesh would mean foregoing around four billion hours of home study by school students over 2021-30. This is equivalent to the time that 278,000 students would spend in school over this period.[11] Given that nine years is more than double the time that most people in Bangladesh have spent in education (NIPORT et al., 2016), this might almost be equivalent to foregoing the education of over 278,000 people.

The Energy Access Dividend in Bangladesh, for the nine-year period, includes 5,734 metric tons CO_2 emissions, which would otherwise have been avoided. Annually, this is 637 metric tons CO_2, equivalent to the per capita emissions of about 518 people. If the analysis considers only emissions from electricity and heat, it is equivalent to the per capita emissions of 3,185 people.

In Bangladesh, a nine-year delay in providing universal access to electricity would lead to the emission of a quantity of black carbon from kerosene lighting, with an equivalent global warming effect to 60.8 million metric tons CO_2. Annually, this is 6.75 million metric tons CO_2e, which is equivalent to 3.5 percent of Bangladesh's annual CO_2e emissions, or about 22 percent of total CO_2e emissions[12] from electricity and heat.

SDG 7 Target Scenario

The dividend in the SDG 7 Target scenario includes $1.2 billion in financial savings over the six-year period. Annually this is $209 million, equivalent to the income of about 157,000 Bangladeshis in 2016.

Over the six years in this scenario, the home study time foregone totals 2.35 billion hours. In annual terms, this is 391.7 million hours, which is equivalent to a school year for about 245,000 students.

Annual CO_2 emission reductions are 561 metric tons CO_2, which is equivalent to the total annual emissions of 458 people. Black carbon reductions each year over the six-year period are 5.9 million metric tons CO_2e, equivalent to 3.1 percent of total annual CO_2e emissions, in 2013.

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[10] Based on GNI per capita of $ 1,330 in 2016 (World Bank, 2017).

[11] Based on a school day of eight hours and a school year of 200 days.

[12] Based on 163.63 million metric tons CO_2e in 2013, excluding LULUCF (WRI, 2017).

TABLE 3.6 NATIONAL ENERGY ACCESS DIVIDEND IN BANGLADESH

National Dividend	Government Target Scenario	SDG 7 Target Scenario
Period over which benefits accrue (years)	9	6
Dividend (Cumulative over period)		
Expenditure on lighting ($ million)	1,941.13	1,139.46
Expenditure on phone charging ($ million)	281.03	116.87
Total expenditure reduction ($ million)	2,222.16	1,256.33
Hours of study: boys (million hours)	1,765.27	1,036.23
Hours of study: girls (million hours)	2,238.66	1,314.12
Total hours of study (million hours)	4,003.92	2,350.35
CO_2 emission reduction (metric tons)	5,734	3,366
Black carbon emission reduction (t CO_2e)	60,802,087	35,691,502
Dividend (Annual over period)		
Expenditure on lighting ($ million/ year)	215.68	189.91
Expenditure on phone charging ($ million/ year)	31.23	19.48
Total expenditure reduction ($ million/ year)	246.91	209.39
Hours of study: boys (million hours/ year)	196.14	172.71
Hours of study: girls (million hours/ year)	248.74	219.02
Total hours of study (million hours/ year)	444.88	391.72
CO_2 emission reduction (metric tons/ year)	637	561
Black carbon emission reduction (t CO_2e/ year)	6,755,787	5,948,583

Source: Author's own analysis.

4. ETHIOPIA

4.1 CONTEXT

Ethiopia has one of the world's lowest levels of electrification. In 2014, 27 percent of Ethiopia's total population (26.5 million people) had access to electricity (IEA and World Bank, 2017). There was a wide disparity between urban and rural areas, with 92 percent of the urban population having access, compared with 12 percent in rural areas. Almost two-thirds of those with access to electricity lived in urban centers, while 80 percent of the total population lived in rural areas.

National electrification targets have been expressed in terms of coverage, i.e., the proportion of population centers that have an electricity supply. The government's Universal Electricity Access Programme was launched in 2005 to connect towns and villages to the grid. During the first Growth and Transformation Plan (GTP), this coverage increased to 60 percent in 2014-15 from 41 percent in 2009-10. Under the second Growth and Transformation Plan (GTP II), the target is 90 percent coverage by 2019-20.

GTP II provides more specific electrification targets for 2019-20: 6.955 million additional customers connected to the grid, and 3.6 million solar lanterns and 400,000 SHS in use. Together, these imply an objective to reach 54 percent household access to electricity by 2019-20. Publication of a new National Electrification Plan, with revised targets, is expected before the end of 2017.

There is limited information about the distribution of households in Ethiopia across the different Tiers of access to electricity. A pilot MTF survey in the Amhara region—which covered only 100 households—found just over half the households (51 percent) with some access to electricity. Most of these had access at Tiers 2 and 3 (22 percent each), with 1 percent at Tier 1 and 4 percent at Tier 5 (Angelou, 2014). In 2014, 7.9 percent of all households had a private metered connection, 12.4 percent a shared meter connection, 3.5 percent solar and 0.5 percent a generator set (Bersisa, 2016).

The Energy Access Dividend estimates for Ethiopia assume the distribution of households across Tiers of access shown in Table 4.1. This distribution is also employed in the analysis of energy access financing needs in SEforALL et al. (2017), and is based on the 2015 SEforALL Finance Committee Report (SEforALL, 2015). It is consistent with government plans to increase access to electricity mostly through grid connections.

The Energy Access Dividend from faster electrification in

TABLE 4.1 DISTRIBUTION OF HOUSEHOLDS ACROSS TIERS OF ACCESS

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Percent households with access	5 %	20 %	15 %	20 %	40 %

Source: SEforALL et al., 2017

Ethiopia will be felt predominantly by rural households, since urban households already enjoy a relatively high level of access to electricity. About 23 percent of the rural population is in the lowest wealth quintile, compared with fewer than 2 percent of the urban population (DHS 2011, 2014). The most recent DHS data show 76.5 percent of the urban population in the highest wealth quintile, compared with 8.7 percent of the rural population. In the poorest households, lighting accounts for a larger share of total household expenditure, though actual monthly expenditure on lighting is lower than in households with higher incomes (Table 4.2) (Lighting Africa, 2013). Expenditure on electricity follows a similar pattern (Kojima et al., 2016), though the difference is not as great.

4.2 TIMEFRAME FOR ANALYSIS

The Energy Access Dividend estimates for Ethiopia are estimated for the SDG 7 Target Scenario where annual benefits accrue over 39 years. This period represents the additional benefits gained by reaching universal access in 2030 compared to continuation of the historic rate of electrification that would close the access gap in 2069.

A Government Target Scenario is also presented. This is the dividend from achieving universal access by 2030, the SDG target, instead of 2031, which is the year universal access would be achieved if the rate of electrification required to deliver the government's planned level of electrification in 2020 is projected forward.

4.3 INDICATORS

This section provides a summary of the evidence available for each indicator in Ethiopia, and states the key assumptions used in estimating the Energy Access Dividend.

INDICATOR 1—VALUE OF SAVINGS ON HOUSEHOLD LIGHTING EXPENDITURE

The main source of energy for lighting in households without access to electricity is kerosene (Lighting Africa, 2008; Barnes et al., 2016; Bersisa, 2016). The national Welfare Monitoring Survey found 64.2 percent of households dependent for lighting on kerosene and candles, 9.3 percent had a private electricity connection, 13.5 percent had a shared electricity connection, and 13 percent used batteries.

TABLE 4.2 PROPORTION OF HOUSEHOLD EXPENDITURE ON LIGHTING, BY EXPENDITURE QUINTILE

	Lowest	Second	Middle	Fourth	Highest	Total
Households using kerosene for lighting (%)	83.4	79.4	83.5	81.7	83.9	82.4
Expenditure on kerosene for lighting ($ per month)	1.72	1.95	2.00	2.16	2.40	2.05
Households using dry cell batteries for lighting (%)	49.3	65.1	65.6	69.7	72.9	64.6
Expenditure on dry cell batteries for lighting ($ per month)	0.63	0.74	0.74	0.84	0.89	0.79
Expenditure on lighting as a percent of total expenditure (%)	7.2	5.4	4.1	3.3	2.5	4.5

Source: Lighting Africa, 2013.

The average rural household consumes 1.9 liters of kerosene a month (Barnes et al., 2016). The pump price of kerosene (since April 2017) is Birr 16.35 ($0.69).[13] However, the price paid by consumers can vary by location and the quantity purchased (Barnes et al., 2016), and an average price of $0.79 is used.

The Energy Access Dividend estimate uses the pump price for kerosene and assumes reductions in kerosene consumption of one liter a month at Tier 1 and 1.9 liters a month at Tiers 2 to 5.

INDICATOR 4—HOURS SPENT STUDYING AT HOME

School students in households with a SHS, spend longer time studying at home than those in households without electricity. Students in households with a SHS spend, in total, 15-20 percent more time studying at home after its adoption than before (Barnes et al., 2016). This effect is felt in about half of households with electricity.

The Energy Access Dividend estimate assumes one hour of additional study time a day for both boys and girls, during a school year of 200 days, at all access Tiers.

INDICATOR 7—VALUE OF SAVINGS ON COSTS OF PHONE CHARGING

The Demographic and Health Survey 2014 found that almost half (49.3 percent) of all Ethiopian households owned a mobile phone. Mobile phones were more than twice as common in urban households (83.7 percent) than in rural households (39.6 percent). Over 70 percent of the households surveyed by Barnes et al. (2016) had a mobile phone. The number of mobile phone subscribers, reportedly, reached 53 million in 2017,[14] which suggests that many phones are used by businesses and some households have more than one phone.

Households without electricity recharge their phone batteries at charging stations, which may be several kilometers away, or at the homes of relatives or neighbors that have electricity. Because of the low level of electrification in rural areas, households with electricity access can earn income from charging the phones of others.

The cost of charging a phone is about $0.10 and the monthly expenditure on phone charging has been estimated at $0.95 (Lighting Africa, 2013) (Table 4.3). The estimate assumes, at all Tiers of access, each household has one mobile phone, and saves $0.95 a month when they gain access to electricity.

INDICATOR 13—CLIMATE CHANGE EMISSIONS

The reduction in greenhouse gas emissions when a household gains access to electricity is proportional to the reduction in kerosene consumption (one liter a month at

TABLE 4.3 PROPORTION OF HOUSEHOLD EXPENDITURE ON PHONE CHARGING, BY EXPENDITURE QUINTILE

	Lowest	Second	Middle	Fourth	Highest	Total
Households using mobile phone charging service (%)	29.6	48.1	46.3	56.8	62.7	48.6
Expenditure on mobile phone charging ($ per month)	0.95	0.89	0.98	0.96	0.97	0.95

Source: Lighting Africa, 2013.

[13] *See: https://addisfortune.net/articles/ministry-revises-fuel-retail-price-2/.*

[14] *See: http://www.2merkato.com/news/alerts/5008-ethiopia-mobile-subscribers-reached-53-million.*

Tier 1 and 1.9 liters a month at Tiers 2 to 5). The estimate assumes a standard 2.4 kg CO_2e reduction per liter.

Black carbon reductions are also proportional to the reduction in kerosene consumption. For each liter of kerosene there is a reduction in particle emissions of 49.95 grams, which has the same global warming effect as 33.97 kg CO_2 (Tedsen, 2013).

4.4 ESTIMATING THE ENERGY ACCESS DIVIDEND IN ETHIOPIA

A summary of the indicator assumptions used for estimating the dividend can be found in Table 4.4.

