CLEAN ENERGY SERVICES FOR ALL: FINANCING UNIVERSAL ELECTRIFICATION

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EXECUTIVE SUMMARY

One in five people around the world, approximately 1.3 billion people,[1] lack access to electricity. Prevailing estimates of the investment required to end this energy poverty rely on a flawed analysis[2] from the International Energy Agency (IEA) which calls for unrealistic investment levels at inappropriate growth rates for inefficient energy delivery. We propose a new approach to end energy poverty that is founded on a clean energy model of delivery and reflects real world investment opportunities and needs. Taken in sum, we believe this approach—Clean Energy Services for All (CES4All)—represents the cheapest, most effective means of delivering on energy access goals, and we urge public and private financiers to align investment priorities accordingly.

KEY FINDINGS INCLUDE:

Energy efficiency unlocks the energy ladder. Affordable energy efficiency advances are shown to unlock energy access. The energy efficiency measures currently available allow energy to be delivered for 50-85 percent less energy input, enabling dramatically reduced capital expenditure. From off-grid LED lighting to “Skinny Grids,”[3] we can revolutionize the cost and effectiveness of rural electrification. Thanks to these energy efficiency advances, we can deliver energy access with a much lower amount of power. However, we do not envision these initial services (lighting, mobile phones, fans, TVs, and a small amount of agro-processing) to be the limit of energy access. We have prioritized energy access for rural populations in an effort to get them on the energy ladder with immediate basic interventions. This will enable them to move out of poverty as incomes expand and markets evolve.

Investment needs are overstated. The IEA’s estimated investments needed for total global energy access, $640 billion over 20 years, is between 300-500 percent higher than current investments in energy access. More importantly, this level of investment represents 30 percent of all current international aid, of which very little is currently spent on energy access.[4] There is little evidence to support

TABLE 1 - CLEAN ENERGY FOR ALL END USE MODEL

	Business as Usual						Energy Efficient					
	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Service description	Kerosene lamps, candles, etc	Task lighting and phone charging (OR radio)	General lighting AND television AND fan (if needed)	Tier 2 AND any low power applicances	Tier 3 AND any medium power applicances	Tier 3 AND any high power applicances	Kerosene lamps, candles, etc	Task lighting and phone charging (OR radio)	General lighting AND television AND fan (if needed)	Tier 2 AND any low power appliances	Tier 3 AND any medium power appliances	Tier 3 AND any high power appliances
Peak available capacity (W)	-	2.5	50	200	2000	2000	-	2.5	25	125	1500	3500
Duration (hours/day)	-	> 4	> 4	> 8	> 16	> 22	-	> 4	> 4	> 8	> 16	> 22
Number of lamps	2	2	4	4	8	8	2	2	4	4	8	8
Lamp technology	Kero	Bulb	Bulb	Bulb	Bulb/halogen	Bulb/halogen	Kero	LED	LED	LED	LED	LED
Watts/lamp	-	15	40	40	60	60	-	1	1	3	5	5
Lumens		150	500	500	750	750		150	500	500	750	750
Hours/day	4	4	4	4	4	4	4	4	4	4	4	4
Phone charger, max mA		500	500	800	800	800		500	500	800	800	800
Number of phone chargers		1	1	2	2	2		1	1	2	2	2
Fan or air-con (watts)			4	30	50	1300			2	15	25	1000
TV (watts)			20	80	200	200			10	20	100	100
Refrigerator, capacity cu.ft				<5	5-15	>15				<5	5-15	>15
Refrigerator (W)				160	240	360				80	120	180
Referigerator, hours on				6	10	12				6	10	12
Washing machine capacity, cu.ft					<4.5 cu.ft	>4.5 cu.ft					<4.5 cu.ft	>4.5 cu.ft
Washing machine (W)					1500	2000					750	1200
kWh/year - lighting		44	234	234	701	701		3	18	18	58	58
kWh/year - phone charging		3	3	8	8	8		3	3	8	8	8
kWh/year - fan or air-con		7	49	82	82	1460		3	15	27	27	1095
kWh/year - TV		0	29	117	292	292		0	15	58	146	146
kWh/year - refrigeration		0	0	350	876	1577		0	0	175	438	788
kWh/year - washing machine		0	0	0	219	292		0	0	0	110	146
kWh/year - other		0	0	0	0	219		0	0	0	0	219
Energy consumption, kWh/year		**53**	**315**	**791**	**2178**	**4549**		**9**	**50**	**287**	**788**	**2461**
							% reduction	83%	84%	64%	64%	46%

*LED lamps are directional, whereas CFLs and bulbs are not, so while lumens are lower, lux levels will be higher, so service is equivalent or better

FIGURE 1 - ESTIMATED FUTURE TOTAL DEMAND FOR CAPITAL FOR THE OFF-GRID ENERGY ACCESS MARKETS

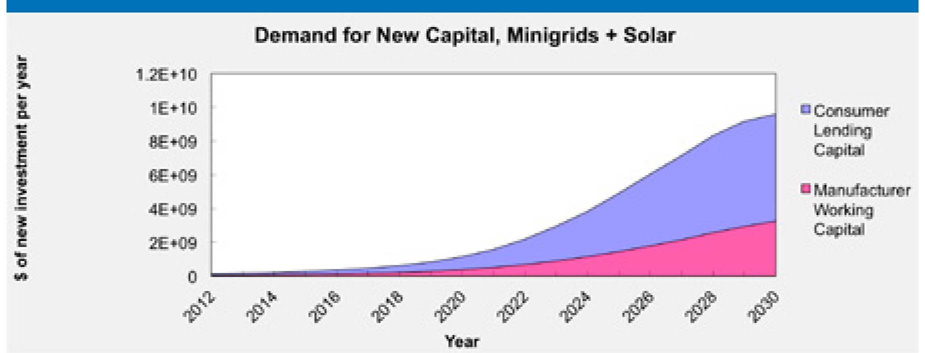
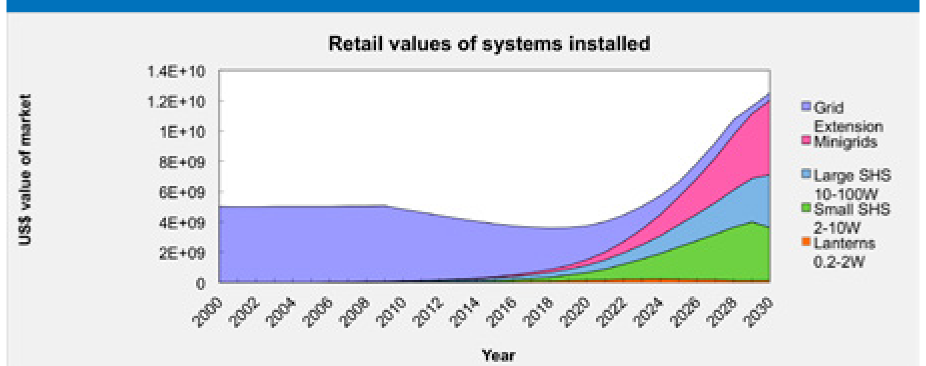


FIGURE 2 - ESTIMATED VALUE OF FUTURE MARKETS OF HOUSEHOLD ENERGY ACCESS PRODUCTS

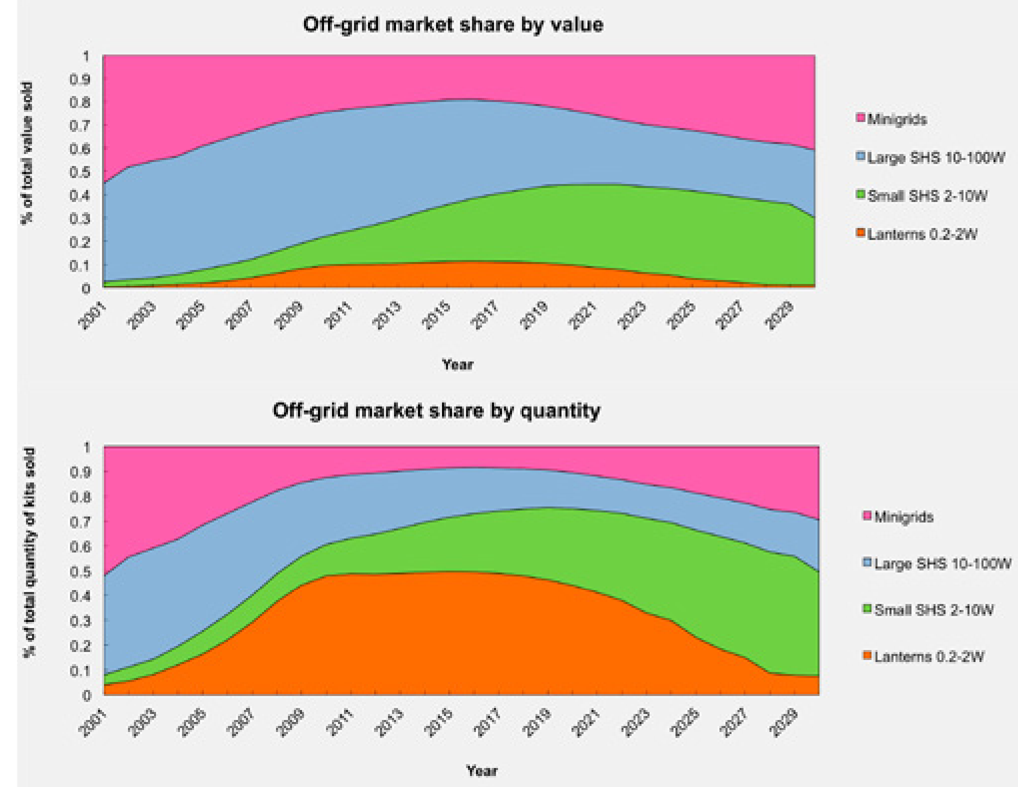


that the amount of money the IEA believes is required for energy access is actually even available.

