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The True Cost of Solar Tariffs in East Africa

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Key Takeaways

- Unelectrified households in East Africa tend to have low levels of disposable income and are sensitive to changes in the price of solar home systems. A 20% import tariff on solar home systems would be expected to yield an 18% reduction in sales of basic systems that include a panel, lights, and phone charging equipment, and a 32% decrease in sales of larger kits that include televisions.
- Higher SHS prices—driven by import tariffs, value-added tax, or profit motivations—have the same effect of slowing the electrification process and making it more difficult to reach national targets. Under a 20% import tariff scenario, households would likely purchase at least 58,100 fewer branded solar home systems every year in Kenya and Uganda, leading to approximately 300,000 fewer people gaining access to electricity every year. Though governments could generate some revenue from these tariffs, the tariff would be highly regressive. As companies would ultimately pass through higher costs to customers, the burden of the tariff would fall squarely on households lacking access to basic electricity.
- Gains to households and society from attaining electricity access through SHSs in the region include reduced kerosene expenditures for lighting, reduced cell phone charging expenditures, increased study time among children, and reduced climate-affecting emissions. These foregone benefits in Kenya and Uganda anticipated under a 20% import tariff scenario equate to $39 per affected household and more than $2.2 million in aggregate annually.

Summary

Over a billion people around the world continue to lack access to basic electricity, many of them unlikely to be connected to the grid for years or decades. Pay-as-you-go solar home systems (SHS)—kits that consumers can frequently purchase on credit that include a small solar panel, battery, light bulbs and wires, phone charging equipment, and sometimes televisions and other appliances—have quickly become a viable, private sector-driven solution that empowers consumers to take control of their energy future.

Many low- and middle-income governments look to import duties and value-added taxes (VAT) to fund critical government services and the bulk of SHS equipment is produced in China. As sales of systems have grown, the question of how these systems should be treated under border taxation regimes has become a prominent issue.

To better understand the trade-offs at stake, actual sales data for 700,000 units of solar home systems was collected from Uganda and Kenya, countries with vibrant SHS markets and where the border tariff debate looms large. The data was analyzed to measure the price sensitivity of consumers of two different SHS product lines in order to better understand the impact of tariffs on system sales as well as broader ramifications for households, electrification goals, and government revenue.

INTRODUCTION

Universal access to electricity is a primary goal for many governments and for the international community. The United Nations' Sustainable Development Goal 7 calls for universal access to affordable, reliable, sustainable, and modern energy by 2030, and many governments around the world have responded with their own aggressive targets: Kenya aims to achieve universal electrification by 2022, Uganda by 2030, Tanzania by 2030, and Rwanda by 2024, for instance.[1] The challenge is substantial: if these goals are to be met, they will require the coordination of domestic policymakers, international organizations such as Sustainable Energy for All, donor agencies, private companies, and communities on the ground, among other actors. The rewards would be significant: access to modern energy has been foundational to the development of productive economies and societies, and widespread economic development and services seen as essential to a high quality of life are unachievable without electricity.

The vast majority of public funds and policy attention has gone to centralized electricity grids, which are the backbone of electricity infrastructure in all industrialized countries and the primary providers of power services in all developing countries as well. In areas where grid extension remains prohibitively expensive—which includes, in particular, many rural areas in Africa as well as South and Southeast Asia—off-grid solutions, supplying power to individual homes or individual villages, are, at least for the foreseeable future, the only way to achieve the ambitious and redoubtable goals of many national and international policy makers.

Off-grid solutions, especially those using photovoltaic solar panels, have become viable alternatives to grid expansion in many markets. Falling energy technology costs—especially related to solar panels and batteries, the rise in cell phone ownership and mobile money usage, and the development of intelligent metering and electricity management systems—are, in many areas, enabling distributed renewable energy solutions to reach rural consumers faster and at a lower cost than extending the grid.

In many markets, low-income households can now afford to invest in home-level solar photovoltaic systems, oftentimes mobilizing credit for the first time. The number of people served by off-grid renewable energy in Africa has grown from just over 2 million in 2011 to over 53 million in 2016. Much of this growth has been through solar lights, but uptake of SHS—which allow the use of televisions, fans, and refrigerators, among other appliances—is also growing rapidly. Four million people used SHSs in 2017, with evidence of continued rapid growth in 2018, especially in East Africa, in part due to innovative approaches to financing in the region.[2] Improving efficiencies across the off-grid solar and appliance value chain is increasing the number and quality of energy services that can be delivered through SHSs. For many poor households with relatively small energy demands, the increasing potential for relatively small SHSs to power larger devices may provide nearly the same services that these households would gain through the grid. Access to off-grid power represents a substantial improvement in quality of life and a step toward engagement with a wider social and economic community. It is also a step that households—at least where systems are available for sale—are empowered to take their own initiative, without having to wait for the grid to arrive or generate the collective action needed to develop and maintain a microgrid or other more complicated distributed energy solutions.

