The Modern Energy Minimum:

The case for a new global electricity consumption threshold

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Summary

Energy is fundamental to modern living and any competitive prosperous economy. SDG7 calls for modern energy for all, but the indicator for tracking progress against this goal is meeting a very low level of residential electricity consumption. We identify five empirical facts about electricity and global development: (1) no high income country is low energy, (2) income and electricity consumption are tightly correlated across time and space, (3) the current threshold used to define modern energy access is too low, (4) the current definition fails to capture consumption outside the home, where the majority of electricity is used, and (5) sufficient energy consumption is a necessary input to economic activity everywhere while its absence is a binding constraint on income and development.

Based on these empirical facts, we propose a new Modern Energy Minimum of 1,000 kWh per person per year, inclusive of both household and non-household electricity consumption. This level tightly correlates with an average income of about $2,500 per year, roughly the midpoint for lower-middle income status. We also suggest how this new metric could be measured with limited additional data collection. The Modern Energy Minimum provides a more ambitious energy target better aligned with historical trends and development aspirations for employment, higher incomes, prosperity, and economic transformation. This new indicator could be adopted by an international body and used to better track progress for the next iteration of SDG7.

The Issue

Energy is fundamental to modern living and any competitive prosperous economy. The current global crisis — with the sharp decline in incomes, rise in poverty, and stark inequality laid bare — has made the agenda of providing adequate energy for everyone even more urgent. Energy is a necessary prerequisite to both recovery and to long-term development.

All members of the United Nations agreed in Sustainable Development Goal 7 to “ensuring access to affordable, reliable, sustainable and modern energy for all.” The principal indicator used to measure progress against SDG7 is the percentage of people with electricity access at home. This access is further defined as a physical connection to the grid or a residential system that can deliver basic electricity, or a minimum level of electricity consumption as defined by the International Energy Agency (IEA) as 50 kilowatt-hours (kWh) per capita per year in rural areas and 100 kWh in urban areas. Buried in the term ‘access’ is the notion of some minimum level of consumption and implied service for every household.

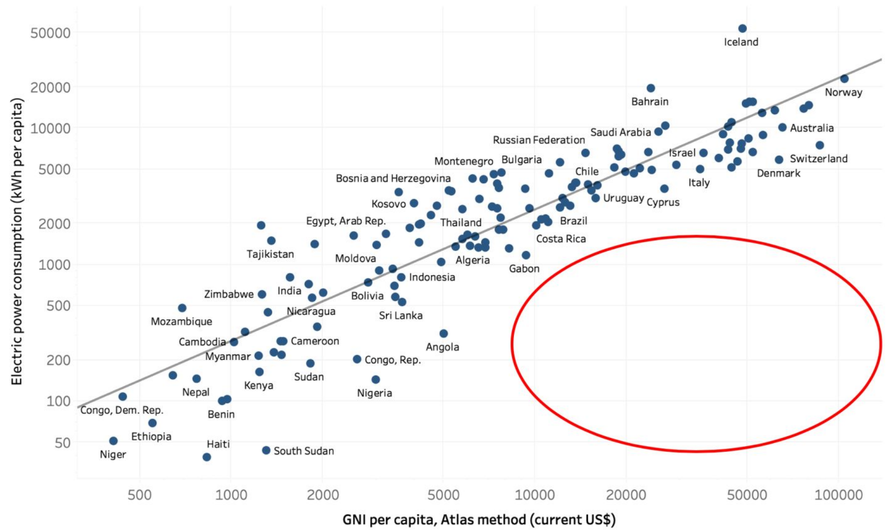
To better reflect the full ambition of SDG7, we propose a new complementary electricity consumption threshold — the Modern Energy Minimum — that is both higher than the current definition and wider than household use. The intention of an additional threshold is to raise the bar on global targets for ending energy poverty and to set goals that are more aligned with the way that energy drives living standards, livelihoods, and income. The proposed new metric allows tracking and energy goal setting that is more consistent with historical evidence and other development objectives, including many of the other sixteen SDGs. Adding the Modern Energy Minimum will help to redefine success and inform energy policies and the allocation of resources to reach SDG7 and the broader global development goals.

