STATE OF THE MINI GRID MARKET GLOBALLY

Mini Grids for Half a Billion People

WORLD BANK GROUP
Energy & Extractives

5th Mini Grid Action Learning Event and Summit

Global Technical Conference on Mini Grids

James Knuckles

June 26, 2019

Table of Contents

Join the conversation on Twitter: @WBG_Energy @jamesknuckles #EndEnergyPoverty

WORLD BANK GROUP
Energy & Extractives

Global Summary of Installed and Planned Mini Grids

Totals calculated	Number of mini grids	Number of connections (Millions)	Number of people (Millions)	Number of developers identified	Median capital cost (US $/kW)	Total capacity (MW)	Total investment (Mil. US $)
Global totals: installed	19,163	10.0	46.9	5,690	4,410	6,481	28,302
Global totals: planned	7,507	8.1	39.1	323	4,444	2,646	12,365
Grand total	**26,670**	**18.1**	**86.1**	**6,013**	**4,420**	**9,126**	**40,667**

Sources: ESMAP research and analysis; Navigant Research; Bloomberg New Energy Finance (BNEF); World Bank surveys; Infinergia; Club-ER. See Annex slides for a full list of sources and detailed methodology.

Notes:
(1) Data from 138 countries and territories.
(2) Data likely underestimate the total number of mini grids globally due to the large number of small-scale diesel and hydro powered mini grids for which no data exists (yet), particularly in Asia, the Middle East, and North Africa.

2

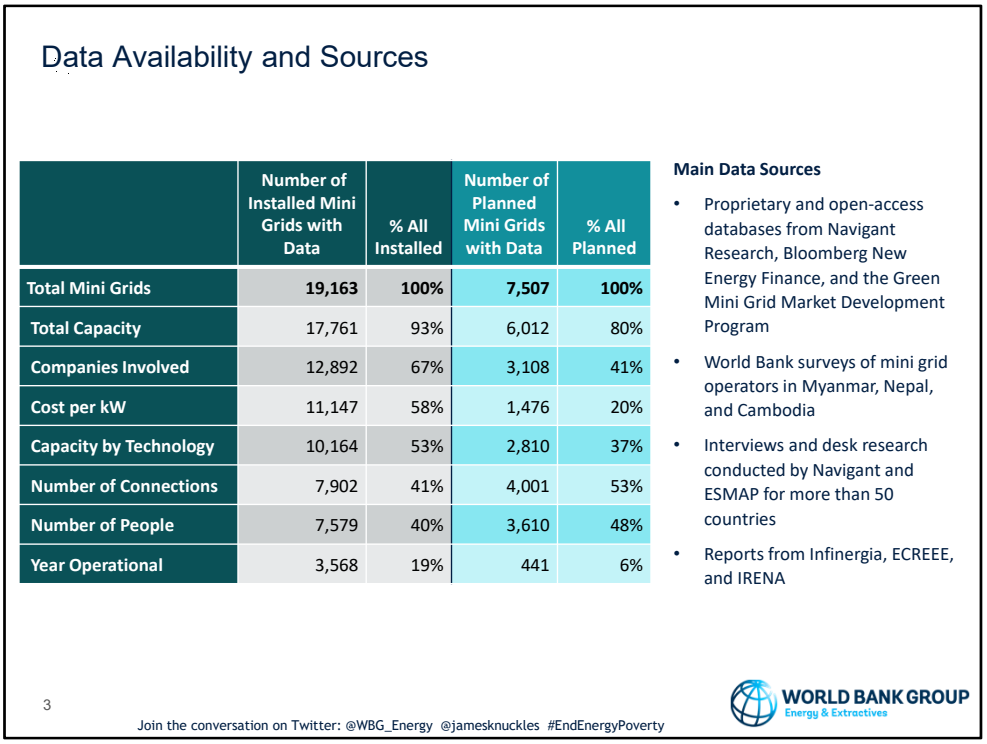
Join the conversation on Twitter: @WBG_Energy @jamesknuckles #EndEnergyPoverty

WORLD BANK GROUP
Energy & Extractives

ESMAP conducted a global survey of mini grid projects, and has developed a database of over 19,000 mini grids in 134 countries and territories, serving almost 47 million people. Another 7,500 mini grids are planned for development in 57 countries and territories. The mini grids in this database are individual line-items -- that is, our database consists of over 26,000 line items.