We have found that energy access can be delivered much more cost effectively. For example, energy services for appliances, including television, fans, lighting, mobile phone charging, and power appliances like refrigerators, can be provided for approximately $200 billion, which is 69 percent lower than IEA estimates.[5]

$500 million in public investment is needed now. Per our analysis, $100 million for new investments in off-grid clean energy manufacturers is needed within the next three years to catalyze the growth of the industry. The investment needs of consumer finance companies in this market will require even larger investments of $400 million over the next two years and will be consistently 8-16 times higher than the investment needs of the manufacturers. Combined, approximately $500 million will be needed in the next two to three years, which is consistent with a letter from the clean energy industry to the World Bank.[6]

FIGURE 3 - FUTURE MARKET SHARES OF OFF-GRID PRODUCTS, BY QUANTITY AND BY VALUE



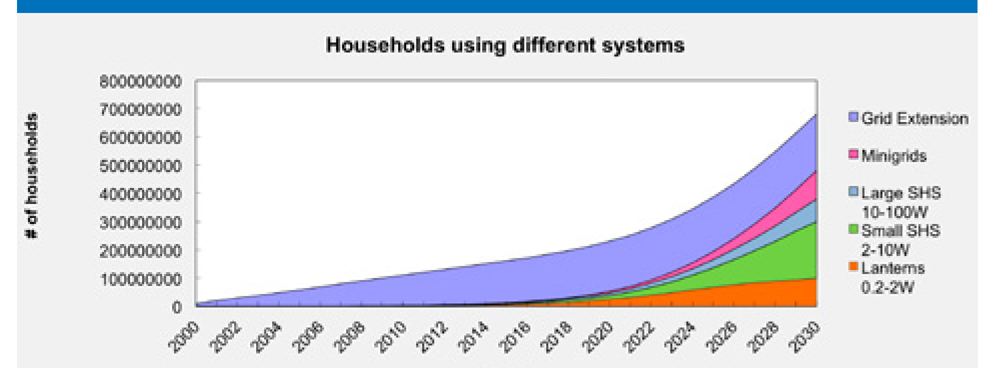
This investment will unlock a $12 billion annual clean energy services market for the poor. The energy access industry, excluding grid extension, is currently estimated as a $200-250 million industry annually. We project a 26 percent compound annual growth rate (CAGR) which will enable the industry to grow to a $12 billion annual market as universal electrification is achieved. By 2030, the solar lantern market alone will reach $125 million per year in investment opportunities while mini-grids and solar home systems will each become $5-7 billion product segments. However, this investment is exponential – starting at roughly $170 million in annual investment and growing to $5-10 billion in annual investment by 2030 – enabling half of all people receiving clean energy services to be serviced by the fast growing, off-grid market. All told, there will be an estimated 700 million new clean energy service connections.

The off-grid market is already growing rapidly. The off-grid solar lighting market is growing rapidly, with estimates of 95 percent CAGR in sub-Saharan Africa alone. In Bangladesh, 80,000 solar home systems are being installed every single month. Similarly to how solar leasing unlocked the market for residential solar in the United States, the off-grid solar market has been unlocked by business and financial model innovations—like mobile money-enabled pay-as-you-go systems. These innovations have primed the sector for further rapid growth, similar to what the mobile phone industry experienced a decade ago.

Achieving Clean Energy Services for all by 2030. It is estimated that it will take until 2025 to reach 50 percent market penetration, and the last half of this market will be reached in the remaining five years. This is a more realistic adoption rate than the simplified near-linear progress assumed by IEA.[7] This underscores the vital importance of initial interventions (e.g. solar lanterns)—which we do not count as full energy access—that allow rural populations onto the energy ladder today rather than forcing them to wait decades for even basic energy services to arrive.

Energy access investment can improve the human condition. Improved energy access has been shown to provide 38 percent of the increase in Human Development Index (HDI)[8] from current poverty levels towards significant poverty reduction by 2030. This is achieved, for example, by eliminating the use of kerosene and saving significant cash expenditures while enabling children to attend school one year longer than normal and creating healthier indoor and outdoor environments. This is thanks to less energy-driven pollution.

FIGURE 4 - ESTIMATED FUTURE USAGE OF ENERGY ACCESS PRODUCTS BY HOUSEHOLDS



BACKGROUND

Approximately 1.3 billion people[9]—around 250-300 million households

TABLE 2 - ENERGY'S CONTRIBUTION TO REDUCING POVERTY

	Baseline	Out of Poverty (2050)			Reducing Poverty (2030)			Kerosene free			Energy Access		
PPP Annual income per capita	$1,000	$10,000			$3,000			$1,020			$1,100		
Expected lifespan, years	50	60			55			50			52		
Years of schooling a 5 year old expects	6	12			9			7			9		
Years of schooling a 25 year old has had	6	9			6			6			6		
			Change	%		Change	%		Change	%		Change	%
Income index	0.32976	0.65957	0.329783	43%	0.48713	0.157346	49%	0.33262	0.332619	27%	0.34343	0.343433	26%
Lifespan index	0.48154	0.64205	0.160514	21%	0.56180	0.080257	25%	0.48154	0.481541	39%	0.51364	0.513644	39%
Education index	0.38260	0.66269	0.280086	36%	0.46859	0.085988	27%	0.41326	0.413260	34%	0.46859	0.468593	35%
HDI	0.39313	0.65471	0.261576	100%	0.50428	0.111151	100%	0.40452	0.404515	100%	0.43561	0.435613	100%
HDI increase		0.28158			0.11115			0.011384			0.042481		
% towards Reducing Poverty		235%			100%			10%			38%		
% towards Out of Poverty		100%			42%			4%			16%		
Capital for energy, US$ per household		$3000			$400			$30			$400		

globally—lack access to electricity. Many additional households and businesses suffer from highly intermittent power supplies. The United Nations has set a target of ensuring all people on the planet have access to sustainable energy by 2030—a plan known as Sustainable Energy for All or "SE4All." This report examines the access to electricity component of that target, with a specific focus on the best mix of interventions to deliver electricity access and the finance required to deploy these solutions.

EXISTING MODELS AND ASSUMPTIONS

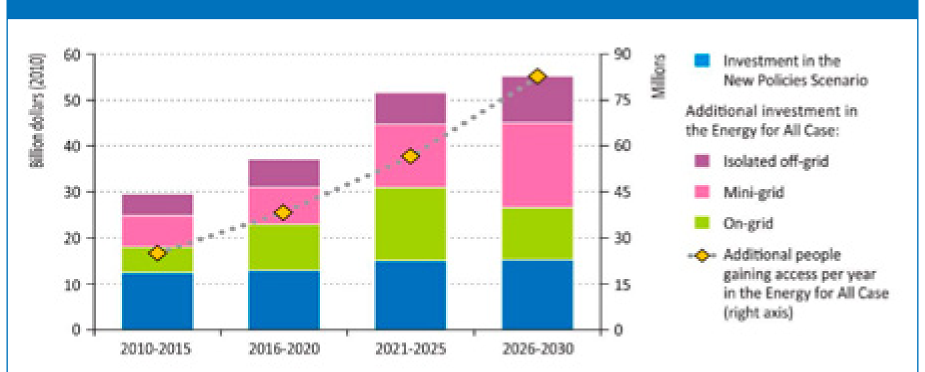
The International Energy Agency (IEA) has suggested that $9 billion per year is currently being invested in energy access globally.[10] While this may rise to an average of $14 billion per year between 2010-2030, one billion people will still lack access to electricity by 2030. The IEA suggests that a total of $48 billion per year is required to attain energy access for all by 2030.

The IEA model focuses on three different interventions: grid extension, mini-grids, and off-grid solutions. For each of these interventions, the IEA assigns a percentage of the increased energy access investment required to achieve their total energy access goals: 36 percent for grid extensions, 40 percent for mini-grids, and 24 percent for off-grid solutions. However, current investments in energy access are nearly all in the form of grid extension, necessitating concerted efforts to align the IEA recommendations with current E4All expenditures.