Five Empirical Facts about Electricity and Global Development

1. No high income country is low energy.

All economies require energy and higher levels of income require even greater energy consumption. In fact, there are no high-income countries today with annual electricity consumption below 3,000 kWh per capita. The median for high-income countries is 6,720 kWh.

FIGURE 1: Income vs. Electricity Consumption

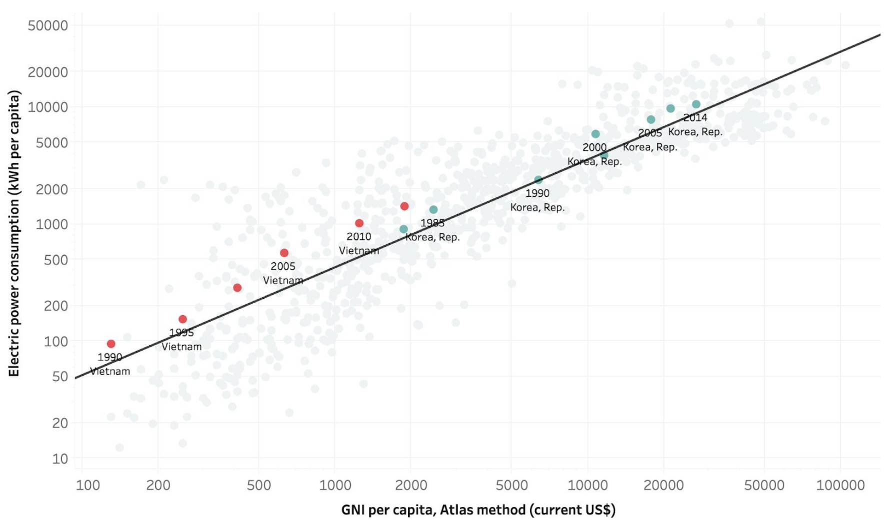


Source: World Bank, World Development Indicators. Notes: Both axes are logged; data is for 2014, most recent available; R2 is 0.81.

2. Income and electricity consumption are tightly correlated across all countries and over time.

Using all available data for all countries going back to 1980, the relationship between income and electricity consumption is very strong. This trend broadly holds for all countries large and small, rich and poor, and across a diverse range of economic sectors and activities.

FIGURE 2: Income vs. Electricity Consumption, 1980-2014



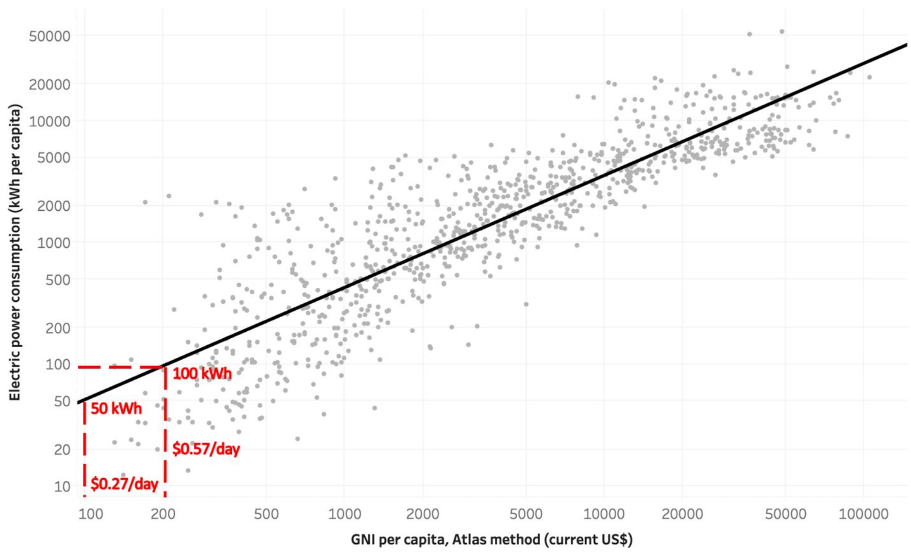
Source: World Bank, *World Development Indicators*. Notes: both axes are logged; R^2 is 0.77; see Annex 3 for methodology.