The fast growth of enterprises that market and distribute solar home systems and solar lights has also caught the attention of government officials who must, among other priorities, raise revenue to build and maintain public infrastructure and services. Given the evident success of companies that provide off-grid solar solutions, the popularity of the products for a wide variety of consumers, and the fact that many of the products are imported from overseas—most commonly from China—these policymakers may consider that imposing tariffs on the imports of kits or components may serve two beneficial purposes. In the short run, the logic goes, tariffs could raise revenue for critical government operations. In the longer run, tariffs could create conditions in which a domestic manufacturing industry could grow up to meet the domestic demand for products. If the price of imported goods were higher, domestic manufactures could in theory come

[1] USAID (U.S. Agency for International Development). 2018. Tanzania Power Africa Fact Sheet. Last updated November 14. https://www.usaid.gov/powerafrica/tanzania; USAID (U.S. Agency for International Development). 2018. Rwanda Power Africa Fact Sheet. Last updated November 14. https://www.usaid.gov/powerafrica/rwanda

[2] International Renewable Energy Agency (IRENA). (2019). "Off-Grid Renewable Energy Solutions Global and Regional Status and Trends." IRENA, Abu Dhabi. Accessed January 2019, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Jul/IRENA_Off-grid_RE_Solutions_2018.pdf

to substitute for, and eventually displace, imports—thus creating a virtuous circle of employment, economic activity, and revenue generation as a larger share of value is created and consumed domestically.

Partly for these reasons, the East African Community (EAC), which includes Kenya and Uganda as well as Burundi, Rwanda, South Sudan, and Tanzania, has recently been reevaluating their Common External Tariff (CET) for solar appliances. After a decade of offering exemptions from import duties, in 2016 the EAC introduced import tariffs on solar appliances, although in spring 2018 the bloc announced its intention to remove these tariffs once again.[3]

Against this backdrop, this policy brief provides quantitative evidence on the impacts of import tariffs on solar home system kits and components. In particular, we consider how customers who purchase solar home systems in East Africa have responded to price variations in the past, which is the best guide to how they might respond to a price shock such as that which would result from a higher or lower tariff. To do so, we have gathered and combined sales data from several companies in the region, combined it with demographic and socioeconomic data from administrative sources, and analyzed consumers' price sensitivity using rigorous and well-accepted methods from economic literature. Further, we evaluate this in the context of realized and potential benefits of electricity access for underserved populations, and the universal access timelines announced by East African Community policy makers. Our results demonstrate that although import tariffs have the potential to raise potentially substantial funds for national governments, this comes at a significant cost, which is borne primarily by households in the poorest and most remote communities. Lastly, the analysis is built upon an understanding of how SHS customers respond to changes in price. Import tariffs are serving as the policy lens through which SHS price changes are examined in this brief, but the underlying driver of the price change could just as easily be a change in the VAT, levies (such as "eco-levies" applied to electrical and electronic products), other types of taxes, company pricing strategies, or other motivations.

MEASURING CONSUMERS' PRICE-RESPONSIVENESS

Economists use the *price elasticity of demand* to describe how consumers respond to changes in the prices of goods and services. The price elasticity of demand provides a quantitative measure of how consumers respond to the prices of goods and services in a market and is a critical parameter for estimating the effect of a tax or tariff increase (see box on page 4.). At least three other studies have attempted to provide a quantitative estimate of consumers' elasticity specifically for home solar lights or kits (see box on page 5). Each of these prior studies offers some insight, but even the best-designed one measures elasticity for a small subset of customers and communities. By contrast, our study uses comprehensive sales data from multiple years across a broad region, and thus complements and extends the work of prior researchers.

To measure the price sensitivity of consumers in East African markets, we assembled actual sales data for 700,000 units of solar home systems, going back as far as 2012. These sales data cover the whole of Uganda and Kenya, spanning all administrative regions in both countries except the Northern Region of Kenya. They were provided by several large companies that manufacture and distribute solar home systems in these countries and others in East Africa.[4] To our knowledge, this represents one of the most comprehensive sales databases of SHSs on the continent. Most importantly, it contains substantial variation in prices. This is important because a wide range of underlying price variability offers a broader basis for inference about the consequences of the change in prices that may result from an import tariff.[5] One drawback is that much of the data come from markets in a relatively early stage, in which substitute products were not

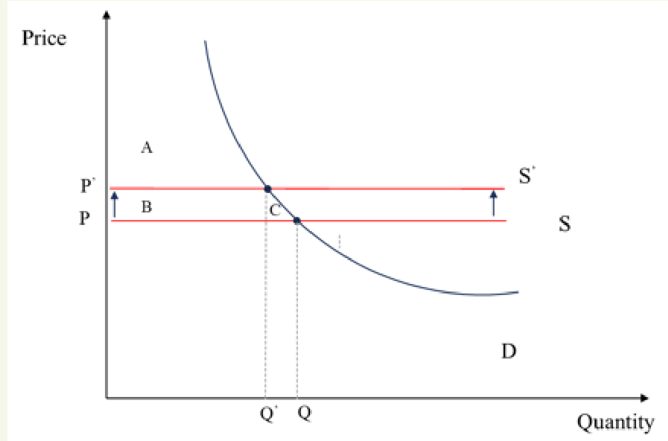
[3] Economic Consulting Associates Limited (2018) Energy Africa - Uganda: Fiscal policy options for Solar Home Systems (SHS) - Final Report, Evidence on Demand, 39p. https://www.gov.uk/dfid-research-outputs/energy-africa-uganda-fiscal-policy-options-for-solar-home-systems-shs-final-report; Xinhua News. "E. Africa to Scrap Solar Tariff to Reduce Dependence on Fossil Fuels." April 24, 2018.