Aside from this fundamental problem, the IEA model suffers from three major flaws: 1) The assumed definition of "access" to energy is a very high consumption rate of 250-800-kilowatt hour per year, rather than attainment of a desirable level of energy services needed to efficiently achieve the goal;[11] 2) The relatively minor growth in capital investments required is unrealistic, given the exponential growth pattern of new industries; and 3) They suggest an unrealistic estimate of capital expenditure.

Of these limitations, the third is perhaps the most important. The total investment estimated by the IEA for E4All—$640 billion over 20 years—represents an investment between 300-500 percent higher than current investments in energy access. There is little evidence to support that this amount of money is currently available from public institutions.[12] In other words, the IEA's aspiration does not appear attainable within real-world budget constraints. Therefore, we need an alternative, pragmatic approach that is reliant on fast-growing distributed clean energy solutions to meeting the E4All objective.

FIGURE 5 - AVERAGE ANNUAL INVESTMENT IN ACCESS TO ELECTRICITY BY TYPE AND NUMBER OF PEOPLE CONNECTED IN THE ENERGY FOR ALL CASE (INTERNATIONAL ENERGY AGENCY, 2011)



CLEAN ENERGY SERVICES FOR ALL (CES4ALL)

First and foremost, a pragmatic approach must consider much higher annual growth rates of investment than currently envisioned. For example, energy access interventions in the off-grid market can, and are, growing much more quickly[13]

FIGURE 6 - OFF-GRID LIGHTING SYSTEM POWER REQUIREMENTS (WATTS)

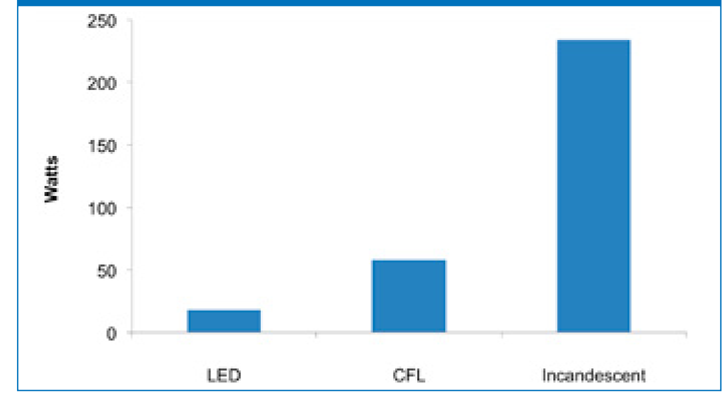


TABLE 3 - DEFINITIONS AND COSTS OF ACCESS TO ENERGY

	Access to Electricity Supply					
Attributes	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
Service description	-	Task lighting and phone charging (OR radio)	General lighting AND television AND fan (if needed)	Tier 2 AND any low power applicances	Tier 3 AND any medium power applicances	Tier 3 AND any high power applicances
Peak available capacity (W)	-	> 1	> 50	>200	>2000	>2000
Duration (hours/day)	-	≥ 4	≥ 4	≥ 8	≥ 16	≥ 22
Evening supply (hours/day)	-	≥ 2	≥ 2	≥ 2	≥ 4	≥ 4
Average costs (US$/household)						
Grid		2000	2250	2500	7500	8250
Minigrid		2500	2750	3200	8000	8800
Stand-alone		70	300	500	9500	10500
Minimum cost	0	70	300	500	7500	8250

TABLE 4 - COMPARING DEFINITIONS OF "ACCESS TO ENERGY"

Energy Access Definition	Power Generation, Watts per Household: Residential only	Power Generation, Watts per Household: Residential + Business + Industrial Needs	Hours of use	Res. Energy, in kWh per house per year	Load Factor
Practical Action	30-70 (50)		4 for lights, 24 for cooling	234	53 percent
African Dev. Bank	110-220 (165)		24	434	30 percent
IIASA	30-340 (150)		24	250-500	29 percent
IEA/WB/UNIDO/UNEP "Full Access"	800	2000	24	2102	30 percent
DIFFER Tier 3	200		8	175-300	30-50 percent
DIFFER Tier 2	50		4	73	17 percent

Assumptions: 5 people per household

30 percent of all available energy is consumed (load factor), unless calculated from definition, and mid-range values are used in calculations from any ranges shown in brackets.

The Energy Ladder

Along with concerns over how much power people in off-grid areas should consume, many discreit initial energy access interventions—such as solar lanterns—as not representing "full access." Rather than viewing these interventions as an end goal, however, they should be viewed as a part of the "Energy Ladder"—a conceptual way of understanding how populations can increase their access to energy services as incomes and energy provision expand.

Off-grid solutions provide a critical first step onto the energy ladder with basic energy services such as lighting, mobile phone charging, fans, and now, super-efficient televisions. Once these basic needs are met, many populations are capable of expanding their energy consumption to include higher level needs like refrigeration or even agro-processing.

Rather than waiting for all needs to be met at once (i.e. grid extension), off-grid interventions help get populations on the energy ladder on a time scale that accelerates impact: days and months, not the years and decades they often must wait for centralized power plants and grid extension. Lighting and mobile phone charging are the beginning, not the end of energy access.

While distributed renewables are essential for rural populations, they also fill important needs for other populations. For many urban Africans and the growing middle class, the centralized grid is unreliable and provides just a few hours of power each day. Solar companies have found an important customer base among grid-connected populations seeking more reliable power through solar and battery technology. Solar panels on these roofs help to keep the electricity flowing even when the grid is not working.

Finally, distributed generation can empower the poor. Often, the poor have not been afforded access to modern energy services due to governance reasons as much as technological or economic reasons. Decision-makers may not see expanding affordable access as a priority, and the poor often lack the means to hold them accountable. With the deployment of distributed generation such as SHS, access to energy is no longer dependent on where the grid will be extended or how much utilities can charge. The smaller project size associated with distributed clean energy removes the ability of governing elites to centralize and control resources and limits opportunities for corruption.

than grid-extension. Adjusting investment needs to reflect differing growth rates allows for much more modest investment levels today, which will then ramp to higher investment levels moving toward 2030. There is ample precedence for such rapid growth rates as seen from the global mobile phone penetration over the past decade.

In addition to adjusting investment pattern growth rates, when enabling rural electrification, considering innovative technologies that bring down investment costs allows us to build a more practical model for delivering energy access. On top of that, careful consideration must be given to what is deemed "access to energy." Taken in sum, we believe CES4All provides the best opportunity to deliver on these energy access goals.

ENERGY FOR ACCESS—HOW MUCH IS ENOUGH?

Energy access debates continue to be defined by attempts to define "access" as a raw supply of energy. This is often measured in megawatts of supply built or miles of transmission and distribution lines installed. Rarely, if ever, is it measured by households connected or, more importantly, services provided. Failing to prioritize services can lead to wasteful use of energy and capital, both of which are in scarce supply.

For example, replacing incandescent light bulbs with LED light bulbs delivers the same energy service for 50-85 percent less energy. The most energy efficient fans move four to eight times as much air per watt as less efficient fans. These efficient fans often utilize highly effective DC motors, which are a natural fit for off-grid system design. There are similar gains possible for refrigeration, a facility that could be, and often is, shared amongst several households so the full energy consumption of a refrigerator need not be assigned to each and every household. Even in an instance where households don't share these larger, more efficient appliances, twice the amount of energy efficiency can still be realized. Energy efficient appliances cost more up front, but cost far less than generating excess power in the long run.

By ensuring access to efficient appliances, peak loads for the initial rungs of the energy ladder drop dramatically.[14] This reduces peak evening loads to expected daytime agro-processing energy demands.[15] Hence, it is possible to consider that, with aggressive demand management, reasonable access to energy can be delivered for a fraction of the energy typically required—but only if implementation focus and investor/donor demands target delivery of services, not kilowatt hours .

For the purpose of this report, we define "access to energy" as Tier 2 in table 3 below, which includes lighting, television, fan, mobile phone charging, and radio. However, our definition also includes at least two hours of daytime agro-processing power to support livelihood generation. From this tier, the goal is to move households up the energy ladder over time.

Table 3 above[16] offers a much-improved analysis of energy access as compared to table 4 used below by the IEA).[17] More importantly, table 3 gives an accurate portrayal of the energy supply required to deliver needed energy services[18] and the vastly different costs associated with the three main interventions available. As you can see below, stand-alone or off-grid interventions are dramatically cheaper than grid extension for the initial rungs of the energy ladder, which can be seen in tiers 1-3 in table 3 above.

More importantly, this new estimate shows that our proposed level of initial household services are similar to those proposed by the IEA[19] but can be provided at a fraction of the cost. Whereas the IEA proposes $48 billion per year, our new estimates show these services can be provided for a mere $14 billion per year, which equates to a 71 percent reduction from the IEA estimate.[20]

Neither the IEA nor the practical action analyses we refer to fully disclose the actual levels of service rural citizens aspire to reach—including illumination, refrigeration capacity, etc.—nor do they disclose the efficiencies with which those services are delivered. In addition, none of the analyses discuss the impact recent energy efficiency technologies have on the amount of energy needed to provide the intended levels of service or the reduction in peak kilowatts used per household. Table 1 below represents our model's vision for end-use technologies, hours of use, and services delivered, all of which might result in even more dramatically expanded residential energy services. This would be for a fraction of the energy requirement of the IEA's basic access goal of 250-500 kilowatt hour per year.

