Considering Access to Energy Services

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About

Persistent Energy Partners (PEP) invests venture capital, advises businesses and incubates companies in the energy access sector in sub-Saharan Africa. PEP also manages three funds with more than 40 investments in solar product, clean cook stove and LPG distribution businesses in 7 African countries. For more information, see www.persistentenergypartners.com.

Introduction

Energy services businesses serving off-grid households in emerging markets are beginning to scale rapidly and attract international attention. One strength of these businesses is that their model takes into account that energy access is not a binary variable ("has" vs. "does not have" access). Rather, various quantities and qualities of electricity can be supplied to these consumers at varying levels of affordability. Sustainable Energy for All's "Global Tracking Framework" introduced a model that more accurately describes these "Tiers" of electricity access. In this paper, we expand on this model by describing the financial characteristics of businesses that can electrify off-grid households at each Tier. We then describe the types of services that households gain access to at each Tier level. These services, not the energy itself per se, are what off-grid consumers want access to and are willing to pay for.

This paper, in conjunction with a forthcoming paper that provides a more in-depth look at distributed energy service companies (DESCOs), provides a picture of our understanding of this market and the businesses that we believe will expand to serve it at scale within the next decade. We have authored this paper to provide a practical discussion of energy access from the perspective of an investor and operator in the sub-Saharan energy access sector.

Overview

There is no universally agreed-upon definition of electricity access. Statistics are usually binary: households either have access or they don't. This is unsatisfactory because certain aspects of electricity access, such as quality, quantity and affordability, are not considered. Moreover, and perhaps more importantly, this binary perspective doesn't provide any information about the kinds of services customers can derive from such access.

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Access to electricity, or rather access to the services that electricity powers, can be provided at different levels. If we are to consider ways to eradicate energy poverty, we must take this into account.

Sustainable Energy for All's "Global Tracking Framework" introduced a matrix for measuring household access to electricity supply and electricity services. The matrix describes stratified Tiers of electricity access from Tier 0, which is equivalent to no access, to Tier 5, which is equivalent to around the clock, practically unlimited access (as is available in most of the developed world).

Figure 1. Matrix for measuring household access to electricity supply
Adapted from 'Global Tracking Framework' Annex 3

Dimension of Electricity Access	**Unit**	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**Tier 5** (i.e. USA)
Power (up to)	[W]	1W	50W	200W	2000W	Unlim.
Usage	[h / day]	4	4	8	16	24
Energy (less than)	[Wh / day]	4	200	1,600	32,000	32,000[1]

In this brief paper, we aim to build on this matrix, by adding 3 additional dimensions to it: 1) the typical capital expenditure required to provide each Tier, 2) the minimum revenue required to provide such Tier access in a commercially viable model, and 3) the typical appliances that can be powered at such level of access. Thereby we intend to inform and ultimately catalyze a faster and more sustainable provision of access to electricity services to the 1.3 billion people, or about 300 million households that have no access to basic electricity services such as electric lighting.

We suggest a model that connects the dimensions of different levels of electricity access. By 'dimensions of electricity access', we mean the interrelated characteristics of a specific electricity access level (e.g. Tier 2), including:

- **Power** available, in Watt peak [W]
- **Energy** capacity per day, in Watt hours [Wh]

[1] According to the EIA, the average consumption in the US is 11,000kWh per year, or 32kWh per day per household (utility customer).

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- Typical **capital expenditure** for the assets that could provide such energy and power[2]
- **Revenue** per household that would be required to pay for the cost of the energy asset in a commercial model within a targeted time frame
- And, the types of **energy services** that could be provided if such energy and power were available

Our model is based on an "energy services" business model, i.e., the user does not purchase the energy assets but instead purchases energy services generated from the asset.[3] Figure 2 below illustrates the output of this model.

Figure 2. Expanded matrix for household access to electricity supply, incl. (i) typical costs of energy assets required to provide such energy service, (ii) minimum revenue required to provide such services in a commercial model and (iii) appliances that can be powered with given energy supply.