Two time periods were analyzed to estimate the Energy Access Dividend for Ethiopia. The first is the difference between the SDG target year (2030) and the year when universal access would be reached under the historical rate of electrification (2069)–the SDG 7 Target Scenario. The dividend under this assumption is calculated over a period of 39 years, and estimates for the dividend (or development benefits lost) if the rate of electrification is not increased.

The second period is the difference between the SDG target year (2030) and the year (2031) when universal access is achieved if the rate of electrification required to achieve the government's 2020 objectives is projected forward–the Government Target Scenario. The household and national Energy Access Dividend for Ethiopia, based on these two scenarios, are summarized in Tables 4.5 and 4.6.

HOUSEHOLD ENERGY ACCESS DIVIDEND

SDG 7 Target Scenario

In Ethiopia, total estimated (gross) expenditure savings foregone per household are $348 at Tier 1 and $544 at Tiers 2 to 5 if access continues at the historical rate and is delivered in 2069 rather than 2030 (Table 4.5). This is equivalent to about 53 percent and 82 percent, respectively, of 2016 per capita income. Annually, the foregone expenditure savings per household ($9 at Tier 1 and $14 at Tiers 2 to 5) are equivalent to 1.4 percent to 2.1 percent of average per capita income.

Each household without access to electricity in Ethiopia foregoes an estimated 168 hours of studying at home annually, equivalent in time to about 10 percent of a school year. Over the period without access to electricity, lost study time at home totals between 818 days per household. This is equivalent to approximately four school years.

CO_2 emission reductions from access to electricity are estimated to be 16.9 kg and 32.16 kg a year per household at Tier 1 and Tier 2 to 5, respectively, equivalent to 1.1 percent and 2.1 percent of total per capita greenhouse gas emissions in 2013. Over the period without access to electricity, these avoidable emission reductions total between 660 kg and 1254 kg, depending on the Tier

TABLE 4.4 SUMMARY OF INDICATOR ASSUMPTIONS

Indicator	Ethiopia
Value of savings on household expenditure, per month	Tier 1: $0.79 Tiers 2–5: $1.50 Based on 1 liter reduction at Tier 1 and 1.9 liter reduction at Tiers 2–5; $0.79 per liter average price.
Hours spent studying at home	Boys and girls: one hour increase per day over a school year of 200 days
Value of savings on costs of phone charging, per month	Tiers 1–5: $0.95
Climate change emissions, annual reduction	Based 1 liter reduction at Tier 2 and 1.9 at Tiers 2–5. CO_2: 2.4 kg/liter Black carbon: 33.97 kg CO_2e per liter

TABLE 4.5 HOUSEHOLD ENERGY ACCESS DIVIDEND IN ETHIOPIA

Household Dividend	Government Target Scenario[a]		SDG 7 Target Scenario	
Period for which benefits accrue (years)		1		39
Dividend (Cumulative per household, over period)	**Tier 1**	**Tiers 2–5**	**Tier 1**	**Tiers 2–5**
Expenditure on lighting ($)	2.6	4.9	218	413
Expenditure on phone charging ($)	1.5	1.5	131	131
Total expenditure reduction ($)	4.1	6.4	348	544
Hours of study: boys (hours)	40	40	3,365	3,365
Hours of study: girls (hours)	37	37	3,177	3,177
Total hours of study (hours)	77	77	6,541	6,541
CO_2 emission reduction (kg)	8	15	660	1,254
Black carbon emission reduction (kg CO_2e)	110	209	9,343	17,752
Dividend (Annual per household, over period)	**Tier 1**	**Tiers 2–5**	**Tier 1**	**Tiers 2–5**
Expenditure on lighting ($/ year)	2.6	4.9	5.58	10.60
Expenditure on phone charging ($/ year)	1.5	1.5	3.35	3.35
Total expenditure reduction ($/ year)	4.1	6.4	8.93	13.95
Hours of study: boys (hours/ year)	40	40	86.27	86.27
Hours of study: girls (hours/ year)	37	37	81.45	81.45
Total hours of study (hours/ year)	77	77	167.73	167.73
CO_2 emission reduction (kg/ year)	8	15	16.93	32.16
Black carbon emission reduction (kg CO_2e/ year)	110	209	239.57	455.18

(a) Government Target Scenario is the dividend from achieving universal access by 2030, the SDG target, instead of 2031, which is the year universal access would be achieved based on projecting forward the rate of electrification required to deliver the government's planned level of electrification in 2020, until universal access is achieved. The difference in time between the government rate and the SDG rate is one year.

Source: Author's own analysis.

of access. Annual black carbon emissions foregone per household are between 240 kg CO_2e and 455 kg CO_2e, depending on the Tier of access, equivalent to 16 percent and 30 percent of total annual CO_2e emissions per capita in Ethiopia in 2013.

Government Target Scenario

The estimate of annual per household expenditure savings is $4 to $6 depending on the Tier of access. About 77 additional hours of study would be lost. CO_2 emission reductions of 8 to 15 kg, and black carbon of 110 to 209 kg CO_2e would be obtained.

NATIONAL ENERGY ACCESS DIVIDEND

SDG 7 Target Scenario

Understandably, the cumulative dividend is much larger for 2030-69 period, with (gross) expenditure savings totaling approximately \$10.5 billion, or \$268.2 million annually. The cumulative total is equivalent to about 14.5 percent of GNI in 2016 (World Bank, 2017). The number of hours of studying at home that would be foregone is 124.7 billion, or 3.2 billion hours annually. The annual lost study time is equivalent to a year's school time for 7 percent of the country's school-age population. Cumulative unavoided emissions would total 23,341 metric tons CO_2 and 330.4 million metric tons CO_2e black carbon.

Government Target Scenario

If the SDG target is reached instead of one year later, the estimate of (gross) expenditure savings is \$328 million, which is equivalent to 0.5 percent of total GNI in 2016. About 640 million additional hours of study would be lost. This is equivalent to a school year for 400,000 students, or 1.4 percent of the school-age population. CO_2 emission reductions of 120 metric tons, and black carbon of 1.7 million metric tons CO_2e would be obtained.

TABLE 4.6 NATIONAL ENERGY ACCESS DIVIDEND IN ETHIOPIA

National Dividend	Government Target Scenario[(a)]	SDG 7 Target Scenario
Period over which benefits accrue (years)	1	39
Dividend (Cumulative over period)		
Expenditure on lighting (\$ million)	314.97	7,970.05
Expenditure on phone charging (\$ million)	12.79	2,490.28
Total expenditure reduction (\$ million)	327.75	10,460.33
Hours of study: boys (million hours)	329.29	64,135.73
Hours of study: girls (million hours)	310.90	60,553.22
Total hours of study (million hours)	640.19	124,688.95
CO_2 emission reduction (metric tons)	120	23,341
Black carbon emission reduction (t CO_2e)	1,696,186	330,365,516
Dividend (Annual over period)		
Expenditure on lighting (\$ million/ year)	314.97	204.36
Expenditure on phone charging (\$ million/ year)	12.79	63.85
Total expenditure reduction (\$ million/ year)	327.75	268.20
Hours of study: boys (million hours/ year)	329.29	1,644.51
Hours of study: girls (million hours/ year)	310.90	1,552.65
Total hours of study (million hours/ year)	640.19	3,197.15
CO_2 emission reduction (metric tons/ year)	120	598
Black carbon emission reduction (t CO_2e/ year)	1,696,186	8,470,911

(a) Government Target scenario is the dividend from achieving universal access by 2030, the SDG target, instead of 2031, which is the year universal access would be achieved based on projecting forward the rate of electrification required to deliver the government's current planned level of electrification in 2020, until universal access is achieved. The difference in time between the government current rate and the SDG rate is one year.

Source: Author's own analysis.

5. KENYA

5.1 CONTEXT

Fewer than one person in five had access to electricity in Kenya in 2010. By 2014, 36 percent of the population of 46 million had access (IEA and World Bank, 2017). The government reports that the level of access reached 70 percent in June 2017, and the target is to achieve universal access to electricity by 2020.

In urban centers, where a quarter of the total population lived in 2014, 68.4 percent of households had access to electricity, accounting for 48 percent of the total population with access. In rural areas, only 12.6 percent of households had access to electricity. The government's last mile connectivity and off-grid solar access programs are intended to redress this disparity. At the historical rate of progress, universal access to electricity will be achieved in 2030.

The Rural Electrification Authority (REA), which was established under the 2006 Electricity Act to accelerate the rate of rural electrification, initially followed a strategy to connect schools, markets and health clinics. By 2013, 90 percent of these public facilities had access to electricity, in contrast to the low level of access enjoyed by households (Lee et al., 2016). By July 2016, 95 percent of 23,411 primary schools had electricity, including 4,171 with solar systems.

Kerosene is the principal source of lighting in households without access to electricity. It accounts for about 2 percent of total household expenditure in Kenya (Bacon et al., 2010; Lee et al., 2016; Lighting Global, 2012). As shown in Figure 5.1, this expenditure share varies between rural and urban areas and across expenditure quintiles.

Electricity consumption also varies across income groups. Nzia (2009) identified six categories of electricity consumer, defined by income (high, middle and low) and location (urban and rural) and analyzed their use of electricity (Table 5.1). Rural, low-income households consumed the least electricity—used primarily for lighting and communications—while high-income households consumed over 25 times more electricity, for a variety of uses.

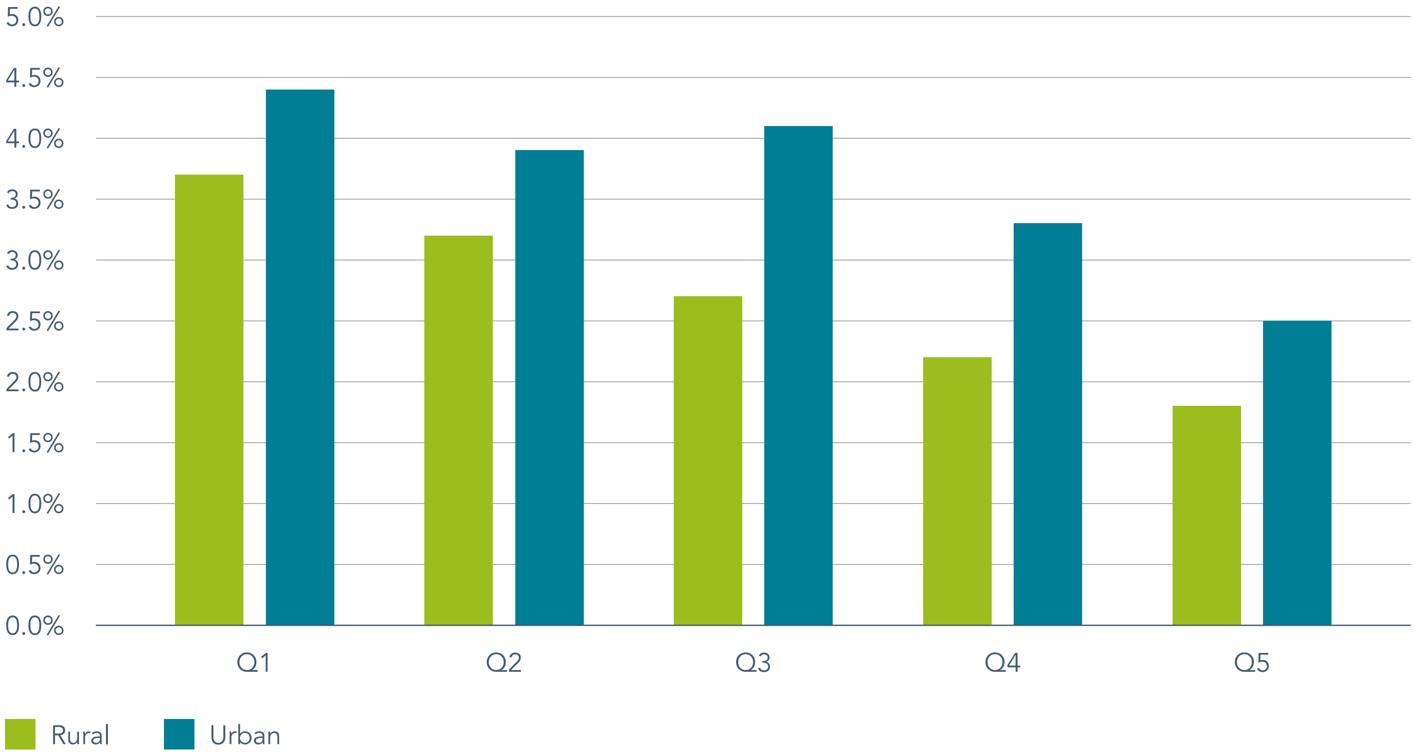
The average annual consumption of Kenya Power's 5 million residential consumers was 443 kWh in 2015-16. This is equivalent to Tier 3 access, as defined in the MTF (Bhatia and Angelou, (2015). A detailed breakdown of recent electricity consumption figures was unavailable for the analysis, to determine the distribution of residential consumers across the Tiers of access. However, estimates of this distribution can be determined from the preliminary results of the MTF baseline survey in Kenya, and from analysis of 2009 data in Nzia (2009). These are shown in Table 5.2.