3. The current threshold used to define modern energy access is too low.

According to the global standard set by the International Energy Agency (IEA), modern energy access is achieved once an individual's household annual electricity consumption reaches 50 kWh per capita in rural areas and 100 kWh in urban areas.[2] This level of electricity consumption is enough to power a few lightbulbs for a few hours per day, to charge a mobile phone, and to occasionally run a small fan.[3] In fact, using cross-country trends, these levels of rural and urban electricity consumption correlate with incomes of just $0.27 and $0.57 per day, respectively.

For this reason, the current annual consumption threshold of 100 kWh is better thought of as an *extreme energy poverty line*, rather than as the international energy target for promoting development and greater incomes. Just as income is tracked above a poverty line and at other higher levels, the same framework could be applied to electricity consumption.

FIGURE 3: Income correlations with IEA definitions of modern energy access



Source: World Bank, *World Development Indicators*. Notes: both axes are logged; R^2 is 0.77; see Annex 3 for methodology.

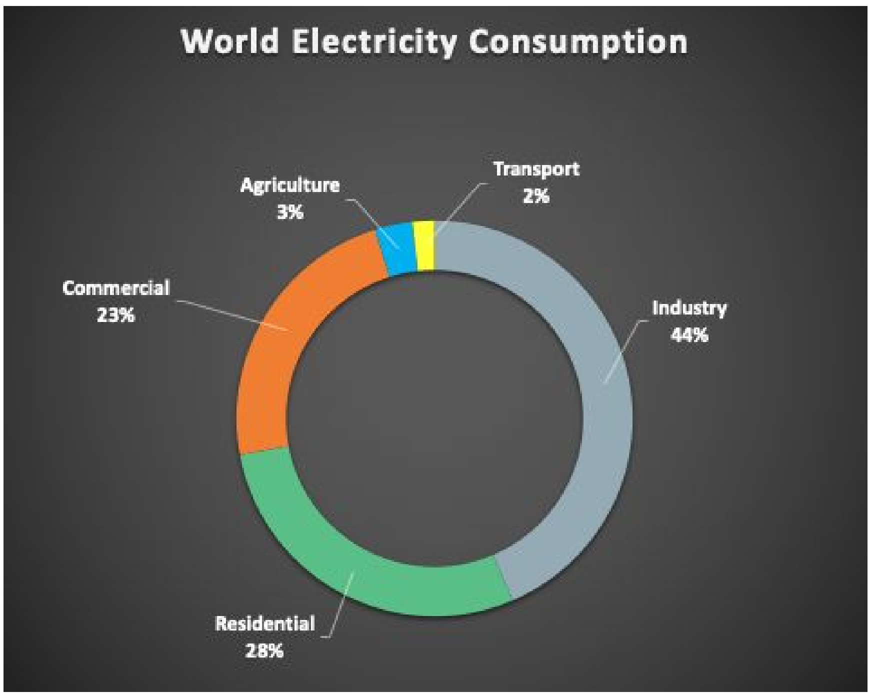
[2] IEA, Defining Energy Access: 2019 Methodology says "electricity access includes a household having an electricity supply connection, with a minimum level of consumption of 250 kilowatt-hours (kWh) per year for a rural household and 500 kWh for an urban household." To calculate per capita rates, we assume a household size of five.

[3] Morgan Bazilian & Roger Pielke, Jr. "Making Energy Access Meaningful." *Issues in Science and Technology*, vol. 29, no. 4, 2013, pp. 74–78. JSTOR, www.jstor.org/stable/43315797. See also Lauren Culver, "Energy Poverty: What You Measure Matters," Stanford University, 2017 and "More Than a Lightbulb: Five Recommendations to Make Modern Energy Access Meaningful for People and Prosperity," Center for Global Development, 2016.

4. The current threshold for modern energy access also fails to capture any consumption outside the home, where the majority of electricity is used.

The current consumption threshold does not provide any information about electricity used in industry, commerce, agriculture, transportation, or public services. This shortcoming is meaningful: non-household uses account for about 70 percent of global electricity consumption.[4] More significantly, while using electricity at home is important for raising living standards, energy used to generate income and other productive uses is generally consumed outside the home. If higher electricity consumption is supposed to help drive incomes higher, we should be paying at least as much attention to non-residential uses.

FIGURE 4: World electricity consumption by sector, 2017



Source: IEA World Energy Balances, 2019.