Dimension of Electricity Access	Unit	**Tier 1**	**Tier 2**	**Tier 3**	**Tier 4**	**US** Average
Power (up to)	[W]	1W	50W	200W	2000 W	Unlim.
Usage	[h / day]	4	4	8	16	24
Energy (less than)	[Wh / day]	4	200	1,600	32,000	32,000
Energy Asset cost	US$	60	350	1400	8000	
Minimum Revenue	US$ / month	2	10	39	222	
Energy Services	Task Light	×	×	×	×	×
	Phone Charging	×	×	×	×	×
	Home lighting		×	×	×	×
	Radio		×	×	×	×
TV/Computer			×	×	×	×
Small productive appliance				×	×	×

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[2] We provide real examples of existing energy assets (technologies and products from solar lanterns to solar home systems to micro- and mini-grids) available today.

[3] Of course Tier 4 and 5 levels in developed regions of the world are utility-based systems where customers purchase electricity in kilowatt-hours. Energy assets for levels of power at Tiers 1-3 could be purchased by users or could be owned by a third party generator, with the services sold to the user on a pay-per-use basis. We are convinced that this energy services model in Tiers 1-3 is the sustainable, commercial pathway to energy access.

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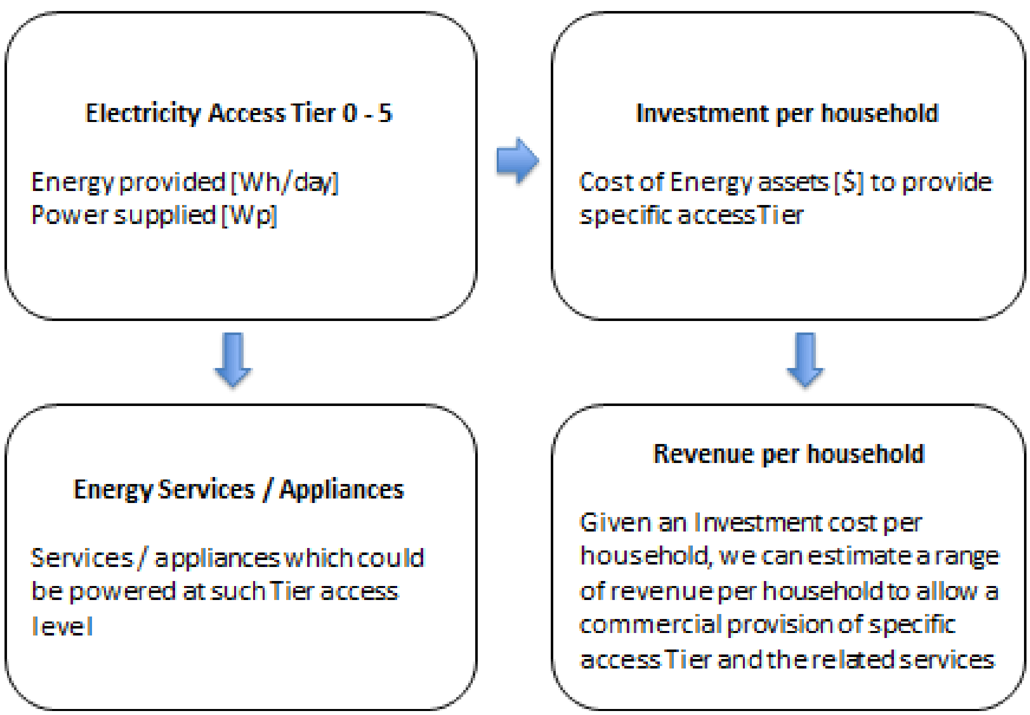
While we don't think the absolute results shown in the table above are the major benefit of this model (or point of this article), these results are realistic given our own experience analyzing and building energy access businesses in sub-Saharan Africa.

We see the major benefit of this model in the link it creates between the different dimensions of energy access: power, energy capacity, cost of energy assets/infrastructure, minimum revenue requirement (cost to end-user) and enabled energy services.

We hope that this model can inform the debate and facilitate the coordination between governments, development agencies, not-for-profits, commercial energy service companies, donors and investors.