The distribution assumed for the Kenya Energy Access Dividend estimate is shown in Table 5.3. This is derived from the SEforALL Action Agenda (MOEP, 2016) and is used to estimate financing needs in SEforALL et al. (2017).

5.2 TIMEFRAME FOR ANALYSIS

The Energy Access Dividend estimates for Kenya are based on the Government Target Scenario where the ag-

FIGURE 5.1 KEROSENE SHARE OF HOUSEHOLD EXPENDITURE BY QUINTILE IN KENYA, URBAN AND RURAL



gregation of annual benefits is over a period of ten years. This period is the difference between the SDG target year (2030) and the government target year (2020). The dividend therefore represents the benefits lost for each year that access is delayed from the government target of 2020 to the SDG 7 target year of 2030. The Dividend is not calculated for the SDG 7 Target Scenario since the historic electrification rate over 2010-14 delivers universal access in 2030, the same year as the SDG 7 goal.

5.3 INDICATORS

INDICATOR 1—VALUE OF SAVINGS ON HOUSEHOLD LIGHTING EXPENDITURE

In Kenya, investigation of the change in household expenditure on kerosene lighting—which follows the adoption of a solar lamp or home system—has focused on a financial analysis. Rom et al. (2016), for example, examine monthly expenditure on kerosene and discuss the reduction in terms of the proportion of total household cash expenditure. Savings amount to 1.9 percent of total cash expenditure (given as $70.75 a month). However, for consistency with the method used to estimate expenditure savings in Bangladesh and Ethiopia, the reduction in kerosene consumption needs to be expressed as liters, and then valued using an up-to-date price.

The average household without electricity in Kenya consumes 2.26 liters per month for lighting (Lighting Africa, 2008). However, Tier 1 access from a solar lamp does not completely replace kerosene lighting. The average household in Kenya surveyed by Rom et al. (2016) had 2.2 kerosene lamps before the introduction of a solar light. The solar light replaced one kerosene lamp. At Tier 2, it is assumed that kerosene lamps are completely replaced by a

TABLE 5.1 ELECTRICITY CONSUMPTION (KWH) BY INCOME GROUP AND SERVICE

	Urban High	Urban Middle	Urban Low	Rural High	Rural Middle	Rural Low
Lighting	1,209	340	98	971	288	122
Sanitary water	1,198	284	15	73	14	0
Entertainment & ICT	907	417	194	294	235	63
Refrigeration	816	214	15	93	77	0
Small kitchen appliances	466	95	6	26	5	0
Air conditioning	395	67	7	20	0	0
Laundry	356	183	115	128	110	33
Cooking	178	30	0	21	4	0
Dishwashing	69	0	0	0	0	0
Water supply	56	6	0	6	0	0
Fitness	46	1	0	0	0	0
House cleaning	43	2	0	0	0	0
Space heating	16	1	0	0	0	0
Grooming	12	2	1	2	0	0
Total	5,767	1,642	451	1,634	733	218

Source: Nzia, 2009.

TABLE 5.2 PROPORTION OF HOUSEHOLDS AT DIFFERENT TIERS OF ACCESS TO ELECTRICITY, KENYA

	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
MTF survey 2017	56 %	10 %	3 %	14 %	10 %	7 %
Nzia, 2009	71 %	1.5 %	7 %	11.4 %	5.6 %	3.5 %

Source: Nzia, 2009.

TABLE 5.3 DISTRIBUTION ACROSS TIERS IN THE KENYA DIVIDEND ESTIMATE

	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Kenya SEforALL Action Agenda	10 %	30 %	35 %	15 %	10 %

Source: SEforALL et al., 2017.

solar lighting system. At Tier 3 and above, additional lighting may be available but it does not reduce expenditure on other kinds of lighting.

An average price of $0.775 per liter is assumed for the calculation. This is 25 percent higher than the $0.62 pump price in Nairobi, to reflect higher prices in rural areas and for purchases of small quantities of kerosene.

INDICATOR 4—HOURS SPENT STUDYING AT HOME

Evidence suggests that access to electric lighting increases the time spent studying at home by school students. In Kenyan households without access to electricity, boys and girls study at home for about 2.5 hours a day. In households that acquired a free solar light (Tier 1 access), boys studied for 31 minutes more each day, but there was no change for girls (Rom et al., 2017). A similar level of increase was reported by Hassan and Lucchino (2014), who also found a correlation with grade improvements.

In the absence of analysis about studying at home for households with higher Tiers of access, the Energy Access Dividend estimate assumes a 30-minute per day increase in home study time for boys, and no increase for girls, at all Tiers.

INDICATOR 7—VALUE OF SAVINGS ON COSTS OF PHONE CHARGING

The great majority of households in Kenya have access to use one or more mobile phones. Per the 2014 Demographic and Health Survey, 86 percent of households have a mobile phone. In urban areas, the proportion rises to 94 percent. Households without access to electricity pay to charge their phones, or charge at no cost through family or neighbors.

At Tier 1, Rom et al. (2017) found monthly savings of $0.21 when a solar light has a phone charger; d.light found a saving of $0.31 a month on phone charging costs (and an average revenue of $0.16 from charging other people's phones). The Energy Access Dividend estimate assumes that each household has one mobile phone and saves $0.21 per month at all Tiers of access.

The number of mobile phones increases as household income increases. Therefore, additional savings may be found if a household moves from no access to Tier 4 or 5, but no empirical evidence for this effect is available, and additional savings are not included to reflect this in the dividend estimate.

INDICATOR 13—CLIMATE CHANGE EMISSIONS

Mills (2003) showed that a kerosene lamp with a glass hood emits 98 kg CO_2 per year. Simple wick lamps emit 3 kg CO_2 per year. Rom et al. (2017) found that, on average, a household without access to electricity has 2.2 kerosene lamps, and that access to task lighting from a solar light reduces the number of kerosene lamps by approximately one. The dividend estimate assumes a 50 percent reduction in emissions from kerosene lighting at Tier 1 and a 100 percent reduction at Tiers 2 to 5.

Black carbon reductions are proportional to the reduction in kerosene consumption. In Kenya, 23.01 grams of black carbon particulates are emitted, on average, per liter of kerosene. This is equivalent to 15.65 kg CO_2e.

5.4 ESTIMATING THE ENERGY ACCESS DIVIDEND IN KENYA

A summary of the indicator assumptions used for estimating the dividend can be found in Table 5.4.

HOUSEHOLD ENERGY ACCESS DIVIDEND

Government Target Scenario

In Kenya, the (gross) expenditure savings foregone annually by households if access is delayed from the govern-

TABLE 5.4 SUMMARY OF INDICATOR ASSUMPTIONS

Indicator	Kenya
Value of savings on household expenditure, per month	• Tier 1: $0.88 • Tiers 2–5: $1.75 • Based on 1.13 liter reduction at Tier 1 and 2.26 liter reduction at Tiers 2–5; $0.775 per liter average price.
Hours spent studying at home	• Boys: 30-minute increase per day • Girls: no increase
Value of savings on costs of phone charging, per month	• Tiers 1–5: $0.21
Climate change emissions, annual reduction	• Based 1.13 liter reduction at Tier 2 and 2.26 at Tiers 2–5. • CO_2: 2.4 kg/liter • Black carbon: 15.65 kg CO_2e per liter

ment target of 2020 to the SDG 7 target date of 2030 is estimated to be $6.91 for households at Tier 1 and $12.48 for households at Tier 2 to 5 (Table 5.5). These savings are equivalent to 0.5 percent and 0.9 percent of per capita annual income (in 2016). Over the ten-year period, the average household foregoes expenditure savings between $69 and $125, depending on the Tier of access.

The hours of study at home foregone by households without electricity in Kenya are estimated to be 32.6 a year per household, at all Tiers, equivalent to 4 days of study. Over the 10-year period, households lose 326 hours of home study, equivalent in time to 20 percent of a school year.

The CO_2 emission reductions foregone by households are 17.3 kg and 34.5 kg a year, depending on the Tier of access. These reductions are equivalent to 2.6 percent and 5.2 percent, respectively, of annual per capita greenhouse gas emissions. Total CO_2 emission savings foregone for the average household are 172 kg at Tier 1 and 345 kg at Tiers 2 to 5.

Black carbon emissions per household over the ten years of the Government Target Scenario are an estimated 1,125 kg CO_2e at Tier 1 and 2,249 kg CO_2e at Tiers 2 to 5. Annually the black carbon reductions are equivalent to 17 percent and 34 percent of per capita CO_2e emissions (in 2013), depending on Tier of access.

NATIONAL ENERGY ACCESS DIVIDEND

Government Target Scenario

The Energy Access Dividend for Kenya is based on a period of 10 years, the difference between the 2030 SDG target year,[15] and 2020, the government target year.

The smaller population results in a smaller total Energy Access Dividend than in Bangladesh (Table 5.6). The national Energy Access Dividend includes an estimated $853.7 million in foregone (gross) expenditure savings over the 10-year period. This is equivalent to 0.1 percent of the country's GNI in 2016.

The Energy Access Dividend includes 2.27 million hours of foregone study at home (by boys), which is equivalent to a school year for 1.42 million students. The emission reductions in the estimate total 2,356 metric tons CO_2, and 15.3 million metric tons CO_2e black carbon emissions over the 10-year period. The CO_2 emissions equal the per capita annual CO_2 emissions of over 1,500 Kenyans,

[15] *Under the historical rate of electrification, 2030 is also the year universal access is achieved in Kenya.*

while the annual black carbon emissions are equivalent to 5.3 percent of Kenya's total greenhouse gas emissions in 2013.

Annually, the expenditure savings foregone for Kenya are equivalent to the annual income of 55,126 people. The foregone hours of study at home are equivalent to the time that 142,000 students would spend in school. The CO_2 emissions savings foregone each year would be equivalent to the annual emissions of 1,930 Kenyans—or 2,359, if emissions from electricity and heat only were considered. While black carbon emission reductions foregone each year in Kenya are equivalent to 0.9 percent of total annual greenhouse gas emissions, they are also equivalent to 50 percent of emissions from electricity and heat.