[4] IEA, *World Energy Balances,* 2019. Total global electricity is approximately 28% residential, 72% non-residential. An unweighted average of 138 countries is 34% residential, 66% non-residential and about three-quarters of countries fall within one standard deviation (~12%). These figures do not account for non-electricity energy use, such as industrial energy or transportation fuels. According to the US Department of Energy's EIA, residential electricity accounts for only 5% of global energy use.

5. Sufficient energy consumption is a necessary input to economic activity everywhere — and its absence is a binding constraint on income and development in many places.

While the relationship between overall energy consumption and income varies by country context, and entails causal links in both directions, it exists in some form everywhere.[5]

- Meta-surveys of macroeconomic analysis point to a clear and strong correlation between energy consumption and GDP, although statistically robust evidence on the direction of causality is difficult to establish as there are few natural experiments and dynamics depend on context.[6]
- Insufficient power systems are frequently a binding constraint to growth, as documented clearly in the literature on Sub-Saharan Africa and South Asia.[7]
- Microeconomic studies on the impact of specific investments in the power sector show positive effects on productivity, job creation, and income.[8]
- Conversely, the negative impact of power outages, which include both unavailability of supply and low quality of power, are profound on firms, especially in Africa.[9] Firms in low-energy consumption environments widely self-report that the cost and reliability of power is a first-order obstacle to productivity, employment, and expansion.[10]

The evidence is comparatively mixed on the impact of household access alone. Studies of very basic household electricity provision in low income environments have not found positive income effects.[11] But based on the current state of research, there is ample reason to believe that insufficient economy-wide energy consumption is a primary constraint on the complex issues of job creation, economic growth, and poverty alleviation.[12]

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[5] While this positive relationship appears nearly universal, some countries at very high income levels see a leveling off of energy consumption or even decreases in consumption. But the vast majority of countries are still on the steep upward part of the consumption and income curve.

[6] See e.g., Robert Bacon and Masami Kojima, “Energy, economic growth, and poverty reduction : a literature review,” World Bank, 2016 and David Stern, Paul Burke, and Stephan Bruns, “The Impact of Electricity on Economic Development: A Macroeconomic Perspective,” Applied Research Programme on Energy and Economic Growth (EEG), 2016.

[7] Alberto Lemma, Isabella Massa, Andrew Scott and Dirk Willem te Velde, “What are the links between power, economic growth and job creation?” *CDC Evidence Review*, CDC Group, 2016.

[8] Anton Eberhard and Gabrielle Dyson, “What is the impact of investing in power?” *CDC Evidence Review*, CDC Group, 2020. See also Stephie Fried and David Lagakos, “Electricity and Firm Productivity: A General-Equilibrium Approach,” NBER working paper 27081, 2020.

[9] Stern, Burke, and Bruns, EEG. 2016; Justice Tei Mensah, “Jobs ! electricity shortages and unemployment in Africa,” Policy Research working paper, no. 8415, 2018; Musiliu Olalekan Oseni, “Costs of Unreliable Electricity to African Firms,” Energy for Growth Hub, 2019.

[10] Enterprise Surveys (http://www.enterprisesurveys.org), World Bank.

[11] Kenneth Lee, Edward Miguel, and Catherine Wolfram, "Does Household Electrification Supercharge Economic Development?" *Journal of Economic Perspectives*, vol 34(1), 2020, pages 122-144; Johannes Urpelainen, “What do we (not) know about the benefits of households’ electrification?” International Growth Centre, 2019.

[12] David Stern, “The Linkages between Electricity Supply and Economic Growth,” Applied Research Programme on Energy and Economic Growth (EEG), 2017.

A New Threshold: the Modern Energy Minimum

The five empirical facts above provide ample justification — and guidance — for creating a new global electricity consumption threshold to supplement the current one. A simple new standard could then be used by governments expecting energy infrastructure to drive economic growth, by international development agencies to identify the most impactful investment opportunities, and by the United Nations to track progress against the new goals that will eventually replace the SDGs. An ambitious standard tied more directly to livelihoods, prosperity, and economic transformation would also provide a lodestar for tracking electricity as a contributor to economic recovery.