Figure 3. The interconnected dimensions of electricity access: illustration of the structure of our approach to access to energy services



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Each Tier of electricity access requires a specific investment in energy assets. The targeted power and energy capacity *drive* the amount of the investment in energy assets that can provide such power and energy. Energy assets comprise all generation, storage, and distribution hardware necessary to provide such a level of access. Of course, the investment amount varies by technology and approach, but ultimately the cost will be closely correlated with the energy and power capacity provided. The level of access defines a range for the capital expenditure; our model provides an estimate of this relationship and outline how we arrived at these estimates.

Given the required capital expenditure per household on average, one can estimate the minimum revenue that is *required* per household in order for the business model to be profitable and therefore sustainable. The fundamental assumption here, and throughout our analysis, is that any potential solution to energy poverty needs to be commercially viable to attract the required capital and to be sustainable in the medium to longer term. We discuss our approach below.

The model also links each Tier to particular energy services that could be provided at that Tier level. The power and energy capacity of a given Tier ultimately *enables* specific energy services. This of course is based on assumptions about power requirements of specific appliances and expected hours of their operation. The model's value is not in the absolute, quantitative result, but in the fact that it makes the assumptions transparent and allows the analysis of different scenarios.

The connection between electricity service Tier and minimum average revenue per household

The energy and power capacity implied in each service level provides the basis for an estimate of the cost of an energy asset such as a solar home system, which can provide such capacity.

For example, assume the goal is to provide Tier 2 access. The energy provided by Tier 2 is up to 200Wh per day[4]. This capacity goal *drives* the size of the energy asset. Given an average direct sunshine amount of 4hrs per day, a 50W Solar PV panel with an appropriately sized battery could provide this amount of energy in most places in sub-Saharan Africa (4hrs/day x 50Wp = 200Wh/day).

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[4] For example, a customer with such Tier 2 access could consume 200Wh in a day by using 5x 10W light bulbs for 4hrs: 5x 10W x 4h = 200Wh.

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The cost of a 50Wp, high quality, certified solar home system (incl. battery and basic appliances)[5] is around $150 to $250 when purchased directly from a manufacturer in the country of origin. It has been our own experience that shipping, import, transportation, and installation add another $100-$200 per household. Accordingly, the total capital expenditure for a business providing such an energy asset would be in the $250 – $450 range (or $5 - $9 per Wp provided). This cost will of course vary by technology (PV, diesel generator, small wind, or hydro), but ultimately the cost will be *driven* by the targeted capacity. We have experience with both solar micro-grids and solar home systems in this range and have added sample systems in Annex 1 to this paper.

Any business providing energy services at this level of service to off-grid households would have to incur such capital expenditures. These capital expenditures would have to be recovered from customer payments. Note that energy service company models for these repayments vary – customers could pay rent (independent of use, perpetual)[6], pay-for-service (dependent on use, perpetual)[7] or lease-to-own (independent of use, defined overall payment)[8] – but the perspective of the business does not: revenues need to recover the capital investment. Given a target '*simple payback ratio*' (capital expenditure / revenue per month), one can calculate the minimum revenue per month a business would have to collect in order to sustain itself.

[5] For example BB17 Kit, http://www.bboxx.co.uk/product-category/solar-kits/

[6] For ehttp://www.bboxx.co.uk/product-category/solar-kits/xample Off-Grid:Electric: Customers pay rent for solar home systems they will never own.

[7] For example Persistent Energy Ghana: Customers pay per use of electricity provided from solar micro-grids, but never own the energy asset.

[8] For example M-Kopa/SolarNow/Mobisol: Customers pay for the system on a fixed schedule and own the system after 1-3 years.

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For example, given a capital expenditure per household of $350 and a target simple payback ratio of 36 (which can be taken to represent a 36-month or 3-year period before the cost of the initial capital expenditure has been recouped), the monthly minimum revenue any business providing energy as a service – pay-for-service or rental model – would have to collect per household is at least $10.

- Any business financing the sale of the asset ('lease-to-own' model) would have to charge a monthly rate higher than $10 even if the period over which the asset is financed is also 36 months long, because such a business would have to recover capital expenditure and generate profits over that timeframe.

- Any business that would simply sell the asset, would have to charge more than $350 of course, to recover cost and generate profit on top.