BUSINESS AS USUAL MEANS FAILURE AS USUAL

Time is ticking. It is now 2014. The surge of billions in investment that the IEA model requires has not come. Even the recently announced $7 billion "Power Africa" program from the Obama administration is likely to end up being directed more towards new generation capacity from grid-connected power stations than to off-grid projects. Should the program bring access to 20 million households over the next 5-10 years as targeted, this will not even keep up with the population growth rate in Africa. Faster, cheaper deployment models must be considered.

As Figure 8 shows, rural electrification often has an exponential nature in the early years of its application then a linear phase and a slow taper at the end, a cycle that generally takes between 10-40 years. There are 16 years left to achieve the E4All mission. Thailand and Vietnam are recent examples to show this can be done, but executing this across 50-100 countries is an immense challenge, especially assuming that the next few years of progress are likely to yield modest increments at best.

A new model is needed that takes this into account, one that still offers hope of rapid success—even in slower-moving countries like India. The IEA model suggested $30 billion per year in early stages, rising approximately three percent per year to $50 billion per year by 2025-30. Our model reshapes this near-linear investment curve to start with an exponential growth of 30-50 percent per year for off-grid solutions[22] and the historically accurate three percent per year for grid extension. Mobile phone and microfinance industries have both shown historical early growth levels of the magnitude suggested for the off-grid sector and were sustained over a 10 year period. Exponential growth curves ultimately reduce immediate investment needs and increase late-stage investment needs. However, by presenting best practices in energy efficiency and cost estimations of our definition of energy access, the following model lowers the overall funding requirement considerably, thus reshaping and reducing the investment required for access to energy for all.

CHEAPER, FASTER, MORE EFFECTIVE: THE CLEAN ENERGY SERVICES FOR ALL (CES4ALL) MODEL

An improved financial model that captures costs of "best practice" initiatives from recent field practitioners and allows for exponential industry growth from the relatively modest current market size, is required.

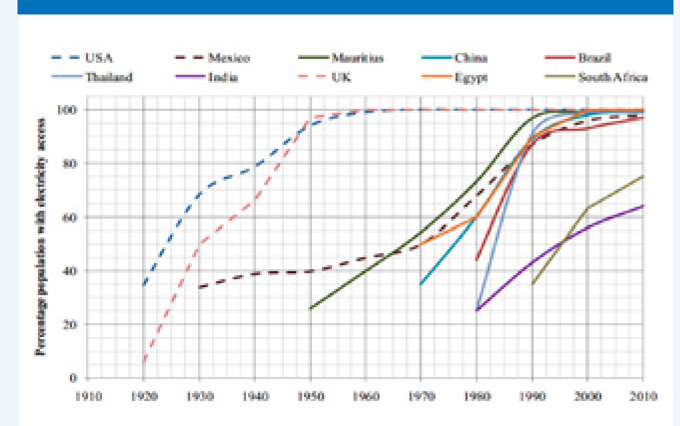
KEY ASSUMPTIONS INCLUDE:

Definition of Access to Energy: "Access" is defined as Tier 2 in our Clean energy for all end use model combined with at least two hours of agro-processing. To meaningfully reduce poverty, non-lighting uses of electricity—such as agro-processing, refrigeration and communication—are required, which the End Use model has shown can be provided with peak power of 30-50-watts per household.[24]

Skinny Grids—rethinking grid extension design

The first application of this electricity is lighting quickly followed these days by mobile phone charging. With the advent of white LED lighting, the light supplied by 100-watt incandescent bulbs can be replaced with just 5-watts of well-designed LED lighting. A phone charger takes similar power, meaning the power per household for basic services has dropped by up to 85 percent. This then leads to an equivalent drop in the current in the "poles and wires" that connect households in conventional grids, and therefore, there is a potential to use much thinner and cheaper wiring. Combined with smaller poles and longer spans, or locally dug underground trenches, the cost per household for reticulated wiring can be vastly reduced via thin-cable designs—also known as "Skinny Grids"—not previously possible for rural electrification before LED lighting.

FIGURE 7 - HISTORICAL EXAMPLES OF ELECTRIFICATION RATES



Combined with innovations like 1-2 kV low cost and low power transformers, such as those used in Andhi Khola in Nepal or those promoted by www.microformer.org, Skinny Grids have the potential to reach households 5-10 kilometers from power sources for considerably less than current rural electrification costs. This in turn cuts the cost per household by more than half.

In some countries, like Nepal, over 95 percent of all households are within 5-10 kilometers of an off-grid telecom tower or the edge of the grid. Telecom towers are often grossly under loaded compared to the power supplied to the tower (e.g. a 3kW load compared to a 15kW installed capacity), and re-lamping households connected to the grid can free up power cheaply and more quickly than building new power generation. This would cost just Negawatts[21] of energy as compared to current prices paid to independent power producers. Therefore, the power generation to connect 10-20-watts of energy load per household may already exist for the majority of the off-grid market, and the only investment needed is $1-2 per meter of Skinny Grid connections. Telecom tower-based mini-grids, which often run on diesel gas, can also quickly be converted to solar and other clean energy power sources. Peak load issues on the grid can also be reduced by 20-50 percent in emerging countries by re-lamping incandescent and fluorescent bulbs with LED bulbs, creating desirable flat demand curves instead of sharp peaks in the evening.

It is proposed that energy efficiency, combined with distributed power and new "high voltage" low power transformers, can revolutionize rural electrification.

Off-Grid Innovation: Mobile Phones, Pay as You Go Solar, And Tower Power

In 1998, mobile phone penetration in developing countries was just one percent. Today, roughly 75 percent[23] of global mobile connections originate in emerging markets. Going forward, four out of every five new mobile connections will come from the developing world where reliable grid access is scarce. That means for much of the world's underprivileged, access to mobile networks has surpassed access to energy, water, and even basic sanitation, leaving an estimated 550 million people with phones whose usage is constrained by the cost and availability of charging them. This mobile phone penetration in rural areas has simultaneously created the demand for power to keep phones charged, and the supply infrastructure backbone innovative approaches to off-grid energy service provision. Two of the most promising approaches stemming from mobile expansion are pay-as-you-go solar services and "Tower Power."

Pay-as-you-go solar utilizes mobile money platforms and Machine to Machine (M2M) technology to allow customers to pay for energy in small amounts as they use it. Mobile money—money loaded onto cell phones—unlocks a solar array providing payment flexibility and built-in financing that, much like solar leasing in the developed world, overcomes the up-front cost barrier to solar deployment. Mobile money platforms that enable pay-as-you-go solar are still nascent, but already M-Pesa in Kenya has enabled over 15 million people to access the financial system and accounts for $12.3 billion in transactions. The Groupe Speciale Mobile Association, an association of mobile operators known as GSMA, found that 60,000 pay-as-you-go solar services were sold in sub-Saharan Africa in 2013 alone.

In addition to the pay-as-you-go opportunity, the dramatic increase in mobile phone users in rural parts of the developing world has created a distributed infrastructure of off-grid cell phone towers. The GSMA estimates that, as of 2012, 639,000 off-grid "base stations" had been built.

These base stations have traditionally been powered by diesel generators reliant on increasingly costly and volatile diesel prices. As a result, mobile phone providers are seeking stable, reliable, and less costly clean energy alternatives. Entrepreneurs are now leveraging this infrastructure that provides anchor demand to deliver "community power" to surrounding communities. They achieve this goal by building excess capacity into the cell tower system, which can then be sold to local communities via mini-grids, transportable batteries, or by directly charging applications on site.

According to this model, cell phone operators provide anchor demand and a stable revenue stream, third party entrepreneurs own and operate the clean energy plants, and local communities receive electricity and provide revenue for the entrepreneur. In essence, this model surpasses the need for centralized grid infrastructure by piggybacking on the most successful leapfrog technology to date: mobile phones. The GSMA forecasts the potential for 200,000 community power projects capable of providing electricity to 120 million people worldwide.

The most exciting aspect of this model is the other services that are able to piggyback on the distributed electricity infrastructure. Already companies are pioneering models to deliver distributed Wi-Fi services as well as electric transportation.