[4] These companies supplied us with data under nondisclosure agreements and data use agreements but did not sponsor this research or analysis. Neither the Energy Access Project nor the Nicholas Institute for Environmental Policy Solutions have any financial relationship with these companies in any way.

[5] The price variation in our data generally arises from companies changing pricing plans or experiencing changing cost structures. However, the source of the price variation does not matter; customers respond to prices along with product characteristics and are rarely if ever concerned with the exact sources or components of price.

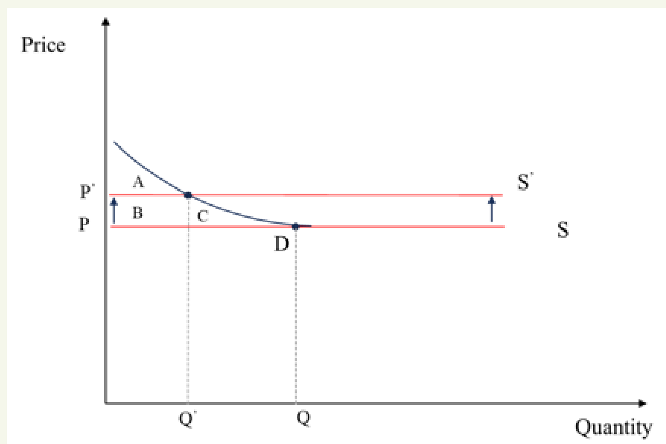
What is the Price Elasticity of Demand?

In general consumers buy less of something when the price goes up; the elasticity of demand measures how much less: the percentage change in quantity demanded, relative to the percentage change in price. Graphically, the elasticity is related to the slope of the demand curve (see figures): a steeper line, like the figure on the left, means demand is more inelastic (an elasticity between 0 and -1), while a less steep line, like the one at bottom, means demand is more elastic (less than -1, or an absolute value greater than one). Gasoline is one product with very inelastic demand: Even when prices rise by a substantial amount, the quantity purchased (in the short run) typically does not change much because most people have limited options for using less gasoline in the short run (there are few substitutes, and the best conservation measure is often to move to an area with better public transit, or to buy a different car). The price elasticity of gasoline in the USA is usually estimated to be around -0.3. By contrast, products that consumers can easily find substitutes for, or easily use less of when the price rises, have more elastic demand.



Elasticity and the Effects of Tariffs

Understanding the price elasticity is critical for estimating the impact of a tariff, for several reasons. First, the elasticity indicates how much sales will drop as a result of a price increase. Because the amount of revenue from a tariff is ultimately driven by sales, the elasticity is important for estimating the amount of government revenue that could be raised. And finally, it helps to measure the welfare loss associated with a tariff—what economists call the deadweight loss. In the figures at right, the rectangle B represents government revenue from a tariff, while area C represents the deadweight loss that accrues from customers changing their buying patterns. In the top panel (inelastic demand), the amount of government revenue raised from a tariff (area B) is relatively high, compared to deadweight loss (area C); in the bottom panel (elastic demand), area B is much smaller relative to area C, indicating relatively high social welfare losses compared to revenue raised.



readily available. Because the availability of substitutes has a substantial effect on estimated elasticity, this may result in underestimating the price elasticity of demand.

Accounting for Place and Time

Customers' purchase behavior depends on product features, income, awareness and education, and advertising campaigns, in addition to the price of the product. To account for customer awareness regarding potential uses of solar home systems, we focused on customers' purchasing behavior in regions where companies had been selling for at least six months. We also incorporated information on customers' income, including both spatial and temporal variation. Since our data reflect actual purchases in market settings, but we do not observe other aspects of individual customers such as occupation or

Prior Research on the Price Elasticity of Demand

At least three other studies offer a quantitative estimate of the price elasticity of demand for off-grid solar home systems. One of these, produced by the Uganda Off-Grid Market Accelerator (UOMA), estimates a price elasticity of -0.5 based on "research and consultations," but offers no additional detail on the source of these consultations or the assumptions that drive the estimate.[1] In the second study researchers at Economic Consulting Associates, a consultancy, assumed a price elasticity of -1.0 for solar home systems, but similarly provide no details regarding the source of this assumption.[2] The third study uses a statistically rigorous and economically well-established method to estimate actual willingness-to-pay for home solar products among 324 households in 16 villages in rural Rwanda.[3] This includes offering different prices to different households, with a random assignment of a given price to a given household, which maximizes the representativeness of the results. These researchers were able to characterize the elasticity over a wide range of prices and levels of uptake; for the system most comparable to the ones in our study (a 20-watt panel with 4 LED lamps, with an approximate retail price of $182), they found an elasticity of about -2.4 at prices close to the market price and about -1.5 at prices around one-half the market price. The finding that demand is more elastic at a higher price is not surprising, since a relatively small percentage change in price (at a high price) may result in a relatively large percentage change in quantity demanded (at a low quantity).

[1] Uganda Off-Grid Energy Market Accelerator (UOMA). *Fiscal Policy Analysis: An Assessment of the Tax and Subsidy Options to Accelerate Solar Home Systems in Uganda*, by D. Cardoso, C. Mugimba, J. Maraka. Kampala Uganda, November 2018. https://shellfoundation.org/app/uploads/2018/12/Uganda-Fiscal-Policy-Analysis-Nov-18.pdf.