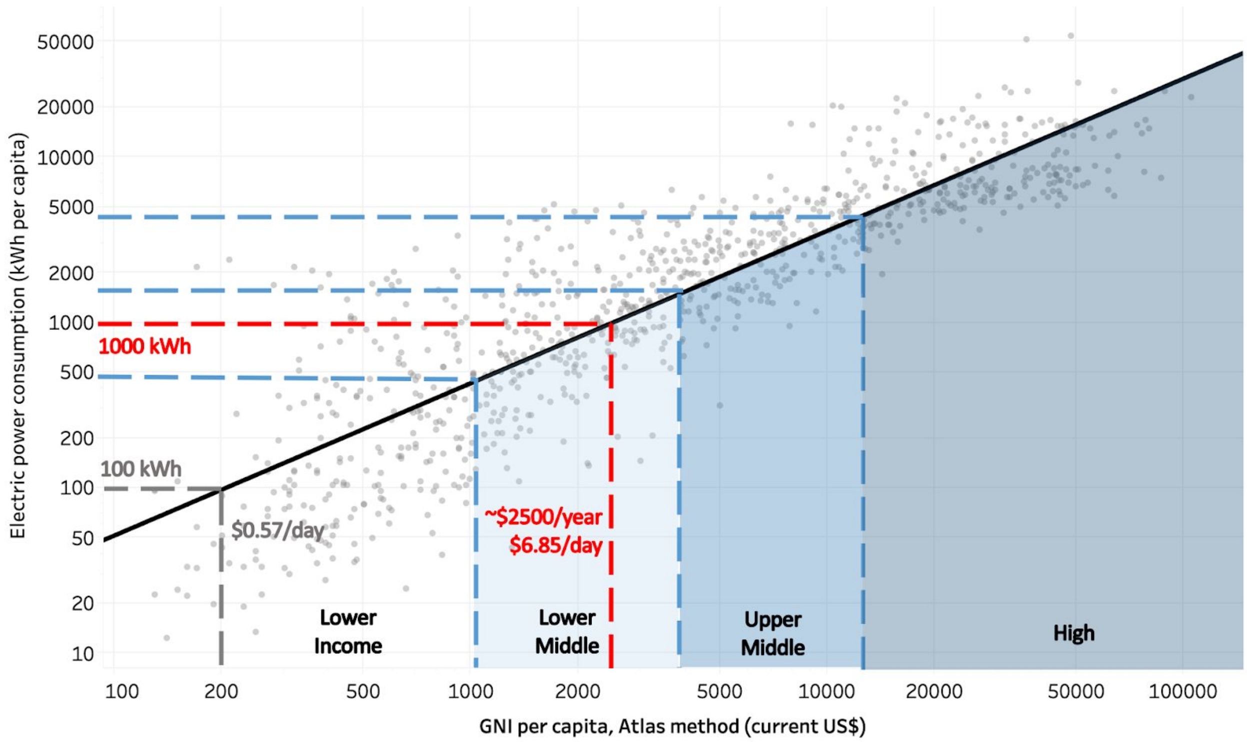
The Next Energy Step: 1,000 kWh per capita per year

If we believe that 50 or 100 kWh is the extreme energy poverty line, what is the next step on the energy ladder? What might be an electricity target for prosperity?

Using the trendline from the full sample of cross-country data, Figure 5 shows electricity consumption levels corresponding to each of the three minimum income levels for the World Bank's country categories. The midpoint for lower-middle income status ($2,511 per capita) correlates almost exactly with an annual per capita consumption level of 1,000 kWh.[13] In other words, if we aspire for all people to reach an income of at least $2,500 per year (or about $6.85 per day), we should also aspire for universal electricity consumption of at least 1,000 kWh. We propose this as the new threshold, or the Modern Energy Minimum.

[13] There is no accepted definition of middle class income, with estimates ranging from $2-20/day and World Bank categories covering ~$3-$34/day. We have selected the midpoint for the lower-middle income group as a reasonable minimum that is achievable yet would represent substantial progress. See Annex 3 on the correlation methodology.

FIGURE 5: Electricity consumption and income levels



Source: World Bank, *World Development Indicators*. Notes: both axes are logged; R^2 is 0.77; see Annex 3 for methodology; income categories are the current World Bank country classifications.