FIGURE 8 - OFF-GRID SOLAR ECONOMICS (SAVIVA RESEARCH)

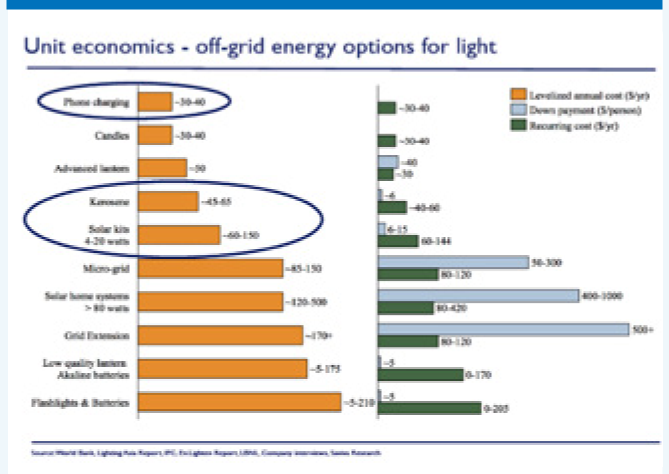


FIGURE 9 - MOBILE MONEY EXPANSION (SAVIVA RESEARCH)

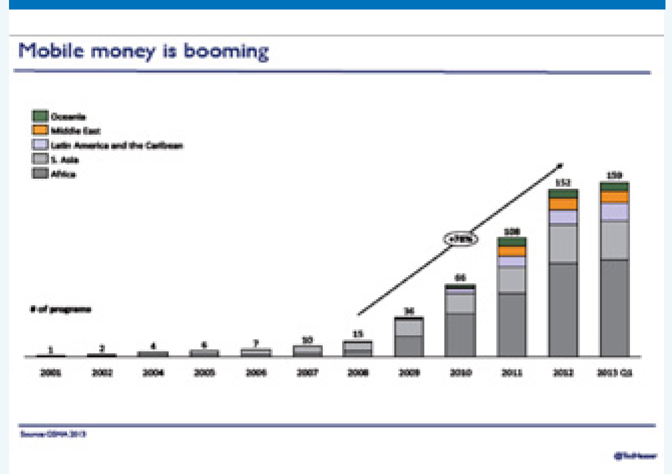


FIGURE 10 - MOBILE PHONE PENETRATION VERSUS ENERGY, WATER, SANITATION ACCESS IN SUB SAHARAN AFRICA (GSMA, 2013)

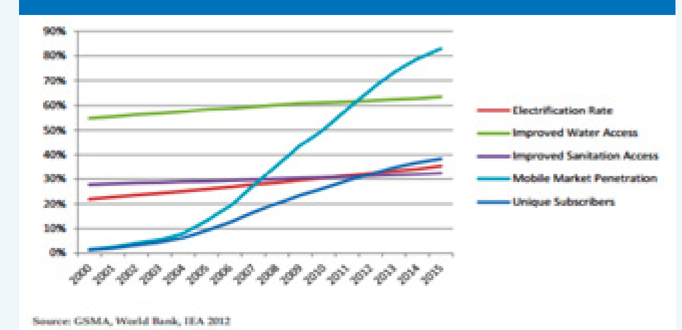


FIGURE 11 - GROWTH IN BASE STATIONS IN DEVELOPING REGIONS 2007-2012 (GSMA, 2010)

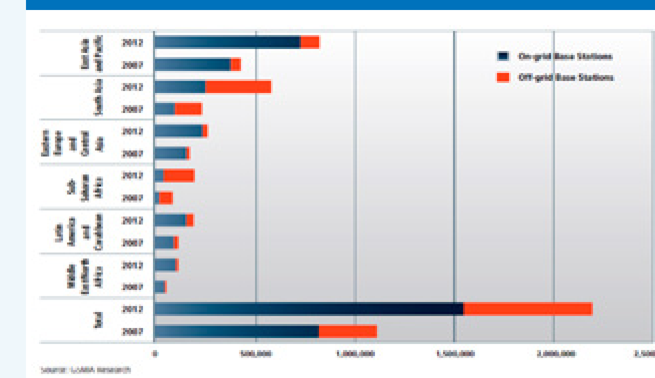
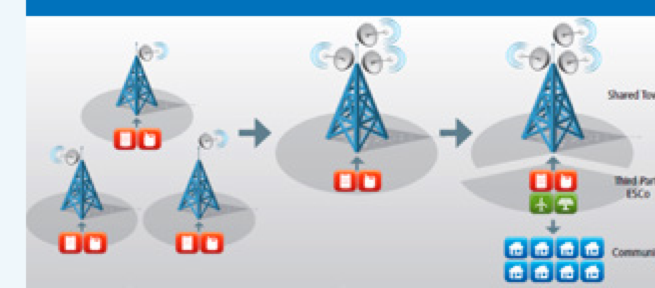


FIGURE 12 - EVOLUTION OF TELECOMS INFRASTRUCTURE BUSINESS MODELS (GSMA, 2010)



In the early periods, interim sales of smaller 0.2-10-watt solar systems are included, but as this is not considered "access," the model assumes that all households purchasing such products do so to get onto the energy ladder. But the model assumes that they will upgrade to more comprehensive systems by 2030 that provide "access." This includes 10-100-watt SHS, mini-grids and grid extensions. In this upgrading model, the total household systems installed will exceed the 250-300 million households that lack access today.

Clean Energy Intervention Classification: Five electricity-supply technologies have been defined as useful sub-categories of the micro energy supply industry, and average retail prices have been included:

1. 0.2-2-watt single-bulb solar lanterns ($25 per household)
2. Small SHS of multiple lamps, 2-10-watts ($125)
3. Large SHS, 10-100-watts ($250)
4. Mini-grids, 10-100-watts ($250)
5. "Skinny" grid extension, 50-200-watts ($500)

Growth Projections: Historical installations since the year 2000 have been modelled, which—with further research—can be supplementally referenced and quantified. Future growth rates are assumed for each technology category, with rapid early growth for solar lanterns that slows in the future due to the substitution of more comprehensive systems. Slower but steady growth is modelled for larger SHS and mini-grids systems, while grid extensions are expected to slow from 10 million households per year historically to two million households by 2030, when the focus will be on the most remote villages. Annual growth rates in the model are similar to the CAGR of the microfinance and mobile phone growth rates in emerging markets over the last 15 years, averaging 30-50 percent per year and slowing down to 10-20 percent per year in the later years of the process.

Financing: It can be safely assumed that 100 percent access will be impossible without some form of lending – a purist cash-sale model will not lead to access for all, only for the richer of the poor. At the moment, most pico-solar devices are cash sales. It is expected and modelled that lending will penetrate the smaller products as well in years to come, and more rapidly for 2-10-watts products than for 0.2-2-watt lanterns.

Loan periods for small products are assumed to be two to three years, five years for large SHS and 10 years for mini-grids. A shorter loan period for mini-grids would decrease affordability, increase capital turnover and hence decrease capital required; the 10-year assumption introduces some capital conservatism and affordability optimism (as investors' confidence grows) compared to current lending practices for mini-grids.

Agro-Processing: To remain consistent with the aforementioned end-use models (which are assumed to be aligned with IEA's modelling), an investment model for agro-processing is not included, though this service is an essential part of the energy access strategy. A note on investment needs for agro-processing services is made at the end of the core model results discussion below.

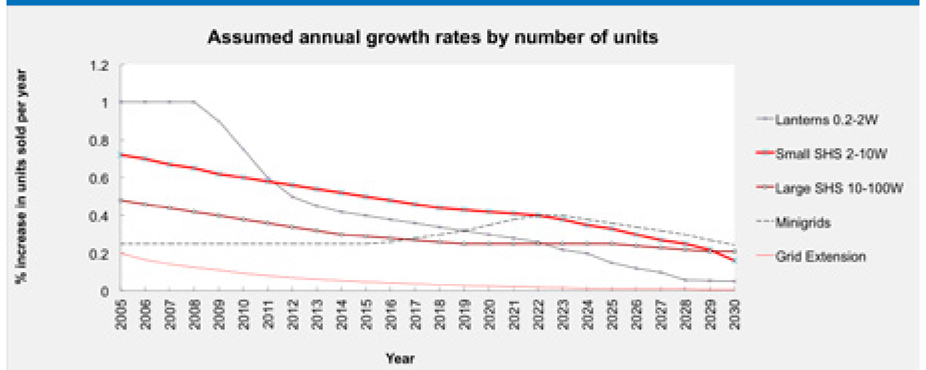
KEY RESULTS INCLUDE:

Clean Energy Products Sold: Over 700 million products will reach the underprivileged by the year 2030, including 50 million replacements, where "product" can mean anything from a 0.2-watt solar lantern to full 24/7 grid access. This is valued at $170 billion retail value, with 58 percent of the value in "thin" grid-connected infrastructure and 42 percent in off-grid infrastructure. This assumes that many of the 250-300 million households that current lack access will graduate from a "basic" 0.2-10-watt technology up to an "access" technology by 2030 and some will possess multiple technologies. Households are expected to graduate from pico-solar interventions to larger SHS systems, mini-grids, and grid connections by 2030.

Role of Skinny Grid Extension: Half of the off-grid population (200 million households) will be reached by low-cost grid extension, while half will be reached by mini-grids or large solar systems. Up to 75 percent of these households will also have bought at some stage a "basic" 0.2-10-watt technology, resulting in 100 million 0.2-2-watt products sold and 200 million 2-10-watt products sold.