[2] Economic Consulting Associates Ltd. *The Impact of Reducing VAT/Duties on Household Energy Products: Technical Assistance to Model and Analyse the Economic Effects of VAT and Tariffs on picoPV Products, Solar Home Systems and Improved Cookstoves in Mozambique*. 2018.

[3] Grimm, M., L. Lenz, J. Peters, and M. Sievert. *Demand for Off -Grid Solar Electricity: Experimental Evidence from Rwanda*. Ruhr Economic Papers #745. 2018.

asset ownership, we used the Uganda National Panel Survey (2013–14) and the Kenya Integrated Household Budget Survey (2015–16) to estimate income variation across regions, matching on the geographic locations of sales as reported by firms.

Customers' disposable income varies not just by location but also by time of year, due to elements such as agricultural planting and harvest seasons, or the timing of school fees coming due. Companies also conduct advertising and marketing campaigns, often around holiday times, that may also alter customers' purchasing behavior. In measuring how customers respond to changes in prices, it is important to account for simultaneous changes in other conditions such as these that may affect purchases for reasons other than the product price. Our estimation method accommodates these seasonal variations, as well as other phenomena that may result in changing levels of sales, using standard economic and econometric techniques.

Pay-As-You-Go and Consumers' Time Preference

The vast majority of solar home kits are purchased on a "Pay-As-You-Go" system, in which customers pay an initial deposit to receive the product, then pay out the remainder of the capital cost over a series of payments, often over one to two years and generally utilizing mobile money. This feature enables credit-constrained consumers to obtain these capital-intensive goods, especially in areas where banking systems may be underdeveloped or saving is challenging for other reasons. Indeed, one of the technological and business model advances that has facilitated the recent growth of solar home kits is the ability of firms, customers, and SHSs to communicate seamlessly. Firms are able to manage SHS operations remotely, providing customers with support when they encounter problems and potentially shutting off access to systems remotely, thus providing a credible threat to non-paying customers. Extending credit and building relationships after the point of sale creates a closer linkage with customers that facilitates the establishment of consumer credit history and a pathway for product upgrades or credit financing for non-energy goods and services.

At first glance, it may seem that a customer would calculate the total cost of the system by summing the stream of daily or weekly payments over a year, then adding the initial deposit amount, and buy the product (or not) based on whether its perceived value is greater than or equal to this sum. In practice, this is not how most customers respond—neither in developing countries nor in OECD markets. Most people tend to prioritize benefits received today (e.g., from a home solar kit) and discount costs they will incur in the future (e.g., from daily repayments), a phenomenon known as *discounting* or *time preference*. Given that customers discount future payments, when we estimate how they respond to prices, we need to compute the total price the way a customer in East Africa would—discounting the stream of future payments based on their rate of time preference.

To determine the appropriate discount rate, we turned to literature from economists who have studied rates of time preference among consumers in developing countries. Importantly, studies among developing-country consumers tend to identify rates that are relatively high compared to consumers in industrialized countries. Based on household studies in Ethiopia, Zambia, Indonesia, and India, we identified a range of rates from 30% to 104%, and accordingly we used a range of rates—from 25% to 100%—to check the sensitivity of our results to the specific rate used.[6]

Product Categories and Differentiation

Solar home system companies sell a diversity of products. All kits include a solar panel, a battery, and several lamps (most often two, three, or four), as well as a port for charging mobile phones. Some kits also include appliances such as a radio or a flashlight. On the upper end of the price range, some kits include a television set, and some companies have also begun to bundle content subscriptions along with the television. To ensure an adequate sample size, with ample variation over prices, regions, and timing of sales, we combined data across these different kinds of products. After testing a range of different methods for combining the sales data, we determined that grouping into two categories made the most sense—one category for solar home kits without television sets, and one category for those with televisions. We exclude sales data for the most expensive products—kits with television sets and bundled content subscriptions—because the way that customers respond to prices for these products is both different from the non-bundled systems, and idiosyncratic, without obvious patterns. (Furthermore, we have very little sales data on this relatively new bundled product, and so we were not able to calculate a distinct price elasticity for these kits.)

Results: Price Responsiveness

After adjusting for the factors explained above—regional and temporal variation in disposable income, customer discount rates, and product combinations and differentiation—we used multiple regression analysis to estimate the price elasticity of demand. Table 1 shows the resulting estimates.

Table 1. Solar Home Kits: Price Sensitivity under Alternative Discount Rate Assumptions

Discount rate	Price elasticity of demand: Kits without televisions	Price elasticity of demand: Kits with televisions
25%	-0.9	-0.03
43%	-0.9	-1.2
50%	-0.9	-1.6
100%	-0.9	-4.1

Our finding that the price elasticity of demand is more inelastic for the kits without televisions is consistent with the notion that households are more likely to see these as necessity goods, so they are less responsive to either increases or decreases in prices. Still, the demand for these kits—which mainly offer lighting, mobile phone charging, and some connectivity to outside events through a radio—is more elastic than might be expected, suggesting they are not an absolute necessity. This may reflect the wide availability of alternative products, including simpler products such as photovoltaic lanterns (without the other components of a home solar kit) or generic versions of solar kits (that do not offer the customer service and warranties that come with brand-name kits, but very price-sensitive customers may not be attentive to this distinction).