Capturing *development-inclusive* electricity: at least 300 kWh at home plus at least 700 kWh in the wider economy

The Modern Energy Minimum encompasses both residential electricity consumption and non-residential consumption in the wider economy. Based on the approximate global average proportions (30/70 residential/non-residential) an overall target of at least 1,000 kWh per person implies at least 300 kWh of electricity consumed at home and at least 700 kWh consumed in the other sectors of industry, commerce, transportation, agriculture, and public services.

Capturing non-residential consumption is integral because electricity used outside the home includes most of the ways energy contributes to economic activity and higher income — which in turn enables household consumption. Since residential and non-residential consumption are intimately interlinked within a wider energy system and economy, having both in the new metric better reflects the full spirit and ambition of SDG7.

The scholarly literature is clear that household consumption alone does not drive income growth. This suggests that a household-only electrification approach — such as setting a residential connection target and intervening to stimulate household energy demand (for instance, via appliance finance) — is unlikely to succeed in improving economic outcomes at scale. Any successful development strategy that aims for far higher household consumption must also tackle the energy needs of commerce, industry, and agriculture to increase productivity and incomes.

Measuring progress with a headcount

Estimating a headcount for those meeting the Modern Energy Minimum requires determining how many people are both consuming at or above both the household and non-household thresholds. The first can be accomplished with current methods of gathering energy statistics. We can combine residential customer utility data, household expenditure and asset surveys, and potentially satellite imagery to approximate the number of people in a particular country or geographic area who consume at least 300 kWh at home.[14]

Pinpointing a person's non-residential electricity consumption is trickier because energy is (a) embedded in many of the products used during a production process, (b) typically a shared resource by many people, and (c) traded across large geographic spaces. For example, while it is relatively easy to track the electricity used by an individual refrigerator in a house, it is far more difficult to track precisely all of the energy used in the supply chain that produced the unit (which is unlikely to be in the immediate geographic area) or all the energy used to earn the income to purchase the appliance and pay for the electricity. For these reasons — and because of the damaging effects of energy constraints on an economy as a whole — it makes sense to treat the non-residential electricity target as an average within a wider geographic space, such as a national economy.[15] As such, the non-residential electricity component could be most easily tracked as a country average.

[14] Options include household utility bills above 125 kWh per month (300 kWh x 5 people annually) or estimates from household expenditure surveys. See Annex 2 for Kenya data or, e.g., Robert Bacon, Soma Bhattacharya, and Masami Kojima, "Expenditure of Low-Income Households on Energy," World Bank, 2010.

[15] This could also be calculated at a subnational level, especially in large countries such as India or Nigeria, or for metropolitan footprints. There is an inherent tradeoff, however, between detailing specific local differences and relevant spatial units for capturing a meaningful range of economic activities.

Thus, the new 1,000 kWh threshold headcount ratio can be calculated as the percentage of people meeting two separate conditions:

(a) consuming at least 300 kWh at home

and also

(b) living/working in an economy with average non-residential consumption above 700 kWh per capita

In countries where non-residential consumption is less than 700 kWh, the headcount will be, by definition, zero. This is a high bar in the short-term for some countries but is consistent with the notion that escaping energy poverty requires living and working in an economy with a minimum energy floor. Based on historical and cross-country evidence, any person living and working in an economy where per capita non-residential electricity is less than 700 kWh could reasonably be described as living in energy poverty, even if their personal consumption at home is above 300 kWh. It is also the case that boosting residential consumption above 300 kWh per person will require a certain level of income earned through economic activity outside the home, for example, to enable the purchase of appliances and to pay for electricity. The Modern Energy Minimum attempts to capture a balance between both residential and non-residential energy use and to set a threshold level consistent with global trends and development goals.[16]

Why two threshold conditions for one metric?

Using separate household and non-household consumption more fully captures what it means to live in energy poverty in different contexts.