Rate of Deployment: It will take until 2025 to reach 50 percent market penetration, and the last half will be reached in five years. This is a more realistic adoption rate than a simplified near-linear progress as assumed by IEA. Over the past 14 years we have reached 200-300 million people with energy access. It will take until 2022 to have less than one billion people lacking access. By 2025, only 500 million people will lack access, and full access will be achieved by 2030.

FIGURE 13 - ASSUMED ANNUAL GROWTH RATES OF SALES, BY PRODUCT CATEGORY



Market Sizing: Retail/installed values of 0.2-2-watt lamps will not exceed $250 million per year and will peak, then decrease around 2025, while SHS and mini-grids will each become $5-7 billion product segments. The industry, excluding grid extension, is currently estimated as a $200-250 million industry, but will reach $1 billion by 2020 and $4 billion by 2025 on its way to a $12 billion per year mature industry as this mission is achieved.

Investment Required: The IEA estimates a need of $650 billion for electricity access. However, we find that services can be delivered for 15 years with $14 billion per year in investments, or a total of approximately $200 billion. We estimate this will require a total of $145 billion in new investment. This is 78 percent lower than IEA estimates.

Near term need: Per our analysis, $100 million of new investment in off-grid clean energy manufacturers is needed in the next three years. In the next two years, $400 million will be required for consumer finance and will be significantly higher than working capital needs of manufacturers. Combined, $500 million is needed in the next two to three years, consistent with a letter from industry to the World Bank.[25]

Long term need: Overall, the energy access industry demand for capital is expected to average $5-10 billion per year. It will initially be dominated by grid investments but will be ultimately dominated by off-grid investments as overall grid investments shift their focus to increasing energy access and away from connecting the few people left that currently lack access and are increasingly remote.

Off-grid market sizing: The current 2013 off-grid market is estimated to have approximately $200-300 million of sales at retail value and is utilizing $150-200 million of primarily equity investment. Refinement of these estimates will not be possible if industry players do not report revenues regularly, as is done in microfinance.

Investing in women—capital for agro-processing to reduce manual labour

In off-grid villages around the world, mostly women typically spend one hour per day manually processing food – hulling rice, grinding maize into flour, and expelling oil from seeds. We explicitly investigated the costs associated with reducing this waste of human talent, and focus on helping these women use their time for a more productive means.

As mentioned previously, the capital needs for agro-processing energy have not been specifically modelled. In order to remain consistent with the assumed end-use models, we assume IEA did not explicitly include investment for agro-processing energy.[26] Our estimate is that 180 million households can be served with long-term agro-processing facilities by 2030 (50 percent of 200 million grid extension customers can already reach a mill),[27] requiring a total investment of $14 billion to our $145 billion total above.[28]

Similar investment models could also be considered for drinking water supply, given that women and sometimes children often spend up to six hours per day collecting water. This service is less monetized than agro-processing, so returns may have to be generated more creatively, through the conversion of time saved into productive exports items from the village which can be sold in local or international markets. Such high risk models will require grants of $20-50 per house to be allocated before a commercial model is proven for basic access to water of 10 litre per capita per day.

ALIGNING INVESTMENT WITH CES4ALL

An appeal for billions in investment, even if lower than expected, is unlikely to yield action unless reasonable returns on the capital can be projected, given there are competing demands for such capital. Thus, a high level but reasonably detailed model is presented for consideration by fund managers, financial institutions, donors and crowd funders.

Working capital for manufacturers is typically not highly leveraged, and one could assume that there is a market of 2:1 debt to equity required until 2030 for the manufacturers of off-grid energy access equipment. This represents a $1 billion equity opportunity, with $20-30 million required in the next three to four years. The investment for supply of grid connection materials is mostly already mobilized, and will decrease in the future, so off-grid investment needs and its forecasted exponential growth are the focus.

Quantifying Impact of Moving Beyond Kerosene

Strenuous demands for impact measurement are often placed on organizations implementing these activities, often on top of investor demands for double-digit returns on debt or equity invested. It is these rare demands for data that are accompanied with a reduction in expected returns, though occasionally grants can be secured to help with the costs. To reduce this burden and more rapidly quantify impact, it is proposed that some standard benefits may be assumed from levels of service delivered.

For example, baseline expenditure on kerosene lighting and phone charging has now been undertaken by several agencies in many countries. Minimal lighting services have been deemed by the Clean Development Mechanism to displace approximately one litre of kerosene per week, which is often worth $1. Based on annual small-scale samples of household-reported data of kerosene displacement (100 percent or lower), financial savings can be estimated. Savings on expenditure are equivalent to increased income, which is one of three major elements of the main measurement of poverty, the Human Development Index (HDI).

HDI has three major components: an income component, expected lifespan, and years of education. Income-producing uses of energy (including time saved via agro-processing machines) can increase income, thus increasing HDI. Innovative school programs like SolarAid's SunnyMoney and SELCO's Light for Education have statistically shown increased school attendance when looking at school records and ultimately increased HDI. Improved cookstove research may be able to quantify a link between indoor air pollution levels and life expectancy, given that respiratory disease is a known killer.

Table 2 demonstrates the effect energy services can have in raising HDI from poverty levels. Eliminating kerosene lamps helps provide 10 percent of the 2030 goal and four percent of the 2050 goal of ending poverty, as households are able to save $100 per year and children are able to attend school one year longer than normal. Building on that first step, energy access should provide sufficient power and link with complementary programs to increase income by $500 per house per year and provide improved cookstoves which will increase life expectancy by perhaps two years. Additionally, this link to energy access will increase school attendance for an average of nine years from a current six years. This will cost between $400 and $1,000 per household, but those costs can still be less than IEA estimates if completed efficiently and strongly integration with non-energy programs. Higher investments for energy may then help end poverty between 2030 and 2050, but the primary focus needs to be the difficult mission of universal energy access by 2030.

FIGURE 14 - HDI CALCULATION AND ITS COMPONENTS

1. Life Expectancy Index (LEI) $= \frac{LE - 20}{82.3 - 20}$

2. Education Index (EI) $= \frac{\sqrt{MYSI \cdot EYSI}}{0.951}$ $= \frac{EYS}{20.6}$ $= \frac{MYS}{13.2}$

3. Income Index (II) $= \frac{\ln(GNIpc) - \ln(100)}{\ln(107,721) - \ln(100)}$

Finally, the HDI is the geometric mean of the previous three normalized indices:

$$HDI = \sqrt[3]{LEI \cdot EI \cdot II}.$$

Additional equity will be required to fund non-working capital aspects of these businesses – mainly those losses incurred before profitable scale is reached, which include product development, sales and marketing, and corporate systems development. From recent experience, one could estimate this need for equity to be on a par with the working capital component, making overall debt to equity needs closer to a 1:1 ratio, which is typical for manufacturers.

By 2020, the Freight on Board (FOB) sales value from off-grid suppliers is estimated to total $750 million. Just five years later, the value of manufacturing enterprises will increase to $3 billion and grow to $6.5 billion by 2030. This five times growth in the value of equity invested ($1-2 billion) over the next 10-15 years represents an approximate 15-20 percent IRR from 2018-2020 onwards as the manufacturers stabilize and become profitable.[29]

Similarly, a model is presented for equity investing in energy lending or consumer finance companies.[30] High leverage of debt is necessary to generate returns equity investors are looking for, and by crowd-sourcing such debt, acceptable risk can be spread considerably. Equity would also be required for initial losses and a similar sum would be used for manufacturers.[31]

The 15-20 percent IRRs this will generate are not extraordinary returns by venture capital standards, and investment horizons of 10-15 years are required, which exceed the typical lifespan of a close-ended fund. Short-term returns will be modest and barely positive before companies are able to reach a profitable scale. Each dollar of revenue will be hard won, with $0.20-$0.60 of equity lost for each dollar of revenue gained until 2020, which equates to up to $500 million from each $1 billion invested. The end result will be a family of strong manufacturing and lending companies generating $1 billion in revenue and worth $2 billion at reasonable valuation by 2020. They will be worth considerably more by 2030.

CONCLUSION

The investment needs for achieving energy access have been vastly over-estimated. This is largely due to embedded assumptions of poor energy efficiency leading to high energy demand and poor cost-modelling of off-grid solutions which, in turn, reduce the projected utilization of off-grid solutions. Moreover, simplistic models for the patterns of market development imply much more front-loaded investment than is actually required.

The model presented above allows for rapid growth of the current rural electrification industry with a particular focus on the off-grid market segments. Modest equity returns may be possible whilst exponentially growing a small industry, but this journey is a necessary one to achieve the mission of energy access for all.

Can it be done? The growth of a rural electrification industry, particularly one focused on isolated systems in villages rather than grid extension, is likely to be strong in the coming years. The microfinance industry grew from $100-200 million in the early 1990s, to $1 billion by 2000, and $30-50 billion by 2010. A similar growth curve can be replicated for the micro energy industry, at 30-50 percent per year growth rate from current levels. However, this will most likely need considerable risk guarantee support for donors before lending default levels reflect a mature industry that can replicate the successes of Grameen Shakti in Bangladesh.[32] This is the same kind of soft support microfinance Grameen Shakti enjoyed in its early years, to a level of tens or hundreds of millions of dollars at a time when investment was more focused on grants and debt leverage and less focused on equity models of financing.