In contrast, for most customers, the demand for larger solar kits that include televisions is substantially more elastic. This reflects the notion that these are more likely to be perceived as optional goods, and if prices rise too high then households

[6] Holden, S. T., B. Shiferaw, and M. Wik. 1998. "Poverty, Market Imperfections, and Time Preferences: Of Relevance for Environmental Policy?" *Environment and Development Economics* 3: 105–130.; Pender, J.L. and T.S. Walker. 1990. "Experimental measurement of time preference in rural India." Progress Report No. 97, Andhra Pradesh: ICRISAT.

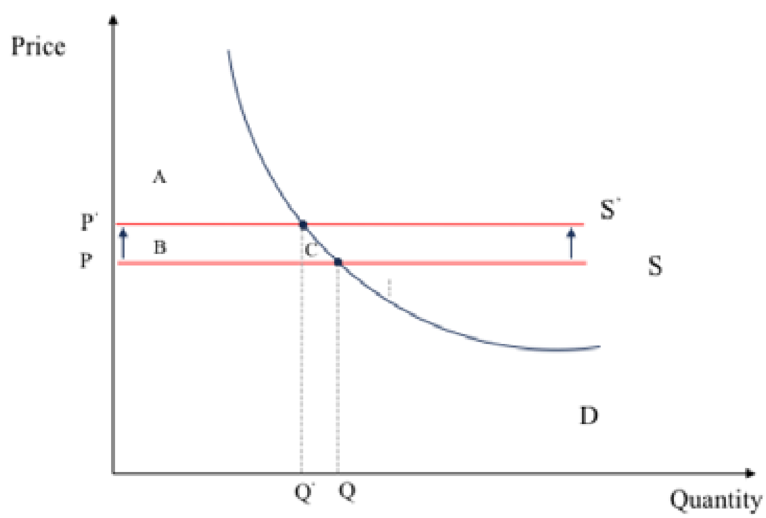
will more quickly scale back their purchases. Furthermore, customers with higher discount rates—that is, those who weight the present more heavily, and more strongly discount future payments—respond more strongly to price differences. This occurs because kits with televisions nearly always require a higher upfront payment (which is an element of companies' pricing strategy, since they want to sell these systems only to customers at the "top of the bottom of the pyramid"—those with high enough incomes who are likely to be able to repay the loan and enjoy the product for its full useful life). Customers with higher discount rates respond more strongly to this initial deposit amount, and this is reflected in the fact that these customers are far more responsive (have a higher elasticity, in absolute value terms) to changes in price.

ECONOMIC EFFECTS OF A TARIFF

Figure 1 shows the effects of an import tariff visually. The price increase resulting from a tariff has the effect of shifting the supply curve up: in the figure, from S to S'. For a given quantity of sales, the price is higher because producers will (eventually) raise their prices in response to the higher costs they face.[7] Customers respond by purchasing fewer systems, with the exact quantitative response based on the price elasticity of their demand. In the figure, purchases fall from Q to Q'.

The government revenue from the tariff is equal to the area of rectangle B, which is the amount of the tariff (P' minus P) times the new quantity purchased (Q'). This constitutes a transfer of wealth from the customers who still purchase the home solar kits to the government. But the customers who are on the margin—those who do not purchase home solar kits because of the higher price—now lose all of the benefits from owning the kits.

Figure 1. Effects of an Import Tariff



Based on the price-responsiveness observed in the data, a 20% import tariff would result in an 18% decrease in sales of kits without televisions, and a 32% decrease in sales of kits with televisions. To estimate the effects in terms of units and dollars, we estimated the current size of the market in each of Kenya and Uganda based on recent sales data from GOGLA[8] as well

[7] Although we did not obtain data on internal costs or profits, it seems reasonable to assume that 100% of any tariff would be passed through to customers because, given abundant price competition and high fixed costs, the firms in this market are likely operating on the edge of profitability. (To the degree that some companies in the region have high valuations, this seems to reflect perceived growth potential in an emerging economy, rather than high profit margins.)

[8] Global Off-Grid Lighting Association (GOGLA). 2018. Global Off-Grid Solar Market Report Semi-Annual Sales and Impact Data January-June 2018. Utrecht, The Netherlands. https://www.gogla.org/sites/default/files/resource_docs/global_off-grid_solar_market_report_h1_2018-opt.pdf.

as the data we collected from suppliers. Tables 2 and 3 show, for Uganda and Kenya respectively, the resulting estimates of changing unit sales and government revenue to consumers.[9]

Table 2. Kenya: Change in Demand and Government Revenue from Import Tariffs

Tariff	Change in demand (%)	Change in demand (#)	Change in government revenue
20%	-18% (kits w/o TV) -32% (kits w/ TV)	-36,500 (kits w/o TV) -6,400 (kits w/ TV)	+$4.97M
15%	-13.5% (kits w/o TV) -24% (kits w/ TV)	-28,600 (kits w/o TV) -5,000 (kits w/ TV)	+$3.90M
10%	-9% (kits w/o TV) -16% (kits w/ TV)	-20,000 (kits w/o TV) -3,500 (kits w/ TV)	+$2.73M

Table 3. Uganda: Change in Demand and Government Revenue from Import Tariffs

Tariff	Change in demand (%)	Change in demand (#)	Change in government revenue
20%	-18% (kits w/o TV) -32% (kits w/ TV)	-13,000 (kits w/o TV) -2,200 (kits w/ TV)	+$1.75M
15%	-13.5% (kits w/o TV) -24% (kits w/ TV)	-10,200 (kits w/o TV) -1,700 (kits w/ TV)	+$1.37M
10%	-9% (kits w/o TV) -16% (kits w/ TV)	--7,100 (kits w/o TV) -1,200 (kits w/ TV)	+$0.96M

BROADER IMPLICATIONS OF TARIFFS

Although the analysis above may suggest that import tariffs could provide a meaningful amount of government revenue, other considerations may enter the decisions of policy makers.