- *A relatively poor person who consumes very little energy at home, but lives in a high-energy consuming economy, suffers from energy poverty. This is why countries like Egypt, Colombia, Thailand, Mexico, and South Africa will have a headcount ratio below 100%.*
- *At the same time, a relatively wealthy person who consumes a lot of energy at home, but is nonetheless living in a low-energy consuming economy, where energy is still a meaningful everyday limitation, also suffers from energy poverty. This is why countries like Nigeria, Angola, Bangladesh, Ghana, and Pakistan will initially have a headcount ratio of zero.*

[16] The ESMAP program at the World Bank created the Multi Tier Framework for tracking household electricity consumption at 5 levels of service quality. There is also a version for productive uses. These are major conceptual advances but are not yet practically trackable at scale. See https://www.esmap.org/node/55526.

Benefits and limitations of the new Modern Energy Minimum

This new approach:

- Creates a simple single metric;
- Provides a definition of modern energy access that complements the current IEA threshold, which is now better described as an "extreme energy poverty line;"
- Establishes a level of consumption high enough to correspond to an income of ~$6-8 per day;
- Covers both residential and non-residential power consumption, which incentivizes a balanced approach that recognizes electricity's contribution to both living standards and productive uses;
- Allows tracking and energy goal setting that is more consistent with other development objectives and historical trends.

This new approach does not:

- Provide a metric that can immediately be measured precisely using existing data;
- Create a near term target for countries at extremely low levels of energy consumption or for those already far above the proposed thresholds;
- Track progress on non-electricity sources of energy, such as transportation fuels or industrial heat.

Conclusion

The Modern Energy Minimum of 1,000 kWh per capita is a necessary complement to the current 50/100 kWh basic definition. This new threshold is not only higher and more consistent with the income aspirations and development goals of all people, but helps to shine a light on the crucial but less visible role of electricity in the economy. Yes, everyone deserves to have lights at home. But the new threshold also covers electricity needed to earn income outside the home.

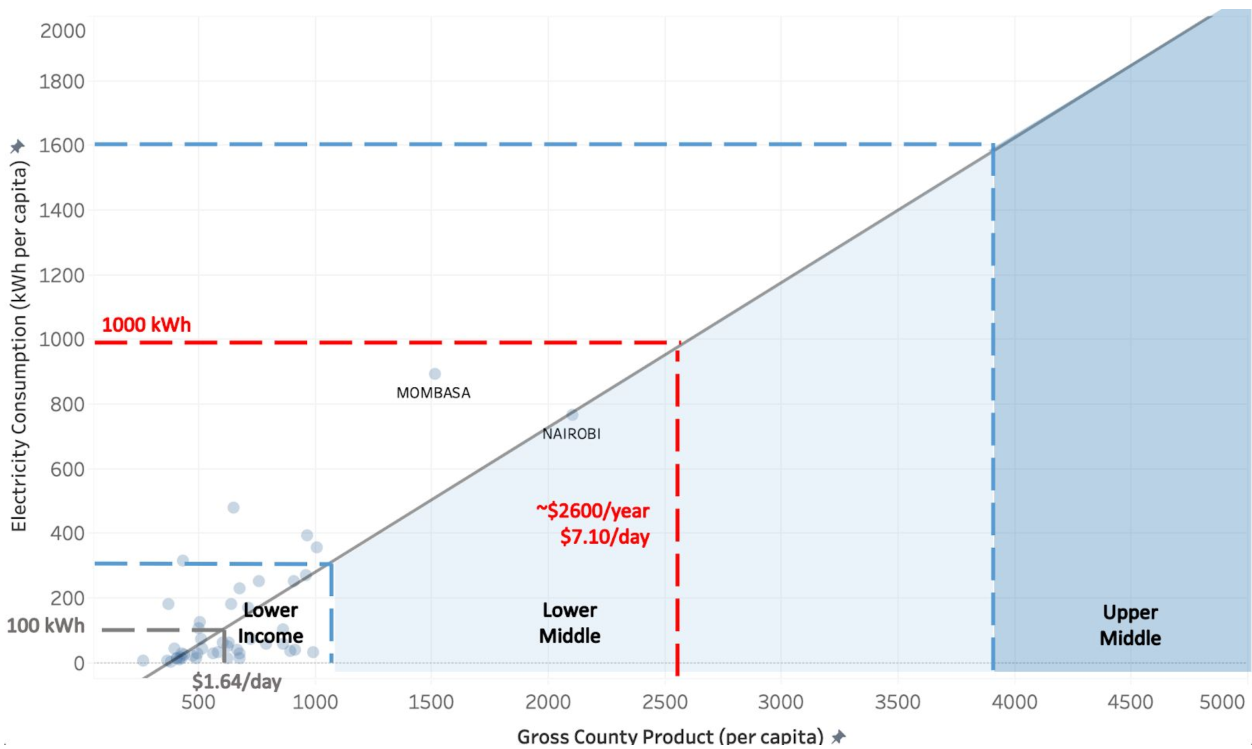
At a practical level, the Modern Energy Minimum provides a target that could be used to influence planning and investment decisions by governments and the allocation of resources by the international community. And it should provide some guidance for prioritization and sequencing of policies and investments in the power sector. For countries with a headcount of zero, it highlights a need to balance household-level approaches with other uses. This might, for instance, suggest a need to prioritize higher consumption growth in the industrial, commercial, and agricultural sectors. That implies different investment decisions and greater attention on cost and reliability. For countries with a headcount between zero and 100, the new metric suggests a far greater focus on equity and inclusion.