TABLE 5.5 HOUSEHOLD ENERGY ACCESS DIVIDEND IN KENYA

Household Dividend		**Government Target Scenario**
Period for which benefits accrue (years)		10
Dividend (Cumulative per household, over period)	**Tier 1**	**Tiers 2–5**
Expenditure on lighting ($)	56	111
Expenditure on phone charging ($)	13	13
Total expenditure reduction ($)	69	125
Hours of study: boys (hours)	326	326
Hours of study: girls (hours)	0	0
Total hours of study (hours)	326	326
CO_2 emission reduction (kg)	172	345
Black carbon emission reduction (kg CO_2e)	1,125	2,249
Dividend (Annual per household, over period)	**Tier 1**	**Tiers 2–5**
Expenditure on lighting ($/ year)	5.57	11.14
Expenditure on phone charging ($/ year)	1.34	1.34
Total expenditure reduction ($/ year)	6.91	12.48
Hours of study: boys (hours/ year)	32.60	32.60
Hours of study: girls (hours/ year)	0	0
Total hours of study (million hours/ year)	32.60	32.60
CO_2 emission reduction (kg/ year)	17.25	34.50
Black carbon emission reduction (kg CO_2e/ year)	112	225

Source: Author's own analysis.

TABLE 5.6 NATIONAL ENERGY ACCESS DIVIDEND IN KENYA

National Dividend	Government Target Scenario
Period over which benefits accrue (years)	10
Dividend (Cumulative over period)	
Expenditure on lighting ($ million)	760.75
Expenditure on phone charging ($ million)	93.00
Total expenditure reduction ($ million)	853.75
Hours of study: boys (thousand hours)	2,269.64
Hours of study: girls (thousand hours)	0
Total hours of study (thousand hours)	2,269.64
CO_2 emission reduction (metric tons)	2,356
Black carbon emission reduction (t CO_2e)	15,362,147
Dividend (Annual over period)	
Expenditure on lighting ($ million/ year)	76.08
Expenditure on phone charging ($ million/ year)	9.30
Total expenditure reduction ($ million/ year)	85.38
Hours of study: boys (thousand hours/ year)	226.96
Hours of study: girls (thousand hours/ year)	0
Total hours of study (thousand hours/ year)	226.96
CO_2 emission reduction (metric tons/ year)	236
Black carbon emission reduction (t CO_2e/ year)	1,536,215

Source: Author's own analysis.

6. DISCUSSION

This section discusses similarities and differences between the Energy Access Dividend estimates for Bangladesh, Ethiopia, and Kenya. The discussion places these figures in context, comparing them to GNI (total and per capita), school years and school age population, and CO_2e emissions (total and per capita). The estimates are then discussed in relation to the 2030 Agenda for Sustainable Development.

It is evident from the Energy Access Dividend estimates that households with access to electricity—at any Tier—have significant benefits over those without access. The estimates show that the economic, social, and environmental benefits of access to electricity are felt as soon as households have a minimal level of access. The analysis shows that a household moving from no access to electricity to the minimal level of service provided by a solar lamp (Tier 1), benefits measurably from electric light and phone charging services which consume less than 4.5 kWh a year. Notably, after gaining access to this level of electricity, a household is likely to reduce its expenditure on kerosene lighting and phone charging, and school students increase the amount of time spent studying at home. There are likely to be net financial savings after deduction of the costs to the household.[16] Members of the household may change the way they allocate their time during the day, with the extended number of hours of light afforded by a solar lamp. The additional benefits the household gains—from reduced household air pollution (HAP), social interaction, and sense of security—may be less measurable, but are nonetheless notable. The environment benefits, as well, from reduced emissions of CO_2 and black carbon.

When a household gains access to electricity at Tier 2, there are additional benefits over Tier 1 access. These include a further reduction in expenditure on kerosene lighting, because with Tier 2 access many households will be able to eliminate dependence on kerosene lamps. There will be additional benefits through reductions in HAP and climate change emissions (CO_2 and black carbon).

Households that gain access at Tiers 3, 4, and 5 will have benefits at least equivalent to those at Tier 2. However, lack of information prevents reliable estimation of any additional benefit over those gained at Tier 2. At higher Tiers, additional benefits may depend on the household's ownership of appliances (e.g., fans, refrigerators). At Tier 5, the level of electricity consumption implies higher expenditure per household in absolute terms. The share of household expenditure given to electricity consumption may also be higher than at lower Tiers.

These estimates of the Energy Access Dividend suggest alternative strategies to achieve universal access to electricity can have significantly different opportunity costs, measured in terms of benefits foregone to households without access.

[16] *The annual expenditure saving for a household at Tier 1 ranges from $13.03 in Kenya to $30.38 in Bangladesh. This compares with the $5.00 a year cost to acquire and maintain access at this Tier, estimated in SEforALL et al. (2017).*

6.1 HOUSEHOLD ENERGY ACCESS DIVIDEND

The range of total financial (gross) savings per household in each country, determined by different Tier assumptions, is shown in Table 6.1. Differences between the countries are due to differences in kerosene prices and baseline household kerosene consumption. The latter was found to be lowest in Ethiopia. As a proportion of average per capita incomes in each country, expenditure savings per household are higher in Ethiopia, where average incomes are lowest. The range across the three countries is between 0.9 percent and 3.6 percent of annual per capita income.

The estimated number of hours of home study per household included in the dividend estimates is shown in Table 6.2. Variations in the numbers of schools and children in each household partly explains the differences between the countries. Based on the evidence available, there are also differences in the amount of additional time students study at home when the household gains access to electricity. Cultural factors may explain this. For the average household in Bangladesh and Kenya, the additional time spent in home study is the equivalent of 3.8 percent of the school year, while in Ethiopia the proportion of the school year is much higher, almost 18 percent.

CO_2 emission savings, as a proportion of per capita annual greenhouse gas emissions, range from 1.9 percent to 5.8 percent at Tier 1 access, and 3.6 percent to 9.9 percent at higher Tiers. The CO_2e emission savings due to the reduction in black carbon emissions is more significant in all three countries, ranging from a about a quarter to three-quarters of annual per capita CO_2e (Table 6.3).

6.2 NATIONAL ENERGY ACCESS DIVIDEND

For a country, the Energy Access Dividend is the aggregation of annual benefits from access to electricity, which are foregone by households without electricity over a defined period. This period is the difference, in years, between

TABLE 6.1 HOUSEHOLD FINANCIAL SAVINGS COMPARISON

	Bangladesh	Ethiopia	Kenya
(Gross) expenditure savings per household ($/ year)	30.38–35.25	15.19–23.74	13.03–23.54
Per capita GNI current (2016) ($)	1,330	660	1,380
Savings as percent of GNI per capita (%)	2.3–2.7	2.3–3.6	0.9–1.7

Sources: Author's own estimates; World Development Indicators.

TABLE 6.2 HOUSEHOLD HOURS OF HOME STUDY COMPARISON

	Bangladesh	Ethiopia	Kenya
Annual hours of study per household (hours)	60.0	285.4	61.5
Equivalent number of days (days)	7.5	35.7	7.7
Number of days as % of school year (%)	3.8	17.8	3.8

TABLE 6.3 HOUSEHOLD EMISSION REDUCTION COMPARISON

	Bangladesh	Ethiopia	Kenya
CO_2 savings per household (kg)	72.0–86.4	28.8–54.7	32.5–65.1
CO_2e savings per household (kg)	763.5–916.2	407.6–774.5	212.2–424.4
Total per capita CO_2e (kg)	1,230	1,510	660
CO_2e savings as % of per capita CO_2e (%)	62.1–74.5	27.0–51.3	32.2–64.3

delivering access to electricity through conventional grid extension, and delivering access more rapidly through off-grid systems.

To illustrate a comparison between alternative electrification strategies, the analysis used the difference, in years, between the SDG target year for universal access and the government target year for Kenya and Bangladesh of 2020 and 2021 respectively–Government Target Scenario. Coincidentally, nine to ten years is the lead-time often given for large-scale power infrastructure development, which has conventionally been the means to achieve electrification. This lead-time is contrasted with the few weeks or months that might be needed to deliver access to electricity through decentralized renewables, in Power for All's conceptualization of the Energy Access Dividend (Power for All, 2016).

In the case of Ethiopia and Bangladesh, an estimate was also made of the dividend to reach universal access in 2030 rather than at the historical rate of progress of 2069 and 2036 respectively—SDG 7 Target Scenario.

For the Government Target Scenario, total expenditure savings are estimated at $2.22 billion in Bangladesh and $854 million in Kenya over this 9- to 10-year period. Table 6.4 details the estimates across the three countries. These savings are equivalent to about 33 percent and 6 percent, respectively, of the total cost of delivering access in these countries at Tiers 1 to 3.[17] As a proportion of one year's GNI, the savings are 1 percent in Bangladesh and 0.1 percent in Kenya.

Annually, over the nine-to-ten-year period, the financial savings would be $247 million in Bangladesh and $85 million in Kenya. This annual dividend is equivalent to the average annual incomes of 185,600 people in Bangladesh and 61,800 in Kenya.

The educational opportunity cost—in terms of time not spent studying at home—is equivalent to the time tens of thousands of students would spend in school. A delay of nine years in providing universal access in Bangladesh would mean foregoing around four billion hours of home study by school students. This is equivalent to the time that 278,000 students would spend in school over this period. Because nine years is more than double the time that most people in Bangladesh have spent in education (NIPORT et al., 2016), this dividend could be regarded as equivalent to the complete education of over 278,000 people. This is approximately one percent of the school age population.

In Kenya, the annual Dividend in additional study at home is equivalent to 16,850 school years (or the school year of 0.1 percent of the school age population).

[17] *The costs are those estimated in SEforALL et al. (2017).*

TABLE 6.4 COMPARISON OF NATIONAL ENERGY ACCESS DIVIDEND ESTIMATES ACROSS THREE COUNTRIES

	Bangladesh	Kenya	Bangladesh	Ethiopia
National Dividend	Government Target Scenario	Government Target Scenario	SDG 7 Target Scenario	SDG 7 Target Scenario
Period that benefits accrue (years)	9	10	6	39
Total expenditure reduction ($ million)	2,222	854	1,256	10,460
Savings equivalent to total cost of delivering access to Tiers 1–3 (%)	33	6	18	76
Savings as a proportion of GNI (%)	1	0.1	0.45	14.5
Total annual expenditure reduction ($ million/ year)	247	85	209	268
Equivalent to the average annual income (number of people)	185,600	61,800	157,000	406,000
Total hours of study (thousand hours)	4,004	2,270	2,350	124,689
Equivalent to time spent in school annually (number of students)	278,000	142,000	244,800	2,000,000
Equivalent annually to education (% of school age population)	1	0.1	0.6	7
CO_2 emission reduction (metric tons)	5,734	2,356	3,366	23,341
Relative to per capita emissions annually, equivalent to emissions (number of people)	637	357	456	396
Black carbon emission reduction (t CO_2e)	60,802,087	15,362,147	35,691,502	330,365,516
Annually as proportion of total CO_2e (% total emissions)	3.5	4.5	3.1	6

The Energy Access Dividend estimates include reductions for CO_2 and black carbon. The latter is measured in terms of its equivalent global warming effect, as metric tons CO_2e. The CO_2 emission reductions over the periods of the estimates are 5,734 metric tons in Bangladesh and 2,356 metric tons in Kenya. Relative to total annual emissions in these countries, the dividend is small. Relative to per capita emissions, the annual CO_2 dividend is equivalent to the emissions of 637 and 357 people, respectively, for Bangladesh and Kenya.