The Unseen Costs of Import Tariffs

While the Sustainable Development Goals (SDGs) identify universal access to safe, reliable, sustainable, and modern energy as a goal in and of itself, it is clear that universal energy access also affects the achievement of many of the other

[9] In principle, the area C in Figure 1—what economists call "deadweight loss"—represents the social welfare loss from a tariff. In practice, in this case, the social welfare loss may be higher than that calculation would suggest, for several reasons. If customers would realize benefits of electricity access that they do not anticipate—and that, therefore, do not enter their willingness to pay—these benefits are not reflected in the deadweight loss. Also not included are any community-level or national-level benefits that individual customers do not "price in" when they determine their willingness to pay. Finally, if the true demand is more elastic than early market sales data suggests—for instance, due to the lack of substitutes in the early market data, compared to the profusion of products available now—then the decline in quantity would be greater, the amount of government revenue raised would be lower, and the deadweight loss would be higher. See Box 1 for a visual representation of the effects of more elastic demand.

SDGs, including the eradication of poverty, education, health, economic growth, reduced inequalities, and climate action.[10] These related impacts represent costs to society, especially for the more than 300,000 Kenyans and Ugandans that would not get access to electricity every year under a 20% import tariff scenario.

On a more practical basis, electricity access saves households money on lighting and cell phone charging costs. It facilitates ownership of radios, fans, televisions, and other appliances. It allows for increased study time in the evening and reduced emissions of harmful pollutants. Previous work has identified thirteen categories of potential benefits, which capture a useful picture of the many ways households and society potentially benefit from access.[11] In addition, there are community benefits such as increased property and home values and nighttime safety and security that come with electricity access. Import tariffs on SHSs reduce the pace of electrification as well as these types of benefits that come with it.

More recent work has further built out the methodology for monetizing many of these benefits, in effect constructing an energy access "dividend" that can provide a snapshot of some of the forgone benefits that accrue when households are not electrified.[12]

In order to give a lower bound estimate of what reduced SHS sales driven by import tariffs would mean in terms of foregone benefits, we looked at just four indicators for which relevant data were available and applied established methodologies.[13] We found that for the average unelectrified household in Kenya and Uganda, access through a SHS would produce an annual benefit of $21.02 from reduced kerosene consumption for lighting, $1.97 from increased study time, $2.52 from reduced cell phone charging expenditures, and $13.70 from reduced climate-affecting emissions. This yields a total annual dividend of $39.20 per unelectrified household, or $2,278,000 in total across the two countries annually.

In calculating the effect of increased study time on earnings, we assumed that electric lighting results in about 33 additional hours of study time for boys (and none for girls),[14] which in turn results in either higher quality education or an increase in years of school, or both. Economic literature suggests returns to schooling on the order of zero to 10% of wages per year of school in most settings.[15] We assumed that the additional study time enabled by electric lighting results in 2.5% higher wages, applied this value to average rural wages in Uganda ($24/month) and Kenya ($70/month),[16] and then calculated the annualized net present value of lifetime earnings accordingly. This results in a dividend of $0.79 per household per year in Uganda, and $2.30 per household per year in Kenya.

These aggregated figures should be considered a conservative lower-bound estimate of electrification benefits enabled by SHSs. There remain many categories of benefits that for reasons of data availability remain unquantified here. As our collective understanding of additional benefit categories related to energy access increases—like how households use their financial savings, health improvements, time use changes outside of increased study time, increased commercial and industrial productivity, and broader community effects—these additional benefits can be incorporated into relevant planning.

Employment and Economic Activity

In addition to the direct household benefits noted above, households frequently report positive impacts on microenterprise development and other economic activity. A recent analysis from GOGLA, funded by DFID, involved a survey distributed

[10] Barron, M., and M. Torero. 2017. Household Electrification and Indoor Air Pollution. Journal of Environmental Economics and Management, 86, 81–92. Lee, K., E. Miguel, and C. Wolfram. 2016. Appliance Ownership and Aspirations among Electric Grid and Home Solar Households in Rural Kenya. American Economic Review, 106(5), 89–94.

[11] Sustainable Energy for All, Power for All, and Overseas Development Institute. 2017. Why Wait? Seizing the Energy Access Dividend. Washington, DC. License: NonCommercial—NoDerivatives 4.0 International (CC BY-NC-ND 4.0).

[12] Pakhtigian, L., E. Burton, M. Jeuland, S. Pattanayak, and J. Phillips. The Energy Access Dividend in Latin America. Forthcoming.

[13] Pakhtigian et al. and Sustainable Energy for All.

[14] Sustainable Energy for All, Power for All, and Overseas Development Institute.

(2017). Why Wait? Seizing the Energy Access Dividend. Washington, DC. License: NonCommercial—NoDerivatives 4.0 International (CC BY-NC-ND 4.0).

[15] Rosenzweig, Mark R. 2010. "Microeconomic Approaches to Development: Schooling, Learning and Growth." *Journal of Economic Perspectives* 24(3):81–96.