A next step is to operationalize and adopt this Modern Energy Minimum. An international body — such as the UN, World Bank, or IEA — could begin collecting and reporting this data. That would enable the Modern Energy Minimum to become an additional indicator for progress that could be used in the next iteration of international development goals. The upcoming successor to SDG7 would be a good place to start.

Annex 1: Subnational analysis from Kenya

While the proposed Modern Energy Minimum was based on cross-country and historical data, Jay Taneja and Bob Muhwezi of the University of Massachusetts at Amherst apply similar analysis at a sub-national scale in Kenya as a check on level assumptions. Their forthcoming study analyzes correlations between county-level electricity consumption and Gross County Product (GCP) in Kenya.[17] Figure 6 shows this analysis, and finds a similar relationship to that found in global cross-country data.

FIGURE 6: Electricity consumption and Gross County Product in Kenya, 2014-15



Source: Author calculations from Taneja & Muhwezi (forthcoming) using KNBS and KPLC. Notes: Data is mean of 2014-2015; R^2 is 0.57; income categories are the current World Bank country classifications; GCP is displayed in US$ by using 2015 conversion rates.

[17] GCP can be thought of as a GDP-like estimate of economic output on a county scale. GCP data is from the Kenya National Bureau of Statistics (KNBS) and electricity consumption data is a random sample from the Kenya Power and Lighting Company (KPLC).

Annex 2: Illustrative household consumption headcount estimate from Kenya

Using the same KPLC data from Taneja and Muhwezi, we are able to estimate an approximate headcount for annual residential consumption above 300 kWh per capita. KPLC data reports an average 3.7 people per household for their customers. To calculate the number of people consuming above 300 kWh only requires determining the number of households with yearly bills above ~1,100 kWh or ~93k Wh/month.

According to the data, about 4 million Kenyans (or ~21% of KPLC household customers) met this criteria in 2015. Given the total population of 48 million in 2015, this suggests that about 8% consume at a level commensurate with the household component of the Modern Energy Minimum.

Kenya's total headcount is still zero as national non-residential electricity consumption is below the requisite 700 kWh per capita threshold. However, this exercise demonstrates one way a headcount figure could be established based on existing utility customer data.

Annex 3: Data & methodology notes for Figures 2, 3, 5

Data was drawn from the World Bank's World Development Indicators using the following indicators:

- Electric power consumption (kWh per capita) which is originally sourced from the IEA and is available up to 2014.
- GNI per capita, Atlas method (current US$) which is sourced from the World Bank and OECD, and is available up to 2018.

The analysis treats every Country/Year data point as the average person in that given country in a given year. For example, Canada in 2000 is understood as the income and electricity consumption of the average Canadian in 2000. We do this for the "average Indian in 2005," the "average Ethiopian in 2010," and so on, as if they are individuals.

Using these cross-country averages, we attempt to characterize the overall relationship between electricity consumption and income in recent decades. For data availability reasons, the sample starts in 1980. Our base model for analysis uses data from all available countries for 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2014. This provides a reasonable sample size (n = 941) and correlation (R^2 of 0.77).

Using every year 1980-2014 created a larger sample size (n = 4113) and nearly identical correlation (R^2 of 0.76), but no substantive difference from our base model.