The reduction in black carbon emissions is more significant in relation to national CO_2e emissions. Annually, over the periods included in the estimates, the reduction in black carbon emissions are equivalent to 3.5 percent of total emissions in Bangladesh and 4.5 percent in Kenya.

For the SDG 7 Target Scenario, this represents a period of 6 and 39 years for Bangladesh and Ethiopia respectively between the SDG 7 target year and the projected year for universal access based on the historic rate. Total expenditure savings are estimated at $1.2 billion in Bangladesh and $10.5 billion in Ethiopia over this period. These savings are equivalent to about 18 percent and 76 percent, respectively, of the total cost of delivering access in these countries at Tiers 1 to 3.[18]

[18] *The costs are those estimated in SEforALL et al. (2017).*

In Ethiopia, the educational dividend is significantly higher than for Bangladesh, equivalent to 7 percent of the school age population compared to 0.6 percent due to the larger number of school-age children per household and the current low rate of electrification.

CO_2 emissions are 3,366 metric tons CO_2 and 23,342 metric tons CO_2, while black carbon emissions are 3.1 percent and 6 percent of annual CO_2e emissions, respectively, for Bangladesh and Ethiopia.

6.3 THE ENERGY ACCESS DIVIDEND AND AGENDA 2030

The Energy Access Dividend estimates for Bangladesh, Ethiopia and Kenya focus on the measurable effects of households' access to electricity on expenditure, education and climate change. The scale of the estimated dividend is significant for each country, in terms of total and per capita GNI, the total amount of time students spend studying, and the country's greenhouse gas and black carbon emissions. The dividend therefore potentially has a bearing on progress towards the objectives of the SDGs.

Savings on expenditure for lighting and charging—which may be net savings for households at Tiers 1 and 2—will contribute to achievement of the goal to reduce inequality (SDG 10) and the goal to "end poverty in all its forms" (SDG 1). Net savings on lighting and phone charging expenditure increase the disposable income of households, allowing higher expenditure on other goods and services. The dividend estimates point to the equivalent of 0.1 percent to 1 percent of GNI being available for additional expenditure in Bangladesh and Kenya in the Government Target Scenario, with a much higher share of GNI in Ethiopia for the SDG 7 Target Scenario due to its current relatively low-level of electrification and longer timeframe. Net savings may be used to purchase essential goods and services, such as food or health care. This can contribute to other SDGs (e.g., ending hunger (SDG 2) or ensuring healthy lives (SDG 3)).

By lowering the unit cost and increasing the quality of lighting, access to electricity reduces the difference between the lighting services enjoyed by households in lower- and higher-income groups. Many households are prepared to pay more for this improved lighting than they previously spent on kerosene lighting. By reducing the cost of using a mobile phone, access to electricity indirectly contributes to easier access to information and communications, contributing to SDG targets 5.b ("Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women") and 9.c ("Significantly increase access to information and communications technology and strive to provide universal and affordable access to the Internet in least developed countries by 2020"). Indirectly, improved communication contributes to the achievement of most SDGs.

The increase in time spent studying at home—which often follows access to electric lighting—can contribute to the achievement of SDG 4, inclusive and equitable education. The Energy Access Dividend estimates show that, over a nine- or ten-year period, the aggregate additional time spent studying amounts to several million days in Bangladesh and Kenya in the Government Target Scenario. This time is approximately equivalent to a year's study by 0.1 percent to 1 percent of the total school age population. In some places, school attendance and the educational performance of students improve after access to electricity, thus contributing to SDG target 4.1 ("ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes"). Universal access to electricity could eliminate educational differences between students attributable to the lack of electric lighting in some homes, helping to "ensure equal opportunity and reduce inequalities in outcome" (SDG target 10.3).

The reduction in CO_2 and black carbon emissions—which follows access to electricity—contributes to the climate change goal (SDG 13). It will also contribute to the goals of the Paris climate change agreement and Emission Reduction Targets in countries' Nationally Determined

Contributions. The reduction in black carbon emissions from kerosene lighting is particularly significant. In the estimates for Bangladesh and Kenya for the Government Target Scenario, these are equivalent to between 3.1 percent and 4.5 percent of total CO_2e emissions annually. However, black carbon emissions are not always included in contributions to address climate change.

The reduction in kerosene consumption—and its complete substitution at higher Tiers of access—also reduces HAP. Although research evidence on the effects of reduced HAP from lighting is limited, lower particulate emissions have a positive effect on health, and can reduce the incidence of acute respiratory infections. This contributes to the "healthy lives" goal and specifically SDG target 3.9 ("substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination"). Other health benefits can include a reduction in accidents in the home and an improved sense of security.

The effect of access to electricity on the use of time by household members has not been included in the Energy Access Dividend estimate, due to the unavailability of information. The limited evidence is inconclusive about whether women will increase or reduce the amount of time they spend on domestic and care work. Extended hours of light allow them to redistribute work during the day, and there is some qualitative evidence to suggest that their work is easier to perform with electric light. In a qualitative way, these changes would contribute to SDG 5, gender equality and women's empowerment. Easier access for women to mobile phones and television—and greater opportunities to socialize in the evening—will also contribute indirectly to SDG 5 (specifically, as already noted, target 5.b).

Quantitative evidence about links between the effects of access to electricity and other SDGs is either inconclusive or unavailable. Some research suggests that access to electricity can have a positive effect on productivity and employment in home-based businesses. This would contribute to SDG 1, poverty eradication, and SDG 8, economic growth, employment and decent work. Increases in leisure time and the use of appliances for entertainment can improve well-being and social cohesion. Increased use of television and radio, enabled by access to electricity, can also improve access to information and knowledge, with indirect effects on health, education and productivity.

The Energy Access Dividend estimates provide an indication of the scale of the benefits that households—and countries—lose when access to electricity is delayed. In aggregate, and over a period of several years, these can be significant. Because access to modern energy services is an enabler of development, delayed access to electricity for large numbers of households will delay any direct or indirect contribution to the SDGs and potentially constrain the achievement of several SDG targets by 2030.

7. RECOMMENDATIONS

7.1 RECOMMENDATIONS FOR POLICY MAKERS

When governments determine their targets for universal access to electricity, they make choices about the rate of electrification and the level of access to be achieved. The capital cost of providing access to electricity is usually a prime consideration. Methods and tools to determine least-cost pathways to universal access are available.[19] However, these do not take the opportunity costs of alternative pathways into account, i.e., what is lost when one pathway is chosen over another. The Energy Access Dividend estimates for Bangladesh, Ethiopia and Kenya, indicate that these opportunity costs can be significant and should be considered when choosing between alternative electrification strategies and their resultant timely impact on development (or SDG) outcomes.

Even with limited data, the analysis indicates that there are significant benefits for households receiving access to Tiers 1 and 2, and sufficient evidence to integrate the financial savings, education and climate change benefits into national electricity and development planning, and economic analysis.

The framework for the Energy Access Dividend provides a structured approach to weigh the relative benefits of providing accelerated access to decentralized energy to households without access, particularly in rural and hard-to-reach areas, compared to services delivered through a grid-based connection later. The benefit, or dividend, analysis can be used in combination with energy supply-demand analysis, electrification scenario planning, and information about the local context, to prioritize the fastest path to provide the unelectrified with the dividends of electricity access.

The approach used here to estimate the Energy Access Dividend provides the basis for considering it in planning for universal access to electricity. Policy makers should consider alternative values for three parameters when they are deciding on an electrification strategy:

- The year that universal access to electricity should be achieved. This is partly a political question, but should consider the country's capacity to deliver electricity at different rates. Population growth and the baseline rate of electrification will also be relevant.

- The Tier of access to be achieved by those without access. This objective should reflect expectations about household consumption of electricity, determined by income levels and income distribution. For example, households in lower-income groups will likely consume small quantities of electricity, equivalent to consumption at Tiers 1 or 2, even if they have reliable grid access. The distribution of households across Tiers of access is needed to estimate the benefits at different Tiers. Where a MTF access survey is underway[20], a baseline distribution will be available, which can support

[19] *For example, LEAP (Long-range Energy Alternatives Planning System) and the open source Electrification Pathways tool.*

[20] *This includes: Kenya, Rwanda, Uganda, Zambia, Ethiopia, Nigeria, Niger, Liberia, India (7 low access states), Bangladesh, Myanmar, Cambodia, Nepal, Honduras, and Haiti.*

disaggregation of benefits across all five Tiers.

- The annual benefits to a household from access to electricity, which can be estimated following the approach used here for Bangladesh, Ethiopia, and Kenya. Savings from reductions in expenditure on kerosene lighting and phone charging can be estimated from information about their consumption, in physical or financial measures. Survey data can provide estimates of the additional time that students spend studying at home. Estimates of CO_2 and black carbon emission reductions, which follow access to electricity, can be made using standard coefficients and information about household consumption of kerosene for lighting, which is also needed for the expenditure savings estimate.

These assessments should be undertaken for all potential electrification pathways, not just the strategy chosen, if they are to contribute to strategic decision-making about electrification.

In some countries, there may be information available to allow quantification of other benefits from access to electricity. For Bangladesh and Kenya, for example, there is some information about changes in the amount of time spent on domestic work and leisure. The larger set of indicators in Section 2.3 and Annex 2, provides some guidance on what might be included.

7.2 RECOMMENDATIONS FOR FINANCIERS AND RESEARCHERS

The availability of research evidence and data limits what can currently be included in estimates of the Energy Access Dividend. Although there is considerable literature about the factors that determine decisions to connect to the grid or adopt solar home systems household-level data about how much electricity is used, and what it is used for—are quite limited. Much of the raw data used in some studies predates the spread of decentralized solar solutions (e.g., Bacon et al., 2010; Kojima et al., 2016), and very little is known about how households progress from one Tier of access to the next.

The framework presented here is a first step towards comprehensive and statistically robust estimates of the Energy Access Dividend. More robust estimates would be possible with improvements in data collection and availability, including:

- Providing guidance on how to adapt the framework for the national context and integrate it into energy planning and economic analysis.

- Extending the number of country estimates to a broader cross section of least-developed countries with high electrification deficits providing an order of magnitude estimate of the global Energy Access Dividend that results with accelerated delivery of universal access to electricity.

- Filling key gaps in data and evidence, specifically to:

    - cover productive[21] and community uses of energy.

    - disaggregate benefits across Tiers of energy service, particularly at Tiers 3 to 5, so that it is possible to weigh the relative development benefits that materialize at different levels of energy service against the costs of providing such services.

    - collect and analyse data about household energy consumption in a consistent and cost-effective way through existing household survey instruments (such as Demographic and Health Surveys (DHS), Living Standards Measurement Study (LSMS) household surveys, and household income and expenditure surveys). Further analysis of raw data about energy consumption in previous surveys should be assessed (for example, consumption by income quintile). Data about household surveys should be used to estimate the benefits linked to SDG 2 (ending hunger), SDG 3 (health and wellbeing for all), SDG 6 (access to water and sustainable water use), and SDG 8 (sustainable industrial development). Panel data should be collected to show how individual households progress from Tier to Tier.

- Extending the framework to allow the quantification of benefits associated with clean fuels and technologies for cooking, and thus provide a comprehensive Energy Access Dividend.

[21] Productive uses of energy are defined as those that increase income or productivity, referred to as value-adding activities. Source: Bhatia, M. & Angelou, N., 2015. Beyond Connections - Energy Access Redefined, Washington: Energy Sector Management Assistance Program.


Mambo

8. BIBLIOGRAPHY

Ahmed, A., K. Ahmad, V. Chou, R. Hernandez, P. Menon, F. Naeem, F. Naher, W. Quabili, E. Sraboni, and B. Yu. 2013. *The Status of Food Security in the Feed the Future Zone and Other Regions of Bangladesh: Results from the 2011–2012* Bangladesh Integrated Household Survey. Washington: International Food Policy Research Institute.