[16] This is based on minimum wages for unskilled and semi-skilled agricultural laborers in Uganda (Besamusca, J., and K.G. Tijdens. 2012. Wages in Uganda: Wage Indicator Survey. Wage Indicator Foundation, Amsterdam, October) and Kenya (https://wageindicator.org/salary/minimum-wage/kenya/), as well as the authors' calculations of the average monthly wage among working individuals in households without grid electricity from the 2015–16 Kenya Integrated Household Survey.

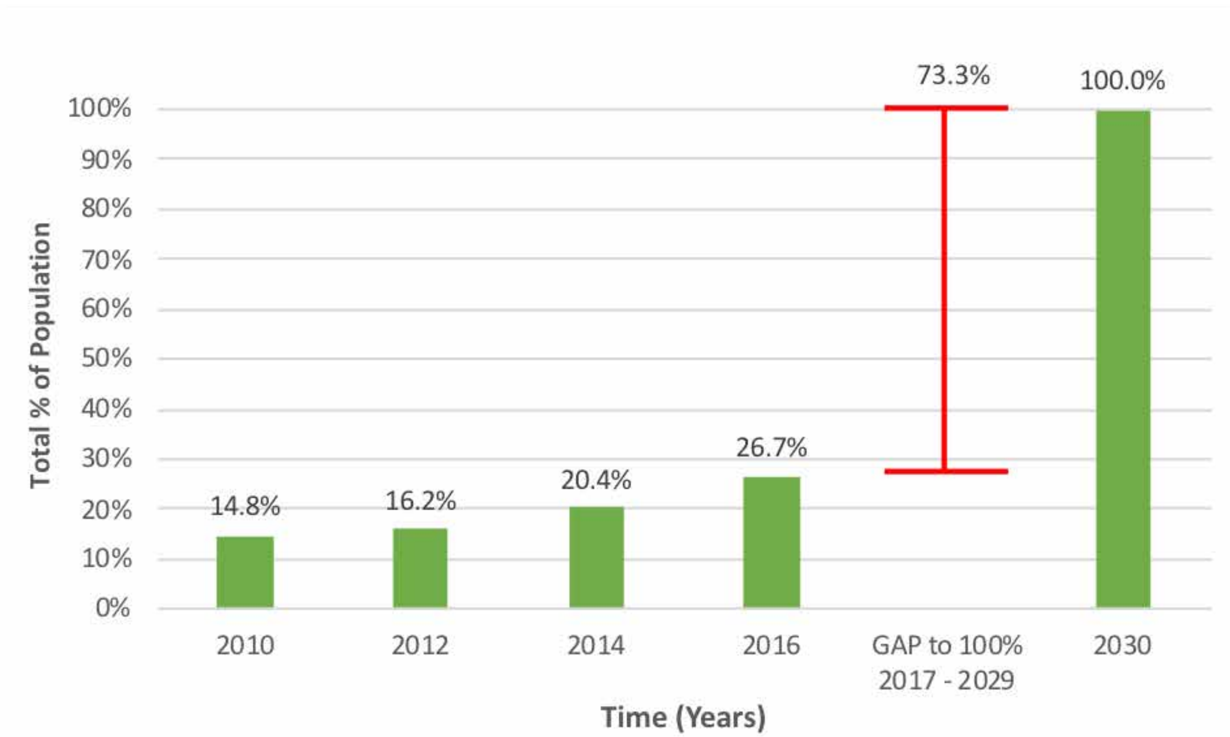
to 2,300 new off-grid solar users in East Africa and found that about 58% of respondents reported increased economic activity within three months of purchasing a SHS. Most of these respondents indicated the SHS allowed them to spend more time at existing jobs, but others reported the SHS enabled a household member to get a new job, or to use the SHS in a household business or income-generating activity.[17] These benefits for employment and income generation translate into wider-scale economic development that may, ultimately, result in a broader and more resilient economic base. SHS distribution, sales, and support also create significant employment opportunities, at all skill levels. This may be especially valuable to EAC governments because the SHS companies typically operate in the formal sector rather than the informal sector, and transitioning economies to function primarily in the formal sector is a valuable policy goal.

Achieving Universal Access

Uganda and Kenya have set aggressive targets to achieve universal electricity access: by 2030 in Uganda (Figure 2) and by 2022 in Kenya (Figure 3). These targets support human development goals and will also facilitate economic development; they are also supported by international frameworks (including the United Nations Sustainable Development Goals) as well as bilateral and multilateral funds. However, it is very unlikely that nations will be able to meet these goals through grid extension alone, and especially in relatively remote and rural areas, off-grid solutions will play (and have played) an integral part.