Of course, the simple payback ratio is only a rough gauge of the overall potential of a business model. It does not necessarily indicate the business' potential profitability, which is driven by {free cash flow} over {capital}, or {revenue less (i) cost of operations, (ii) asset replacement and maintenance cost (amortization), (iii) administrative overhead, and (iv) cost of capital} over {capital}.

This does not change the fact that a business with a smaller simple payback ratio has a higher potential to be profitable and therefore sustainable. We have analyzed many energy service companies in sub-Saharan Africa and we believe that in order to be profitable, a simple payback of more than three years is unrealistic. For a more detailed explanation, see below:

Why is it important for businesses operating in sub-Saharan Africa and aiming to attract millions of $s in investments (a majority of it in debt) to provide a short simple payback? How many years are realistic?

One could argue that a business should not assume a liability which is shorter in duration than the time period it would take the business to repay such liability from its {free cash flow}. The payback period – {free cash flow} / {capital} – of a

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business is therefore a good estimate for the duration of a liability that can be sustained by a business.

> For example: A business that needs $100 in capital and generates $10 in free cash flow from such capital each year, should seek to raise debt that is 10 years in duration, or more. If the liability would mature in 6 years, the business could only be sustained if it finds fresh capital to re-finance the $40 it has not been able to collect yet from its free cash flow.

Investors on the other hand prefer shorter maturities to longer maturities. Capital markets associate higher risk with longer dated maturities, which is typically expressed through a higher interest rate. Therefore, a business, which requires longer maturities because of a longer implied payback period, will have more difficulties finding investors to provide such debt.

We also know that investors in sub-Saharan African markets are unlikely to accept any maturity longer than 10 years by taking a look at the sovereign bond market. Sovereign (government) debt is typically considered the least risky debt in any market and its interest curve serves as the basis for corporate debt. Corporate debt in the same market is typically more expensive and of equal or shorter maturity than government debt[9]. And, according to Barclay's Africa Sovereign Index, not a single instrument in sub-Saharan Africa's $12bn market extends beyond 10 years from today.

Therefore, if the payback ratio is a good first estimate for the 'minimum' maturity of a debt instrument and if capital markets in Africa show that there is no appetite for debt extending beyond the 7-year mark (10yrs is the maximum), any business that aims to truly scale in this market, needs a faster payback period than 7 years.

The simple payback – {revenue}/ {capital} – is of course shorter than the payback period – {free cash flow} / {capital} – by about a factor of 2x, or more. The only reason we use the simple payback in this context is that it is readily available and can be calculated directly from two of the dimensions of energy access: **average revenue per user** and **average capital expenditure per user**.

[9] While we would not be surprised if this were different for sub-Saharan Africa, we still think it is at least worth to consider a limitation that should typically apply.

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In a larger context we use the simple payback ratio to compare different business models pursuing an energy service business model targeted at off-grid customers. It is one of the first steps we consider in our investment process.

The purpose of linking electricity access Tiers to minimum average revenue per user (ARPU)

There are several perspectives on this nexus between capital expenditures and minimum revenue required for a commercial and sustainable solution.

1. **Estimate the impact of a connection-based subsidy on affordability:** Once the relationship between capital spending and minimum average revenue per user is established, one can use the model to estimate the impact of a connection-based subsidy. Such subsidy would decrease the capital expenditure and accordingly the minimum revenue a business would have to collect per user. The model would establish a direct link between subsidy and affordability.

2. **Adapt appropriate tariff structures and regulations:** This analysis can inform the debate about what level of tariffs, or prices, energy service companies can charge their customers. The starting point is the fact that any business that does not properly manage the relationship between average investment and average revenue per user will not survive. It is interesting to look at the above example from that perspective and consider the implied tariff an energy service company would have to charge.
    - The energy asset costs $350 to install and the maximum simple payback is '36 months.'
        - The minimum average revenue per month is $10.
    - The energy asset can provide 200Wh per day, or 3kWh per month if used to its full potential.
        - The business would have to charge $3.30 per kWh to have a chance to be profitable.
        - This may be 10x more than on-grid customers pay for the same amount of electricity, but it is about the same that the off-grid customers currently spend to light their homes with kerosene lamps, candles and batteries. The service they are getting for the expense (200Wh per day, 30W for 6.5hrs), such as 4 LED lights,

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a radio, and mobile phone charging, is much better than light from a kerosene lantern.