Aklin, M. 2016. *Access to Clean Cooking Energy and Electricity: Survey of States in India*. (ACCESS), Harvard Dataverse. Cambridge: Harvard University.

Angelou, N. 2014. *Multi-Tier Measurement of Access to Energy: Why and How to Measure Energy Access*. Presentation, 19 February 2014. Washington: ESMAP.

Asaduzzaman, M., D. Barnes, and S. Khandker. 2010 *Restoring Balance: Bangladesh's Rural Energy Realities*. World Bank Working Paper No. 181. Washington: World Bank.

Asian Development Bank (ADB). 2015. *Sustainable Energy for All Tracking Progress in Asia and Pacific: A Summary Report*. Manila: Asian Development Bank.

Attigah, B. and Mayer-Tasch, L. 2013. The Impact of Electricity Access on Economic Development: A Literature Review. *In Productive Use of Energy (PRODUSE): Measuring Impacts of Electrification on Micro-Enterprises in Sub-Saharan Africa*, edited by Mayer-Tasch, L., Mukherjee, M. and Reiche, K. Eschborn: GIZ.

Azimoh, C., Klintenberg, P., Wallin, F. and Karlsson, B. 201. *Illuminated but not electrified: An assessment of the impact of Solar Home System on rural households in South Africa*. Applied Energy, 155, 354-364.

Bacon, R., S. Bhattacharya and M. Kojima. 2010. *Expenditure of Low-Income Households on Energy*. Washington: World Bank. http://siteresources.worldbank.org/EXTOGMC/Resources/336929-1266963339030/eifd16_expenditure.pdf

Bangladesh Bureau of Statistics (BBS). 2011. *Report of the Household Income & Expenditure Survey 2010*. Dhaka: Government of Bangladesh.

Bangladesh Bureau of Statistics (BBS). 2015. *Population and Housing Census 2011*. Dhaka: Government of Bangladesh.

Barnes, D., R. Golumbeanu and I. Diaw. 2016. *Beyond Electricity Access: Output-Based Aid and Rural Electrification in Ethiopia*. Washington: World Bank.

Barron, M. 2014. *Essays on Household Electrification in Developing Countries*. PhD dissertation. Berkeley: University of California.

Bernard, T. and M. Torero. 2015. "Social interaction effects and connection to electricity: Experimental evidence from rural Ethiopia." *Economic Development and Cultural Change* 63 (3): 459-484.

Bersisa, M. 2016. *Multidimensional Measure of Household Energy Poverty and its Determinants in Ethiopia. East Africa Research Papers in Economics and*

Finance. Jönköping: Jönköping International Business School, Jönköping University.

Bhatia, M. and N. Angelou. 2015. *Beyond Connections: Energy Access Redefined*. ESMAP Technical Report 008/15. Washington: World Bank.

Blalock, G. and Veloso, F. (2007). Imports, Productivity Growth, and Supply Chain Learning. *World Development*, 35(7), 1134-115

Bonan, J., S. Pareglio, and M. Tavoni. 2014. *Access to Modern Energy: A Review of Impact Evaluations*. Nota di Lavori 96.2014. Milan: Fondazione Eni Enrico Mattei.

Brander, M., A. Sood, C. Wylie, A. Haughton, and J. Lovell, J. 2011. *Electricity-specific emission factors for grid electricity*. Technical Paper. London: Ecometrica.

Brossmann, M. 2013. *Off-grid Rural Electrification and Fighting Poverty. A Comparative Impact Assessment of Solar Home Systems and Small Solar Home Systems in Rural Bangladesh*. Global Studies Working Papers. Tübingen: University of Tübingen.

Central Statistical Agency (CSA). 2010. *Ethiopia Population and Housing Census 2007*. Addis Ababa: Central Statistical Agency.

Central Statistical Agency and ICF International. 2012. *Ethiopia Demographic and Health Survey 2011*. Addis Ababa: Central Statistical Agency.

Central Statistical Agency. 2014. *Ethiopia Mini Demographic and Health Survey 2014*. Addis Ababa: Central Statistical Agency.

Clark, D. 2013. *Information paper 5: Emission factors for black carbon*. London: Cundall Johnston & Partners. http://www.cundall.com/Cundall/fckeditor/editor/images/UserFilesUpload/file/WCIYB/IP-5%20-%20Emission%20factors%20for%20black%20carbon.pdf

Clean Development Mechanism (CDM). 2014. *Small-scale Methodology: Substituting fossil fuel based lighting with LED/CFL lighting systems, Version 5.0*. CDM AMS III-AR. United Nations Framework Convention on Climate Change.

Collings, S. 2011. *Phone Charging Micro-businesses in Tanzania and Uganda*. London: GVEP International.

Cropper, M. 2013. *How Should Benefits and Costs Be Discounted in an Intergenerational Context?* Resources for the Future Online Magazine, Issue 183. http://www.rff.org/research/publications/how-should-benefits-and-costs-be-discounted-intergenerational-context-0

Department of Environment (Bangladesh). 2013. Grid Emission Factor (GEF) of Bangladesh. Dhaka: Government of Bangladesh. http://www.doe.gov.bd/site/notices/059ddf35-53d3-49a7-8ce6-175320cd59f1/Grid-Emission-FactorGEF-of-bd

Dinkelman, T. 2008. *The Effects of Rural Electrification on Employment: New Evidence from South Africa*. Research Report 08-653. Ann Arbor: University of Michigan Population Studies Center.

d.light. 2015. *d.light Solar Home System Impact Evaluation*. San Francisco: d.light.

Eckley, L., Harrison, R., Whelan, G. and Timpson, H. 2014. *The social value of solar lights in Africa to replace the use of kerosene: Scoping report*. Liverpool: Centre for Public Health, Liverpool John Moores University.

Economic Consulting Associates. 2014. *Correlation and causation between energy development and economic growth*. London: Department for International Development.

Energising Development (EnDev). 2009. *Energising Development Report on Impacts*. Eschborn: Deutsche Gesellschaft für Technische Zusammenarbeit.

Energising Development (EnDev). 2015. *Empowering People Report on Impacts*. Eschborn: Deutsche Gesellschaft für Internationale Zusammenarbeit.

Green Mini Grid Market Development Programme (GMG-MD). 2017. *Mini Grid Market Opportunity Assessment: Ethiopia*. Abidjan: African Development Bank and Sustainable Energy for All Africa Hub.

Grimm, M., Munyehirwe, A., Peters, J. and Sievert, M. et al. 2014. *A First Step Up the Energy Ladder? Low Cost Solar Kits and Household's Welfare in Rural Rwanda*. Policy Research Working Paper 7859. Washington: The World Bank.

Groh, S., S. Pachauri, and N. Rao. 2016. "What are We Measuring? An Empirical Analysis of Household Electricity Access Metrics in Rural Bangladesh." *Energy for Sustainable Development*, 30: 21-31.

GSMA. 2011. *Community Power from Mobile-Charging Services*. London: GSMA

Halder, P. and M. Parvez. 2015. "Financial analyses and social impacts of solar home systems in Bangladesh: A case study." *International Journal of Renewable Energy Research*, 5 (2).

Harun, Md. A. 2015. *The Role of Solar Home Systems (SHS) in Socio-Economic Development in Bangladesh*. MA thesis. Dhaka: BRAC University.

Hassan, F. and Lucchino, P. 2014. *Powering Education. Enel Foundation Working Paper*. London: London School of Economics.

International Council for Science (ICSU). 2017. *A Guide to SDG Interactions: from Science to Implementation*. Paris: International Council for Science.

International Energy Agency (IEA). 2017. *Energy Access Outlook 2017, From Poverty to Prosperity*. Paris: International Energy Agency.

International Energy Agency (IEA) and World Bank. 2017. *Global Tracking Framework 2017*. Washington: World Bank.

Jacobson, A., T. Bond, N. Lam, and N. Hultman. 2013. *Black Carbon and Kerosene Lighting: An Opportunity for Rapid Action on Climate Change and Clean Energy for Development*. Washington: The Brookings Institution.

James, J. 2016. *The Impact of Mobile Phones on Poverty and Inequality in Developing Countries*. Springer.

Kenya National Bureau of Statistics (KNBS). 2015. *Kenya Demographic and Health Survey 2014*. Nairobi: Kenya National Bureau of Statistics.

Kenya National Bureau of Statistics (KNBS). 2016. *Statistical Abstract 2016*. Nairobi: Kenya National Bureau of Statistics.

Khandker et al. 2009. *Welfare Impacts of Rural Electrification: A Case Study from Bangladesh*. Policy Research Working Paper 4859. Washington: World Bank.

Khandker, S., Samad, H., Ali, R. and Barnes., D. 2012. *Who Benefits Most from Rural Electrification? Evidence in India. Policy Research Working Paper 6095*. Washington: The World Bank.

Khandker et al. 2014. *Surge in Solar Powered Homes: Experience in off-grid rural Bangladesh*. Washington: World Bank.

Kojima, M., X. Zhou, J. Han, J. de Wit, R. Bacon, and C. Trimble. 2016. *Who Uses Electricity in Sub-Saharan Africa? Findings from Household Surveys*. Policy Research Working Paper 7889. Washington: World Bank.

Komatsu S. 2013. *Determinants of user satisfaction with solar home systems in rural Bangladesh*. Energy, 61, 52-58.

Komatsu S., Kaneko, S., Shrestha, R. and Ghosh, P. 2011. *Non-income factors behind the purchase decisions of solar home systems in rural Bangladesh, Energy for Sustainable Development*, 15, 284–292.

Kudo, Y., Schonchoy, A. and Takahashi, K. 2015. *Impacts of Solar Lanterns in Geographically Challenged Locations: Experimental Evidence from Bangladesh*. IDE Discussion Paper No. 502. Chiba: Institute of Developing Economies.

Kumar, S. and Rauniyar, G. 2011. *Is electrification welfare improving? Non-experimental evidence from rural Bhutan*. Munich: University of Munich.

Lam et al. 2017. *The Pollutant Exposure Impact of Solar Lighting: Results from a pilot experiment in rural Kenya*. University California Berkeley and Acumen.

Lee, K., E. Miguel, and C. Wolfram. 2016. *Experimental Evidence on the Demand for and Costs of Rural Electrification*. Working Paper 22292. Cambridge: National Bureau of Economic Research.

Lemaire, X. 2016. *Household Solar: Extent of Evidence Relating to Impacts of Household Solar*. London: Evidence on Demand, Department for International Development.

Lighting Africa. 2008. *Lighting Africa Market Assessment Results: Quantitative Assessment – Ethiopia.* Washington: International Finance Corporation and World Bank.

Lighting Africa. 2013. *Ethiopia: Market Intelligence*. Washington: International Finance Corporation and World Bank.

Lighting Asia. 2014. *Snapshot Assessment of the Off-grid Solar Lighting Appliance Market Opportunity in Bangladesh*. Dhaka: Lighting Asia Bangladesh.

Lighting Global. 2012. *Household Lighting Fuel Costs in Kenya*. Market Intelligence Note. Washington: Lighting Global.

Mayer-Tasch, L., M. Mukherjee, and K. Reiche. 2013. *Productive use of energy – PRODUSE: Measuring Impacts of Electrification on Small and Micro-Enterprises in Sub-Saharan Africa*. Eschborn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Mills, E. 2003. *Technical and Economic Performance Analysis of Kerosene Lamps and Alternative Approaches to Illumination in Developing Countries*. Berkeley: Lawrence Berkeley National Laboratory, University of California.