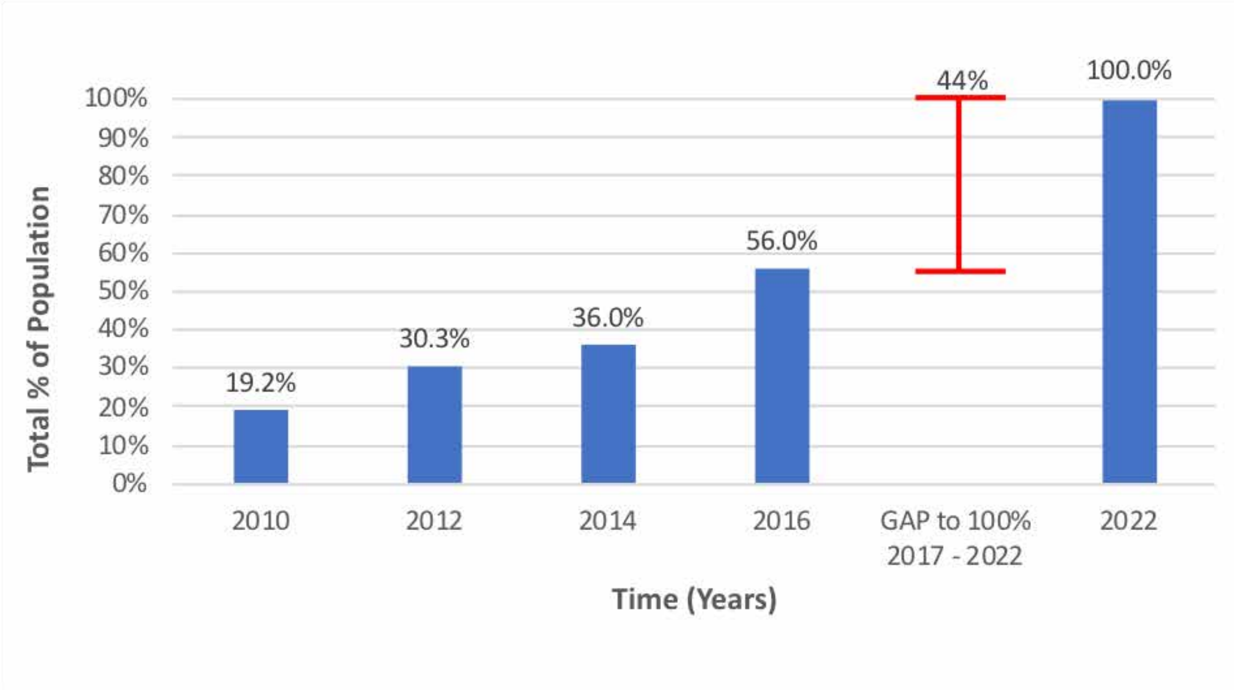
Seen from this vantage point, implementing an import duty on solar home systems—whose effects would be most deeply felt by low-income customers in rural and peri-urban areas, who can least afford to pay—seems counterproductive. While SHSs cannot provide the full spectrum of benefits that high-quality grid power enables, the commercial nature of the technology and the speed with which it can reach unconnected households makes it a valuable platform for integrating into electrification plans.

Figure 2. Uganda's Path to Universal Access



[17] GOGLA. 2018. Powering Opportunity: The Economic Impact of Off-Grid Solar. Utrecht, The Netherlands. https://www.gogla.org/sites/default/files/resource_docs/gogla_powering_opportunity_report.pdf

Figure 3. Kenya's Path to Universal Access



Growing a Domestic Industry

Some policy makers suggest that by setting high import tariffs, nations not only generate badly needed revenue to run the government but also helps the country to build up a manufacturing industry and thus secure higher-value manufacturing jobs for themselves, as well as build capacity among skilled workers and managers, create positive externalities for other manufacturing businesses, and perhaps even export to other nations and thus receive foreign exchange. The actual effects of a tariff in this setting may be more complicated, however, and would depend on two key factors. The first is the importance of economies of scale for driving down costs and guaranteeing high quality in production. In the context of solar home systems, China's tremendous cost advantage and extensive manufacturing infrastructure—including for custom-designed and branded products—may be very difficult to surmount. The second factor is the capacity of domestic industry to manufacture or assemble the key components (panels, battery, wires, bulbs, TVs, chargers). While collecting extensive data on the status of manufacturing capacity in East Africa was out of the scope of this study, at the moment, no company in the region produces a significant amount of solar home systems or individual components. This underscores the likely difficulty of producing these components domestically, and also suggests that domestic supply would be unlikely to serve as a significant substitute for imports in the near term.

CONCLUSION

Solar home systems offer consumers the opportunity to realize immediate improvements in their livelihoods and quality of life, without waiting for costly and sometimes uneconomical grid extension. East African Community governments have recognized the many benefits that electricity offers and, accordingly, have made significant strides toward universal electrification for their populations, but as long as grid extension remains expensive and slow to reach households in rural and some peri-urban areas, solar home systems offer many of the benefits of basic electricity. In this context, maintaining or increasing import tariffs on SHS products is likely to be counterproductive. This report quantifies the economic and human costs and benefits of tariffs, based on 700,000 units of solar home system sales from Uganda and Kenya, countries with vibrant SHS markets and where the border tariff debate looms large. We find that while a tariff would potentially raise some government revenue, such a tariff would be quite regressive, and the net effect on households and communities is likely to be negative and substantial.

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Review

The work reported in this publication benefited from review from experts in the field.

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The Energy Access Project at Duke University is a new research and policy effort that aims to address the challenges around increasing access to modern energy solutions to underserved populations around the world. It takes an interdisciplinary approach to developing sustainable, modern energy for all. The Energy Access Project is working to provide policy makers, project developers, investors, civil society and impacted communities with the tools and analysis to help drive this transformation. Key Duke collaborators in this effort include the Nicholas Institute for Environmental Policy Solutions, the Duke University Energy Initiative, the Sanford School of Public Policy, Bass Connections, and the Nicholas School of the Environment.

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