Such risk guarantees played an instrumental role in the rural electrification of the U.S. and in other countries. Indeed, highly centralized and capital-intensive power generation projects – particularly nuclear power – enjoy such support. The time is now for a level and truly competitive playing field to boost the confidence of equity and debt investors and leverage their support to create a multi-billion dollar industry in the next 10 years.

ANNEX—DETAILED MODEL ASSUMPTIONS & RESULTS

- "Access" is taken as similar to Tier 2 in Table 3 and the lower end of the IEA range (which was aimed at rural households, where most of those lacking access live). If this cannot be achieved, higher levels of universal access will unlikely be achieved with current investment trends. Lower levels of access, such as for lighting only or Tier 1, should not be considered as sufficient to have the desired development impact. To meaningfully reduce poverty, non-lighting uses of electricity such as agro-processing, refrigeration, and communication are required, which the End Use model has shown can be provided for with peak power of 30-50-watts per household.[33]
- In the early periods, interim sales of smaller 0.2-10-watt solar systems are included, but as this is not considered as "access", as the model assumes that all households purchasing such products do so to get onto the energy ladder. But the model assumes that they will upgrade to more comprehensive systems by 2030 that provide "access". This includes 10-100-watt SHS, mini-grids and grid extensions. Due to this upgrading model, the total household systems installed will exceed the 250-300 million households that lack access today.
- Five electricity-supply technologies, similar to DIFFER categories, have been defined as useful sub-categories of the micro energy supply industry, and average retail prices have been included:
    6. 0.2-2-watt single-bulb solar lanterns ($25 per household)
    7. Small SHS of multiple lamps, 2-10-watts ($125)
    8. Large SHS, 10-100-watts ($250)
    9. Mini-grids, 10-100-watts ($250)
    10. 'Skinny' grid extension, 50-200-watts ($500)
- We assume retail cash or fully-installed project prices. Unit costs are assumed to remain constant until 2030. In reality it is likely LED lamps, solar panels and even modern batteries like LiFePO4 will see cost reductions in years to come.
- To model the capital needs of the manufacturers, Freight on Board (FOB) equivalent prices have also been modelled. These FOB prices are, respectively for the products above, $10, $50, $125, $125, and $250. The difference between ex-factory/FOB prices and retail or fully-installed prices include international and local freight costs, taxes, duties, and profit margins of the supply chain (manufacturers, distributors and retailers).
- Historical installations since the year 2000 have been modelled, which with further research can be supplementally referenced and quantified. This is useful in calculating historical industry growth rates, which are likely to be similar to or higher than future growth rates.
- Future growth rates, shown in Figure 14, are assumed for each technology category, with rapid early growth for solar lanterns that slows in the future due to the substitution of more comprehensive systems. Slower but steady growth is modelled for larger SHS and mini-grids systems, while grid extensions are expected to slow from 10 million households per year historically to two million households by 2030 when the focus will be on the most remote villages. Mini-grid investment growth rates are expected to rise in the next five years. Annual growth rates in the model are similar to the compound annual growth rate (CAGR) of the microfinance and mobile phone growth rates in emerging markets over the last 15 years, averaging 30-50 percent per year and slowing down to 10-20 percent per year in the later years of the process.
- After 10 years, all technologies need replacing, so some sales will be for replacement of old products and will not increase access to energy. This is accounted for. It is recognized that smaller products may not have 10-year technical life spans, but these do not contribute to "access" and will be replaced by upgrading, for simplicity 0.2-10-watt products do not have separate lifespans.
- The global population is assumed to grow at approximately two percent per year and, by definition, so will the number of people seeking access to electricity.
- There are an average of five people per household, which is assumed as unchanging across the analysis period, although there is a good chance this may trend downwards. This effect may offset to some degree the conservatism in holding product prices constant over the analysis period.
- While some products will sell for cash, some (or many) will be loaned or leased and require financing. Lending will greatly increase the amount of capital required to achieve universal electrification but will allow the impoverished to access the products without an upfront cost barrier. It can be safely assumed that 100 percent access will be impossible without some form of lending—a purist cash-sale model will not lead to access for all, only for the richer of the poor. At the moment, the small 0.2-10-watt technology categories are dominated by cash sales, while the larger SHS and mini-grids are dominated by three to 10 year lending periods. It is expected and modelled that lending will penetrate the smaller products as well in years to come, and more rapidly for 2-10-watt products than for 0.2-2-watt lanterns.
- Loan periods for small products are assumed to be two to three years, five years for large SHS, and 10 years for mini-grids (similar to the five to seven year loans for hundreds of mini-grids in Nepal available now through the Alternative Energy Promotion Centre).[34] A shorter loan period for mini-grids would decrease affordability, increase capital turnover and hence decrease capital required, so the 10-year assumption introduces some capital conservatism and affordability optimism (as investors' confidence grows) compared to current lending practices for mini-grids.
- To remain consistent with the end-use models from above (which are assumed to be aligned with IEA's modelling), an investment model for agro-processing is not included, though this service is an essential part of access to energy. A note on investment needs for agro processing services is made at the end of the core model results discussion.

Key results include:

- Over 700 million products will reach the poor by the year 2030, including 50 million replacements, where "product" can mean anything from a 0.2-watt solar lantern to full 24/7 grid access. This assumes that many of the 250-300 million households that current lack access will graduate from a "basic" 0.2-10-watt technology up to an "access" technology by 2030, and some will possess multiple technologies.
- Half of those off-grid populations (200 million households) will be reached by low-cost grid extension, while the other half will be reached by mini-grids or large solar systems. Up to 75 percent of these households will also have bought at some stage a "basic" 0.2-10-watt technology, resulting in 100 million 0.2-2-watt products sold and 200 million 2-10-watt products sold.
- It will take until 2025 to reach 50 percent market penetration, and the last half will be reached in five years. This is a more realistic adoption rate than a simplified near-linear progress as assumed by IEA.
- From 2000 to now, the number of people lacking electricity has dropped from 1.6 billion to between 1.2-1.3 billion. It took 14 years to reach 200-300 million people. It will take until 2022 to have less than one billion lacking access (noting that 300 million people using 0.2-10-watt products will not count towards access). By 2025, only 500 million people will lack access, and full access is expected to be achieved by 2030.
- By 2020, sales of off-grid products will increase from current levels of two million total household products (or mini-grid connections) per year to three million "access" products plus five million "basic" 0.2-10-watt products per year. Basic products sales are expected to peak at 10 million per year in 2025 and drop to five million by 2030, while 2-10-watt products will rise to 15 million sold by 2015 and peak at 30 million in 2030. Energy access products will also rise to 15 million by 2015 and 30 million by 2030 but will require substantially more capital than basic products.
- Current grid connections are assumed to be 10 million per household, but as China completes its mission and invests in increased (not initial) access, and as more remote villages are reached and off-grid, solutions become more competitive. Grid connections are forecast to fall to five million per year by 2020 and one to two million by 2030. Connections off the grid to those with access (10-100-watt SHS or mini-grids) are not included, and a lot of future grid investment, which are not included in this model, are expected to be for "increasing access" and not for initial access.
- Retail/installed values of 0.2-2-watt lamps will not exceed $250 million per year and will peak then decrease around 2025, while small SHS, large SHS and mini-grids will each become $3-5 billion product segments.
- The industry, excluding grid extension, is currently estimated as a $200-250 million industry, but will reach $1 billion by 2020 and $4 billion by 2025 on its way to a $10-12 billion per year mature industry as the mission is achieved. As China's access to energy mission has now largely been achieved, an investment dip in grid connections (for initial access) is forecast, which will continue as off-grid solutions start to exceed grid installation values from 2023 onwards (Figure 2).
- To summarize all sales: approximately 680 million products will be sold by 2030 worth $170 billion at retail value with 58 percent of the value in "thin" grid-connected infrastructure and 42 percent in off-grid infrastructure. Of this total, 380 million products are sufficiently large enough to provide access to energy as defined previously, including large SHS (80m units worth $20 billion), mini-grids (100m worth $25 billion) and grid connections (200m worth $100 billion). The remaining basic products (300 million) are 0.2-10-watt systems that do not qualify as full "access to energy" solutions. Households who purchase these basic products are expected to graduate up to larger SHS systems, mini-grids and grid connections by 2030. One hundred million 0.2-2-watt systems are expected to be sold by 2030 worth $2.5 billion, and 200 million 2-10-watt systems are expected to be sold, worth an estimated $25 billion.