1. **Identify scalable businesses:** The analysis could also be used to estimate the potential of a business model to reach scale. First, if the simple payback is too long, a business is unlikely to be able to attract the capital required to scale. Second, if the payback is reasonably short, the required minimum revenue indicates how many customers such a business model can actually sustainably reach. Clearly, a business model requiring monthly average revenue of $20 can only reach a small fraction of the 300mm off-grid households in sub-Saharan Africa, many of which live on less than $5 per day.

The connection between service Tier and enabled energy services

Customers ultimately do not want electricity as such; they want to run specific appliances and they want to enjoy the services that these appliances offer. In particular and approximately in order of priority, they want 1) the ability to charge their mobile phones, 2) clean and bright lights, and 3) entertainment and access to information (radio, TV, Internet). Beyond these basic personal energy services, there is of course demand to power appliances for productive use such as sewing machine, a grain mill, a water pump or a fridge.

It is informative to consider concrete examples of which energy services can be provided at which Tier levels.

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Figure 4. Services available at a given Tier level

Tier	Appliance providing energy service	Power need	Usage amount	Energy need appliance per day	Cumulative energy need per day^{+}	Example product
	Unit	*[Wp]*	*[hrs / day]*	*[Wh / day]*	*[Wh / day]*	
Tier 4 < 1,600Wh per day	Grain Mill	750	4	3000	3744	
Tier 3 < 800Wh per day	Water Pump	150	2	300	744	Sunpump SDS 128
	Fridge	150	2	300	444	Steca PF 166, no battery
TIER 2 < 200Wh per day	TV / Tablet Comp	12	6	72	144	MacBook pro (65Wh), iPad (34Wh)
	Lighting	10	6	60	72	Fosera Lamp 200 (1.6W)
	Phone	5	2	10	12	iPhone (10Wh)
	Task Light	0.5	4	2	2	d.light s1/s2

$^{+}$ The 'Cumulative energy / day' - column reflects the cumulative energy need if all appliances would be used in a given day. For example, running a task light, phone, lights and TV for the hours shown above would require a total of 144Wh. Adding a fridge would require a total of 444Wh and so on.

This table illustrates, among other things, that most basic energy services can already be provided within the boundaries of Tier 2, for less than 200Wh a day. In particular, it is interesting to note that 200Wh per day are sufficient to light a home and power an efficient computer such as a laptop or tablet PC. Such a device, if Internet were available, could provide entertainment, information and communication services for 5 hours per day without using more than 50-75Wh in total.

Tier 3 can power small productive appliances in addition to the basic appliances above; a small fridge (160L), a DC sewing machine, a DC grain mill or small water-pump (120 gallons/hour) each use between 200 and 400Wh per day and Tier 3 ranges from 200Wh to 800Wh in energy capacity.

Tier 4 already provides sufficient power for extended productive use.

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Conclusion

The different dimensions of energy access – *power, energy, capital expenditure, minimum revenue and enabled services* – should always be considered simultaneously. And, these dimensions should be put into the context of the needs of the customers, the customers' ability to pay, the providers' business model, and the availability of commercial capital, which is ultimately required to reach true scale.

Additional comments

Our work in plotting the dimensions of energy access has led us to some additional conclusions. These present the basic principles for our investing and advising in the energy access sector.

It should take less capital than prevailing estimates to provide the majority of the estimated 300mm households globally with access to meaningful energy services. The energy amount of 200Wh per day is sufficient to light a home, charge a mobile phone and power an efficient PC. The cost of installing the infrastructure that can provide such energy services is less than $450[10]. To reach 300mm households with Tier 2 electricity access should therefore require a capital investment of less than $135bn, or 9bn per year over the next 15 years. This compares to IEA estimates of $48bn per year and IIASA estimates of $15bn per year[11] to achieve universal access by 2030.

Most of the capital needed could come from commercial investors provided that government regulation is conducive to private energy services companies. In the world of public utility tariff regulation—even in developing countries – $3.30 a kWh would be a shocking rate for grid-connected electricity. Yet it should be clear that conventional tariff rate structures will not attract the capital necessary to meet the challenge of energy access. This requires a rethinking on several levels: from tariffs per kWh to costs per service level; from centralized grid infrastructure to customized distributed energy assets; from monopolistic energy

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[10] Note that $450 is the upper end of the Tier 2 capital expenditure range estimate.