Ministry of Energy and Petroleum (MOEP). 2016. *Sustainable Energy for All (SE4All) Kenya Action Agenda*. Nairobi: Ministry of Energy and Petroleum.

Ministry of Energy and Petroleum (MOEP). 2017. *Multi-Tier Framework Survey Kenya: Preliminary results for 14 underserved counties in Kenya*. Presentation at the Vienna Energy Forum, 9 May 2017.

National Environment Management Authority (NEMA). 2014. *Grid Emission Factor Report for Kenya: Report on the standardised baseline*. Nairobi: Government of Kenya.

National Institute of Population Research and Training (NIPORT), Mitra and Associates, and ICF International. 2016. *Bangladesh Demographic and Health Survey 2014*. Dhaka, Bangladesh, and Rockville, Maryland, USA: NIPORT, Mitra and Associates, and ICF International.

Nilsson, M., D. Griggs, M. Visbeck, and C. Ringler. 2016. *A draft framework for understanding SDG interactions*. Paris: International Council for Science.

Nzia, M. 2009. *End Use Based Model for Residential Power Consumption Forecasting in Nairobi, Region, Kenya*. Nairobi: University of Nairobi.

Orlandi, I, Tyabi, N. and Chase, J. 2016. *Off-Grid Solar Market Trends Report 2016*. London: Bloomberg New Energy Finance and Lighting Global.

Planning Commission. 2012. *Perspective Plan of Bangladesh 2010-2021: Making Vision 2021 a Reality*. Dhaka: Government of Bangladesh.

Power Africa. 2016. *The Roadmap: A Guide to Reaching 30,000 Megawatts and 60 Million Connections*. Washington: USAID.

Power for All. 2016. *Decentralized Renewables: The Fast Track to Universal Energy Access*.

Practical Action. 2010. *Poor People's Energy Outlook 2010*. Rugby: Practical Action.

Practical Action. 2016. *Poor People's Energy Outlook 2016*. Rugby: Practical Action.

Pueyo, A., F. Gonzalez, C. Dent, and S. DeMartino. 2013. *The Evidence of Benefits for Poor People of Increased Renewable Electricity Capacity: Literature Review*. Brighton: Institute of Development Studies.

Pueyo, A. and R. Hanna. 2015. *What Level of Electricity Access is Required to Enable and Sustain Poverty Reduction? Annex 1: Literature review*. Bourton-on-Dunsmore: Practical Action Consulting and Institute of Development Studies.

Ramji, A., S. Patnaik, S. Mani, and H. Dholakia. 2017. *Powering Primary Healthcare through Solar in India: Lessons from Chhattisgarh*. Delhi: Council on Energy, Environment and Water (CEEW) and Oxfam India.

Rao, N., A. Agarwal, and D. Wood. 2016. *Impacts of Small-Scale Electricity Systems: A Study of Rural Communities in India and Nepal*. Washngton: World Resources Institute.

REN21. 2017. *Renewables 2017 Global Status Report*. Paris: REN21 Secretariat.

Rom, A., I. Günther, and K. Harrison. 2016. *Economic Impact of Solar Lighting: A Randomised Field Experiment in Rural Kenya*. Study Report. Version v1.1. Zurich: NADEL Center for Development and Cooperation, ETH.

Rom, A., I. Günther, and K. Harrison. 2017. *The Economic Impact of Solar Lighting: Results from a randomised field experiment in rural Kenya*. London: Acumen.

Rysankova, D. 2017. *Beyond Connections: Improving Ways of Tracking Electricity Access*. Presentation, Vienna Energy Forum, 9 May 2017. World Bank.
Samad, H., S. Khandker, M. Asaduzzaman, and M. Yunnus. 2013. *The Benefits of Solar Homes: An Analysis from Bangladesh*. Policy Research Working Paper 6724. Washington: World Bank.

SolarAid and SunnyMoney. 2015. *Impact Report*. London: SolarAid.

Squires, T. 2015. *The Impact of Access to Electricity on Education and Other Essays in Spatial Economics*. PhD Diss. Brown University, Providence, Rhode Island.

Sustainable Energy for All (SEforALL) Africa Hub. 2017. *Mini Grid Market Opportunity Assessment: Ethiopia*. Green Mini Grid Market Development Programme, African Development Bank.

Sustainable Energy for All (SEforALL). 2015. *SE4All Advisory Board's Finance Committee Report on Scaling Up Finance for Sustainable Energy Investments*. Washington: Sustainable Energy for All. Available at: http://www.se4all.org/sites/default/files/SE4All-Advisory-Board-Finance-Committee-Report.pdf

Sustainable Energy for All (SEforALL). 2016. Going Further, Faster - Together: A Strategic Framework for Results 2016-21. Vienna: Sustainable Energy for All.

Sustainable Energy for All (SEforALL), Climate Policy Initiative (CPI) and the World Bank. 2017. *Understanding the Landscape - Tracking finance for electricity and clean cooking access in high-impact countries*. Washington: Sustainable Energy for All.

Sustainable Energy for All (SEforALL). 2015. *Scaling Up Finance for Sustainable Energy Investments*. Report of the SE4All Advisory Board's Finance Committee. Washington: Sustainable Energy for All.

Sustainable Energy for All (SEforALL). 2017. *Energizing Finance: Scaling and Refining Finance in Countries with Large Energy Access Gaps*. Washington and Vienna: Sustainable Energy for All.

Sustainable Energy for All (SEforALL), Practical Action and E3 Analytics. 2017. *Taking the Pulse: Understanding Energy Access Market Needs in Five High-Impact Countries*. Washington: Sustainable Energy for All.

Tedsen, E. 2013. *Black Carbon Emissions from Kerosene Lamps: Potential for a new CCAC initiative*. Berlin: Ecologic Institute.

Tegene, G., G. Berhe, and D. Teklemariam. 2015. "Impact of Rural Electrification on Poverty Reduction: Evidence from Rural Districts of Tigrai, Northern Ethiopia." *Journal of Business Management & Social Sciences Research* Volume 4, No.1.

Tracy, J. and A. Jacobson. 2012. *The True Cost of Kerosene in Rural Africa*. Washington: Lighting Africa.

UNESCO. 2014. *A View Inside Schools in Africa: Regional education survey*. Paris: UNESCO.

van de Walle, D., Ravallion, M., Mendiratta, V. and Koolwal, G. 2013. *Long-term impacts of household electrification in rural India*. Policy Research Working Paper 6527. Washington: The World Bank.

Wang, L. et al. 2011. *Quantifying Carbon and Distributional Benefits of Solar Home System Programs in Bangladesh*. Policy Research Working Paper 5545. Washington: World Bank.

Winther, T. and Wilhite, H. 2015. *Tentacles of Modernity: Why Electricity Needs Anthropology*. Cultural Anthropology, 30(4), 569-577.

World Bank. 2002. *Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits*. ESMAP Report 255/02. Washington: The World Bank.

World Bank. 2008. *The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits*. An IEG Impact Evaluation. Washington: World Bank.

World Bank. 2016. *Access Investment Model. Energy Access: From Talk, to Walk* … to Run. Presentation to Civil Society Policy Forum, 2016 Spring Meetings. Washington: World Bank.

World Bank. 2017. *World Development Indicators*. Online at: www.data.worldbank.org

World Bank. 2017b. *State of Electricity Access Report 2017*. Washington: World Bank.

World Resources Institute (WRI). 2017. *CAIT Climate Data Explorer*. Online at: www.cait.wri.org/historical/

Zhang, Y., T. Postlethwaite, and A. Grisay. (eds.). 2008. *A View Inside Primary Schools: A World Education Indicators (WEI) cross-national study*. Paris: UNESCO.

ANNEX 1

METHODOLOGY AND ASSUMPTIONS

The Energy Access Dividend estimate is determined by three factors: the number of households without access to electricity, the benefits of access to electricity and the number of years a household is without electricity. These can be represented in an equation, as follows:

$$EAD = \sum Ht \times Bt \times T$$

where:

- EAD is a country's Energy Access Dividend.
- Ht is the number of households without access to electricity in year t.
- Bt is the annual benefit of access to electricity in year t.
- T is the average number of years a household is without electricity.
- Ht is a function of the total population, average household size and the proportion of the total population without electricity, and can be represented as:

$$Ht = (Pt \div h) \times At$$

where:

- Pt is the total population in year t, as provided in the World Bank's population forecast. The Energy Access Dividend estimates include population growth.
- h is the average number of people in a household, as provided in the most recent national census. The national average is used.
- At is the proportion of the population without access to electricity. The Global Tracking Framework (IEA and World Bank, 2017) provides the baseline.
- Bt is an estimate of the annual benefit of access to electricity. This is a function of the multiple benefits of access to electricity, and can be represented by:

$$Bt = f\ (\$, \Delta T, S, Y, C)$$

where:

- $ is gross reduction in expenditure on kerosene lighting and phone charging. Expenditure on other sources of light (e.g., candles, dry cell batteries) is not included, because the data were not available in all countries. However, the literature shows that kerosene is the principal source of lighting in the great majority of households without access to electricity.
- ΔT is change in use of time by household members. Data are available for additional time spent studying at home. Evidence about other changes (e.g., domestic work) is not sufficiently available and robust.
- S represents social benefits (e.g., education, health, entertainment). The lack of research evidence attributing changes to changes in energy consumption prevents their inclusion in the estimate.

- Y is productivity.

- C is reduction in greenhouse gas and black carbon emissions, which affect climate change. The estimate uses standard coefficients to estimate emission reductions and research evidence based on the incidence of different kinds of kerosene lamps.

Total Bt in any year is also a function of the distribution of households across Tiers of access, because the benefits of access to electricity to a household differ between Tiers of access.

The number of years a household is without electricity (T) is estimated using the number of households without electricity each year in the period between the base year (2014) and the year universal access is achieved, divided by the rate of electrification in the period until universal access is achieved.

There are two key assumptions in this approach to estimating the Energy Access Dividend:

- the rate of electrification until universal access is achieved, and

- the distribution of households across Tiers of access.

ANNEX 2

ELECTRICITY ACCESS IMPACTS ON BUSINESSES AND COMMUNITY-BASED PUBLIC SERVICES

Peer reviewed and grey literature on the following indicators of the impact of electricity access on productive uses and community-based public services were reviewed. As shown in Table A2.1, data and research evidence is limited preventing further consideration in the estimates of the Energy Access Dividend presented in this report.

VALUE OF SAVINGS ON BUSINESS LIGHTING EXPENDITURE

The literature reviewed provides no research evidence about savings on energy expenditure when businesses gain access to electricity. The focus of most analysis about electricity and businesses is on the effects of unreliable electricity.

TIME SPENT ON PRODUCTION

There is evidence that businesses (e.g., retail shops) extend their business hours when electricity is available (ESMAP, 2002; Lemaire 2016; Rao et al., 2016). This effect is likely to be the same across Tiers of access. Interruptions to production from unreliable power receive more attention in the literature than the effect of gaining access.

CHANGE IN PRODUCTIVITY

Extended hours and the use of electrical machinery can lead to increased sales or lower costs. Although there is evidence of increases in non-farm enterprise incomes following electrification (Blalock and Veloso, 2007; Kumar and Rauniyer, 2011; Attigah and Meyer-Tasch, 2013; Rao et al., 2016), the evidence about impacts on enterprise productivity is inconclusive. Other studies find no systematic impact on enterprise profitability (e.g., EnDev, nd; Grimm et al., 2011). The available published data are not sufficiently disaggregated for Energy Access Dividend estimates.