Per our analysis, $100 million of new manufacturer debt investment is needed in the next three years. However, this manufacturer need is dwarfed by the long-term debt needs to finance growth of distribution and service companies. The debt capital needs from distribution companies in this market are currently around $150-200 million, but in the next two years, $400 million will be required, and will be consistently eight to 16 times higher than working capital needs of manufacturers. Combined, approximately $500 million is needed in the next two to three years, consistent with a letter from industry to the World Bank.[35]

- Demand for new manufacturer debt capital will remain under $100 million per year to 2020 and then rise to $400 million per year as the mission goal is approached.
- The total capital required for manufacturers off off-grid products will be around $3.3 billion, of which only $50 million is required for 0.2-2-watt products, and $0.8-1.5 billion is required for each of the small SHS, large SHS, and mini-grid segments. Grid extension is assumed to be using $1.5 billion per year of manufacturer capital now for producing materials that give new access to electricity, and this will decrease in the future as a higher proportion of grid investment is for increased access to electricity, and not new access.
- The cumulative total lending capital required for two to 10 year loans for off-grid systems and 30 year loans for grid extension is approximately $40 billion for off-grid needs and $100 billion for 'thin' grid extensions. No allowance for loan default costs is included, and capital needs may increase if an investment cycle does not recover initial loans made for off-grid lending (grid extensions are assumed to not recover or recycle any investments made before 2030).
- Of this total cumulative off-grid lending capital, $50 million is required for the 10 percent of 0.2-2-watt products that are lent, $8-10 billion for each of small and large SHS (of which 70-80 percent are expected to be financed for while 20-30 percent are sold for cash). Approximately $22 billion is required for mini-grid financing at $250 per household per 10-year loan. Lending for off-grid projects requires $100 million per year now and this will increase to $1 billion per year of new capital by 2020, dominated by large and small SHS up to 2025, after which mini-grid lending needs are higher. Off-grid lending will then climb to $5

billion by 2025 and $10 billion by 2030, while grid extensions will fall from $5 billion per year now to less than $1 billion by 2030.

- Overall, access to energy demand for debt investment to finance consumers is expected to average $5-10 billion per year and will be initially dominated by grid investments. Ultimately, it will be dominated by off-grid investments as grid investments shift focus to increasing access to energy and away from connecting those few people left that lack energy access and are increasingly remote. Even after adding up to $400 million per year of manufacturing working capital, this capital estimate is considerably lower than the DIFFER and IEA estimates between $14-48 billion per year, mostly due to the lower costs for mini-grid solutions in particular and other off-grid solutions and slightly due to the model accounting for recycling of loaned capital.

- Off-grid market shares by number of products sold and by the value of kits sold are shown in Figure 3. The market leader of off-grid village electrification, by value, is arguably Grameen Shakti, who installs mostly larger SHS systems. Smaller systems of 2-10-watts from Barefoot Power and M-Kopa, and 0.2-2-watt lanterns from Dlight, Greenlight, and others are dominating the market by quantity, but not by value, or wattage installed, or lighting service delivered.

- Many mini-grids are also installed in Nepal each year and possibly had more significant market share before Grameen Shakti's growth from 2000 onwards. The earliest promoters of stand-alone LED systems include Light Up the World and Mighty Light, who both started between 2000-2005.

- Overall, the current 2013 off-grid market is estimated to have approximately $200-300 million of sales at retail value and is utilizing $150-200 million in capital. Refinement of these estimates will not be possible if industry players do not report revenues regularly, as is done in microfinance at www.MixMarket.org.

- The model can easily be adjusted for different growth rates and average costs in order to investigate alternate scenarios.

- The IEA estimates a need of $650 billion for electricity access, or higher. Tier 3 services can be delivered in 15 years with $14 billion per year in investments, or a total of approximately $210 billion. Our estimate for Tier 2+ services (almost as high as Tier 3) is $100 billion of 'thin' grid extension investment, $40 billion in off-grid investment, and $3.3 billion of working capital for manufacturers, for a total of $145 billion.

- This capital required decreases from $2000-3000 per household to $400 per household. Rather than $14-48 billion per year required in near-linear investment, our model also provides for a reduction in current grid extension investments from $5 billion to $1 billion or less. Exponential growth in off-grid demand for capital will decrease from the current $150-200 million to $10 billion by 2030, totalling $5-10 billion per year overall.

ENDNOTES

1 Financing Energy Access for All. IEA. Available at http://www.iea.org/media/weowebsite/energydevelopment/weo2011_energy_for_all.pdf Ibid.

2 Available at http://www.iea.org/publications/worldenergyoutlook/resources/energydevelopment/energyforallfinancingaccessforthepoor/

3 Available at http://www.greentechmedia.com/articles/read/Skinny-Grids-LEDs-Harness-More-Distributed-Energy-for-Less

4 We estimate 1-2 percent currently flows to energy access

5 See appendix.

6 http://sierraclub.typepad.com/compass/2012/05/energy-access-entrepreneurs.html

7 Available at http://www.iea.org/publications/worldenergyoutlook/resources/energydevelopment/energyforallfinancingaccessforthepoor/

8 See our calculations in the annex/HDI section.

9 Available at http://www.se4all.org/our-vision/our-objectives/universal-energy/.

10 Available at http://www.iea.org/publications/worldenergyoutlook/resources/energydevelopment/energyforallfinancingaccessforthepoor/.

11 The normative IEA numbers do not take into account modern improvements in technologies that reduce energy use needed to provide services such as LED illumination.

12 This level of investment represents 30 percent of all current international aid, of which very little currently goes towards energy access.

13 There is a Ninety-five percent Compound Annual Growth Rate in Sub Saharan Africa according to Lighting Africa and the World Bank.

14 They drop from 50-200-watts to 25-12-watts.

15 Given households consume 2-3 kilograms of rice or maize per day as their staple, and a 3-kilowatts diesel mill can process 100-200 kilograms per hour, processing 1000 kilograms per year/house of crop will require five to 10 hours of mill time per year, or 15-30-kilowatts per hour per household per year. Such a mill is regularly shared between 200-300 households, suggesting 10-20-watts of peak power per household is required for basic agro-processing services.

16 "The way towards universal access - Putting value on electricity services" by DIFFER has also been published (Erichsen et. al. 2013).

17 Available at http://practicalaction.org/ppeo2010 on page 3.

18 We define "household energy access needs" as lighting, TV, fan and mobile charging and includes at least two hours of agro processing which is critical for generating and supporting livelihoods

19 This is the equivalent of 200-watts per house, delivered more than eight hours per day.

20 This cost savings is enabled by a reduced cost estimate of $500/household for stand-alone (off-grid) systems, compared to IEA costs of $2,000-2,500 for similar requirements.

21 Negawatt power is a theoretical unit of power representing an amount of energy (measured in watts) saved. The energy saved is a direct result of energy conservation or increased energy efficiency.

22 Lighting Africa estimates that the sub Saharan off grid lighting market is already growing at 95 percent CAGR

23 Green Power for Mobile: Sustainable Energy and Water Access through M2M connectivity, 2013

24 Unlike the Tier 2 definition, more than four hours/day of access to power may be required for daytime uses like milling, powering office equipment, and refrigeration.

25 http://sierraclub.typepad.com/compass/2012/05/energy-access-entrepreneurs.html

26 Hours of service for Tiers 2 and 3 are limited to four hours/day, so it can be assumed this is only evening service, and no daytime use of energy was included. Assuming pro-rata investment needs for IEA of 10 percent of $48 billion per year, it could be suggested that IEA estimates for agro-processing capital needs are $4.8 billion per year (excluding the mill itself) or $65 billion by 2030 in total.

27 This will come at a cost of $10,000 over 10 years, whether a renewable or diesel plant is used, and lower if a grid-based mill is used.

28 This could be reduced to $10 billion or less if mobilization of $2 billion can be achieved by 2020 and a five year loan cycle can be successfully commercialized, allowing two more rotations of this seed capital.

29 Lower IRRs of 0-10 percent during 2007-2015 will be experienced while cumulative invested equity is less than twice FOB annual revenue, but as this ratio increases to 2:5, respectable IRRs can be attained. This $1-2 billion of equity would be invested via tranches of $25-50 million of invested to date, $150-250 million by 2020, $0.5-1 billion by 2025 and similar thereafter. As such, the window for private equity is before 2020, and IPOs and public markets may need to provide equity after 2020, though the microfinance industry has shown public offerings are not necessarily required.

30 Equity would be required to leverage debt, starting at 50 percent of capital in 2000 to reflect early lessons learned, and dropping to 20 percent by 2010 as models like Grameen Shakti mature, and thereafter to 15 percent by 2015 and 10 percent from 2020 onwards.

31 This is targeted as the equity for capital but drops to just 10 percent of this by 2020, or one percent of total capital, and five percent of the capital available now.

32 http://www.gshakti.org/index.php?option=com_content&view=article&id=58&Itemid=62

33 Unlike the Tier 2 definition, more than four hours/day of access to power may be required for daytime uses like milling, office equipment and refrigeration.

34 http://www.cd3wd.com/cd3wd_40/JF/JF_OTHER/SMALL/MOSTERT.PDF

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