- In our database, we identified over 6,000 developers, organizations, and companies that have built, or are planning to build, mini grids
- The installed and planned mini grids have a combined power capacity of over 9 gigawatts (GW)
- The mini grid market currently represents US$28 billion of investment, with an additional US$12 billion investment expected for mini grids currently being planned.

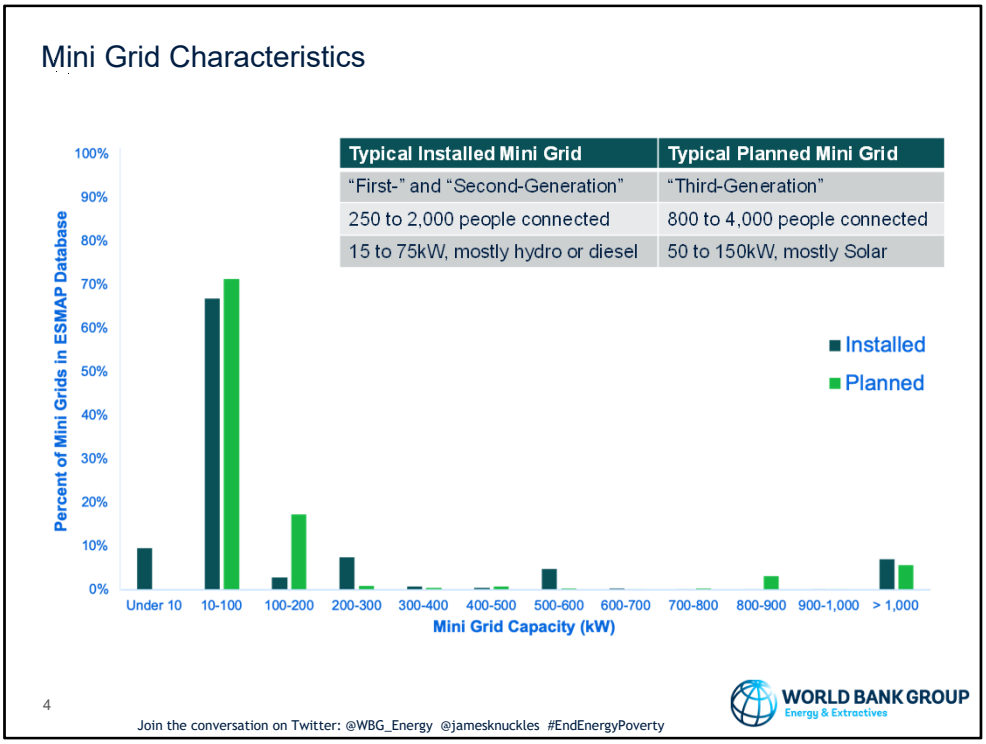
Installed mini grids are those that we know to have been built. We did not count mini grids that we knew to be not operational, but it was impossible to determine the operating status of all 19,000 installed mini grids. Planned mini grids are those for which project-specific data was available, or for which funding had already been allocated.



Just a quick note on our data sources and the availability of data. The first thing to note is that, to our knowledge, this is the first attempt to count and characterize mini grids on a global scale. We intend to do a similar global survey on an annual or biannual basis. To that end, we welcome your inputs and collaboration to help us refine and expand our database.

On our data sources, we leveraged proprietary databases from Navigant Research and Bloomberg New Energy Finance, and an open-source database from the Green Mini Grid Market Development Program. We also used data from nationally representative World Bank surveys of mini grid operators in Cambodia, Myanmar, and Nepal. With Navigant Research, we also conducted interviews and extensive desk research for more than 50 countries.

In our database of mini grid projects, we have better data availability on installed mini grids than planned mini grids. For the installed mini grids, we had more robust data for total capacity and companies involved. For planned mini grids, we had good data on total capacity. Data for the remaining metrics for installed and planned mini grids was available for half or fewer of the projects.