SCHOOL FACILITIES WITH ACCESS TO ELECTRICITY

Access to electricity in schools enables the use of electrical equipment in teaching (e.g., televisions, video machines, and computers) and allows the use of school facilities during hours of darkness. The availability of electricity may also assist the retention of teachers in rural areas, where the electrification of schools is lower. In 2008, only 27 percent of rural schools in India had access to electricity, compared with 76 percent in urban areas (Zhang et al., 2008). In Peru, fewer than half of rural schools had electricity, while in Sub-Saharan Africa four out five primary schools lack access (UNESCO, 2014). In Kenya, however, 95 percent of public primary schools were electrified by 2013.

While data on the proportion or number of schools with access to electricity is available for many countries and could serve as a proxy for improved education, evidence of the impact on educational performance is limited. Information about the relationship between the electrification of schools and electrification more broadly is also unavailable. This suggests that the indicator is not yet appropriate for Energy Access Dividend estimates.

CHANGE IN COSTS OF HEALTH SERVICE PROVIDERS

The logic of this indicator is that access to electricity will reduce the costs of health service providers, through lower energy costs and/or reduced losses of vaccines and other supplies. The only evidence found for this is for India (Ramji et al., 2017) and it is not possible to generalize from this to other countries.

CHANGE IN MATERNAL MORTALITY

The logic for including this indicator is that access to electricity in health facilities will improve the quality of health services and thus health outcomes. While data are available in many countries about the number of health facilities with access to electricity, there is little evidence about the effect that access to electricity has on the quality of health services and health outcomes. There is no systematic evidence available to substantiate this, though Ramji et al. (2016) begin to address this gap in knowledge.

CHANGE IN MORTALITY

See discussion for 'change in maternal mortality'.

USE OF DIGITAL TECHNOLOGIES BY GOVERNMENT SERVICES

No information was found about how access to electricity affects the use of digital technologies to provide government services. In Kenya, over 90 percent of public facilities are reported to have access to electricity and data are available on the use of ICTs, but it is not possible to relate this to changes in electrification or the quality of public services.

TABLE A2.1 INDICATORS OF IMPACTS FROM GAINING ACCESS TO ELECTRICITY FOR BUSINESSES AND COMMUNITY-BASED PUBLIC SERVICES

Indicators of impacts from gaining access to energy	Units	Availability of research evidence	Supports the achievement of SDG	Supports measurement of SDG Indicator
Indicators of impacts on businesses				
1 Value of savings on business lighting expenditure	$	GAP	SDG 2—End hunger, achieve food security and improved nutrition and promote sustainable agriculture. SDG 8—Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.	2.3.1—Volume of production per labor unit by classes of farming/pastoral/forestry enterprise size. 2.3.2—Average income of small-scale food producers, by sex and indigenous status. 8.5.1—Average hourly earnings of female and male employees, by occupation, age and persons with disabilities.
2 Time spent on production	Hours	GAP		
3 Change in productivity (sales)	$	INCONCLUSIVE		
Indicators of impacts on community-based public facilities				
4 School facilities with access to electricity	Percent schools	GAP	SDG 4—Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.	4.1.1—Proportion of children and young people: (a) in grades 2/3; (b) at the end of primary; and (c) at the end of lower secondary achieving at least a minimum proficiency level in (i) reading and (ii) mathematics, by sex. 4.4.1—Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill. 4.6.1—Percentage of population in a given age group achieving at least a fixed level of proficiency in functional (a) literacy and (b) numeracy skills, by sex.
5 Change in costs of health service providers	$	LIMITED	SDG 3—Ensure healthy lives and promote wellbeing for all at all ages.	3.1.1—Maternal mortality ratio.
6 Change in maternal mortality	Mortality rate	GAP		
7 Change in mortality	Mortality rate	GAP		
8 Use of digital technologies by government services	Percent services using ICTs	GAP	SDG 16—Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.	16.6.2—Proportion of the population satisfied with their last experience of public services.

ANNEX 3
SUMMARY TABLES

TABLE A3.1 QUANTIFIABLE ANNUAL BENEFITS PER HOUSEHOLD FROM ACCESS TO ELECTRICITY AT DIFFERENT TIERS, IN BANGLADESH, ETHIOPIA AND KENYA

	Expenditure savings			Hours of study		CO_2 emissions (kg)	Black carbon (kg CO_2e)
	Lighting ($)	Phone charging ($)	Total ($)	Boys	Girls		
Bangladesh							
Tier 1	24.38	6.00	30.38	26.60	33.40	72.00	763.50
Tier 2	29.25	6.00	35.25	26.60	33.40	86.40	916.20
Tier 3	29.25	6.00	35.25	26.60	33.40	86.40	916.20
Tier 4	29.25	6.00	35.25	26.60	33.40	86.40	916.20
Tier 5	29.25	6.00	35.25	26.60	33.40	86.40	916.20
Ethiopia							
Tier 1	9.49	5.70	15.19	146.80	138.60	28.80	407.64
Tier 2	18.04	5.70	23.74	146.80	138.60	54.72	774.50
Tier 3	18.04	5.70	23.74	146.80	138.60	54.72	774.50
Tier 4	18.04	5.70	23.74	146.80	138.60	54.72	774.50
Tier 5	18.04	5.70	23.74	146.80	138.60	54.72	774.50
Kenya							
Tier 1	10.51	2.52	13.03	61.50	0.00	32.50	212.20
Tier 2	21.02	2.52	23.54	61.50	0.00	65.10	424.40
Tier 3	21.02	2.52	23.54	61.50	0.00	65.10	424.40
Tier 4	21.02	2.52	23.54	61.50	0.00	65.10	424.40
Tier 5	21.02	2.52	23.54	61.50	0.00	65.10	424.40

Source: Author's own estimates.

TABLE A3.2 QUANTIFIABLE NATIONAL BENEFITS PER HOUSEHOLD FROM ACCESS TO ELECTRICITY AT DIFFERENT TIERS, IN BANGLADESH, ETHIOPIA AND KENYA

		Financial savings			Hours of study			CO_2 emissions (t)	Black carbon (t CO_2e)
		Lighting expenditure ($ '000)	Phone charging ($ '000)	Total ($ '000)	Boys ('000 hours)	Girls ('000 hours)	Total ('000 hours)		
BANGLADESH	**Government Target Scenario**								
	Tier 1	0	0	0	0	0	0	0	0
	Tier 2	97,056	9,955	107,011	88,263	111,933	200, 196	287	3,040,104
	Tier 3	194,113	19,909	214,022	176,526	223,866	400,392	573	6,080,209
	Tier 4	388,226	39,818	428,044	353,053	447,731	800,784	1,147	12,160,417
	Tier 5	1,261,733	211,351	1,473,084	1,147,422	1,455,127	2,602,549	3,727	39,521,356
	Total	1,941,128	281,032	2,222,160	1,765,265	2,238,656	4,003,921	5,734	60,802,087
	SDG 7 Target Scenario								
	Tier 1	0	0	0	0	0	0	0	0
	Tier 2	56,973	5,843	62,817	51,812	65,706	117,517	168	1,784,575
	Tier 3	113,946	11,687	125,633	103,623	131,412	235,035	337	3,569,150
	Tier 4	227,893	23,374	251,266	207,246	262,823	470,069	673	7,138,300
	Tier 5	740,651	75,964	816,615	673,550	854,176	1,527,725	2,188	23,199,477
	Total	1,139,463	116,868	1,256,332	1,036,230	1,314,116	2,350,346	3,366	35,691,502
ETHIOPIA	**Government Target Scenario**								
	Tier 1	8,490	639	9,129	16,465	15,545	32,009	3	45,719
	Tier 2	64,521	2,557	67,078	65,858	62,179	128,037	25	347,467
	Tier 3	48,391	1,918	50,309	49,394	46,635	96,028	18	260,600
	Tier 4	64,521	2,557	67,078	65,858	62,179	128,037	25	347,467
	Tier 5	129,042	5,114	134,157	131,716	124,359	256,075	49	694,933
	Total	314,965	12,786	327,751	329,290	310,897	640,187	120	1,696,186
	SDG 7 Target Scenario								
	Tier 1	214,826	124,514	339,340	3,206,787	3,027,661	6,234,448	629	8,904,731
	Tier 2	1,632,678	498,057	2,130,735	12,827,146	12,110,644	24,937,790	4,781	67,675,955
	Tier 3	1,224,509	373,543	1,598,051	9,620,360	9,082,983	18,703,343	3,586	50,756,966
	Tier 4	132,678	498,057	2,130,735	12,827,146	12,110,644	24,937,790	4,781	67,675,955
	Tier 5	3,265,357	996,114	4,261,470	25,654,293	24,221,287	49,875,580	9,563	135,351,910
	Total	7,970,049	2,490,284	10,460,332	64,135,732	60,553,219	124,688,951	23,341	330,365,516
KENYA	**Government Target Scenario**								
	Tier 1	14,917	3,577	18,495	87,299	0	87,299	46	301,235
	Tier 2	319,638	38,324	357,962	935,282	0	935,282	990	6,454,630
	Tier 3	283,415	33,981	317,395	829,290	0	829,290	878	5,723,151
	Tier 4	87,370	10,475	97,845	255,649	0	255,649	271	1,764,302
	Tier 5	55,405	6,643	62,048	162,119	0	162,119	172	1,118,828
	Total	760,745	93,000	853,745	2,269,638	0	2,269,638	2,356	15,362,147

TABLE A3.3 TOTAL BENEFITS FOREGONE UNDER AN HISTORICAL RATE OF ELECTRIFICATION

	Bangladesh	Ethiopia	Kenya
Reduced expenditure on kerosene lighting ($ million)	4,311.0	9,806.4	1,093.2
Reduced expenditure on phone charging ($ million)	442.2	3,173.8	138.0
Additional time spent studying at home: boys (million hours)	3,920.4	81,738.4	3,367.0
Additional time spent studying at home: girls (million hours)	4,971.7	77,172.6	0.0
Reduced CO_2 emissions (metric tons)	12,734.0	29,747.0	3,385.0
Reduced black carbon emissions (million metric tons CO_2e)	135.0	421.0	18.6

Source: Author's own calculations.

TABLE A3.4 TOTAL BENEFITS FOREGONE UNDER GOVERNMENT TARGET RATE OF ELECTRIFICATION

	Bangladesh	Ethiopia	Kenya
Reduced expenditure on kerosene lighting ($ million)	1,230.4	2,151.4	332.4
Reduced expenditure on phone charging ($ million)	44.2	696.3	45.0
Additional time spent studying at home: boys (million hours)	1,119.0	17,932.0	1,097.4
Additional time spent studying at home: girls (million hours)	1,419.0	16,930.3	0.0
Reduced CO_2 emissions (metric tons)	3,634.0	6,526.0	1,029.0
Reduced black carbon emissions (million metric tons CO_2e)	38.5	92.4	5.7

Source: Author's own calculations.

TABLE A3.5 TOTAL BENEFITS FOREGONE UNDER SDG 7 RATE OF ELECTRIFICATION

	Bangladesh	Ethiopia	Kenya
Reduced expenditure on kerosene lighting ($ million)	3,171.5	1,836.4	1,093.2
Reduced expenditure on phone charging ($ million)	325.3	683.5	138.0
Additional time spent studying at home: boys (million hours)	2,884.2	17,602.7	3,367.0
Additional time spent studying at home: girls (million hours)	3,657.6	16,619.4	0.0
Reduced CO_2 emissions (metric tons)	9,368.0	6,406.0	3,385.0
Reduced black carbon emissions (million metric tons CO_2e)	99.3	90.7	18.6

Source: Author's own calculations.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