[11] Neither the IEA nor IIASA estimate the cost of TIER 2 access in particular.

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markets that require extensive regulation to markets shaped by competition (yet regulated for public welfare) – which require light-handed regulation.[12]

This market represents a unique opportunity for businesses. Many households pay more than $10 per month alone to charge their phones and light their homes with kerosene. An energy asset such as a solar home system or solar micro-grid, which costs $250-$450 per household, can provide a far superior service. Such a system can light a home with electric light, charge phones and power a TV, for example. If a business can place such energy assets with these households and collect the amounts the household previously paid for kerosene effectively and efficiently, it can run sustainably and provide commercial returns to investors.

A new "energy services" sector is emerging. While this opportunity has existed for some time, only the proliferation of the wireless communication networks (mobile phone and data networks) enables the efficient and effective collection of payments for services from distributed energy assets (solar home systems and micro-grids). The falling prices for solar PV equipment and high efficiency DC appliances have further increased the potential of the business model. The leading energy service companies (M-Kopa[13], Off-Grid:Electric) are approaching a scale of 50,000 customers, a point at which they may become profitable. Venture capital (Koshla Ventures[14], Vulcan[15]) and strategic capital (SolarCity[16]) are flowing into the sector and by 2015 an increasing amount of capital should be raised in the form of debt.

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12 Tanzania has already done so by exempting VSPPs (Very Small Power Producers) from tariff regulation. VSPPs are power producers with an installed capacity of 100 kW or less. THE ELECTRICITY ACT (CAP 131), THE ELECTRICITY (DEVELOPMENT OF SMALL POWER PROJECTS) RULES, 2013.

13 http://www.gsma.com/mobilefordevelopment/m-kopa-solars-new-funding-a-landmark-for-off-grid-energy-service-companies

14 http://www.ft.com/intl/cms/s/0/e49fc980-68a2-11e3-996a-00144feabdc0.html#axzz2yWIGcEZq

15 http://www.ventures-africa.com/2014/03/africas-off-grid-solar-market-attracts-another-7m-investment/

16 http://venturebeat.com/2014/03/21/off-grid-electric-gets-7m-to-light-africa-in-a-decade-exclusive/

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Annex 1: Concrete examples for system providing specific TIER level access. Note that we include solar home systems as well as micro-grids and that the different solutions to provide energy access overlap in TIER 2 and TIER 3. We view the technologies as complementary, each with its particular advantages and disadvantages, and believe that the most successful energy services companies will not be defined by using any particular technology (i.e., the market will not be driven by any particular technology).

Access Level		Power [W]	Usage [h / day]	Energy [Wh / day]	Example Products					
					Systems / Kits			Micro-grids		
Tier 1	Less than	1W	4	4	d.light S2, www.dlightdesign.com/productline/s2/	Barefoot Firefly, www.barefootpower.com/index.php/products/item/2-firefly-mini	Greenlight Planet ECo, www.reenlightplanet.com/our-products/eco			
Tier 2	Less than	50W	4	200	M-Kopa d.light d20g, www.m-kopa.com/products/	BB17 Kit, www.bboxx.co.uk/product-category/solar-kits/	Mobisol 20 - 200W, www.pluginttheworld.com/mobisol/product/	Devergy/PEG Micro-grid, www.devergy.com	Mera Gao Power, Microgrid, www.meragaopower.com	
Tier 3	Less than	200W	8	1,600	Mobisol, www.plugintheworld.com	Solar Now, 50W - 100W system, www.solarnow.eu		Devergy/PEG Micro-grid, www.devergy.com	Powerhive, Microgrid, www.powerhive.com/technology/	Inensus, Microgrid, www.inensus.de/en/home0.htm
Tier 4	Less than	2000W	16	32,000				Powerhive, Microgrid, www.powerhive.com/technology/	Inensus, Microgrid, www.inensus.de/en/home0.htm	

Source: Persistent Energy Partners

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