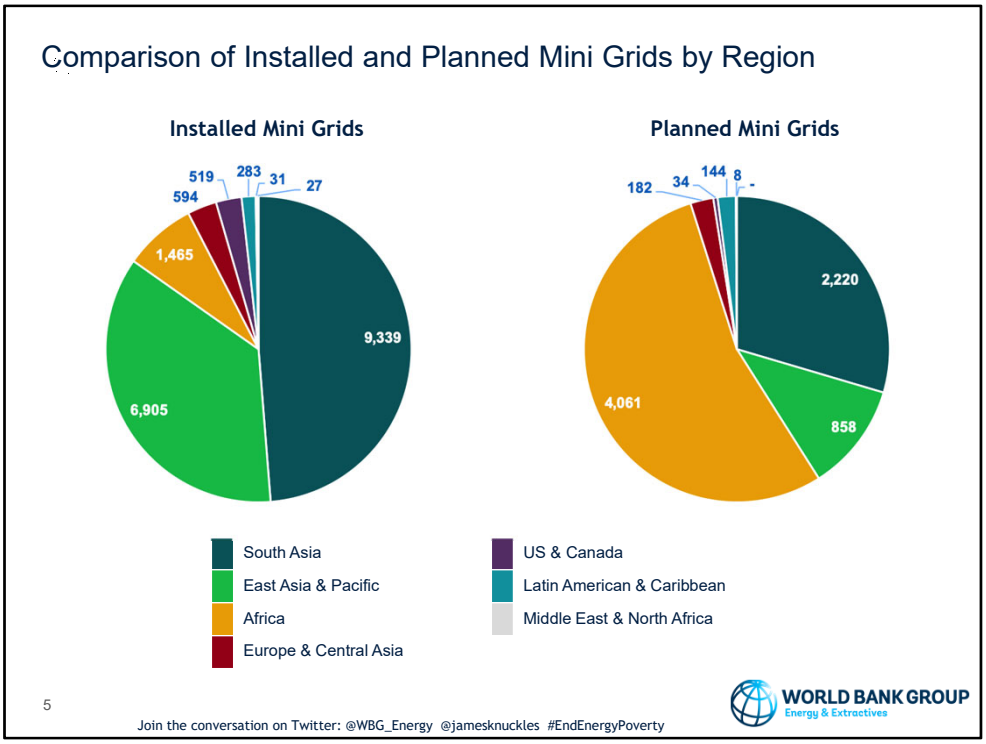


To count as a mini grid for our database, the system had to serve multiple customers. Nearly all mini grids in our database were isolated from the main grid. Those few that were grid-connected had the ability to isolate themselves from the main grid.

We did not set strict bounds on mini grid size, but most mini grids in our database are between 10 and 100kW in size, but there is a long tail that contains hundreds of mini grids that are 500kw or larger.

We see a significant difference between mini grids that are currently installed (the dark green bars), and mini grids that are being planned for development (the light green bars). Installed mini grids in developing countries tend to be what we call first- or second-generation mini grids: they are mostly small diesel and hydro-powered systems serving between 200 and 2000 people. The diesel systems tend to provide only intermittent power.

Planned mini grids, on the other hand, tend to be larger, and serve more people. They are mostly solar or solar-hybrid.



Again comparing installed and planned mini grids, the headline here is that Asia has the most mini grids installed, but Africa has the largest share of planned mini grids.

Our database indicates that Asia—including South Asia, East Asia, and the Pacific—has a combined total of more than 16,000 installed mini grids, representing 85 percent of the global total. The majority of the installed mini grids in Asia are in just three countries: Afghanistan with almost 5,000 mini grids, Myanmar with almost 4,000, and India with almost 3,000 mini grids.

Our data show, however, that most planned mini grids are in Africa, where more than 4,000 are currently being planned. The two biggest markets for planned mini grids in Africa are Senegal and Nigeria. These two countries alone account for about 2,000 of the 4,000 planned mini grids in Africa.

Regional Summary of Installed Mini Grids

Region	Number of mini grids	Number of connections (millions)	Number of people (millions)	Number of developers identified	Median capital cost ($/kW)	Total capacity (MW)	Total investment (million $)
South Asia	9,339	2.9	16.2	537	1,850	298	632
East Asia and Pacific	6,905	2.9	12.1	4,158	4,379	1,721	8,236
Africa	1,465	3.0	14.9	479	6,668	783	3,966
Europe and Central Asia	594	0.1	0.3	56	5,015	1,007	5,050
United States and Canada	519	0.2	0.6	246	3,973	2,152	8,551
Latin America and Caribbean	283	0.7	2.7	188	3,800	456	1,632
Middle East and North Africa	31	0.1	0.1	17	3,387	32	110
Other Island Territories	27	> 0.1	> 0.1	9	3,986	31	125
Global total	**19,163**	**10.1**	**46.9**	**5,690**	**4,410**	**6,481**	**28,302**

Note: Data remain scarce for the Europe and Central Asia, Latin America and Caribbean, and Middle East and North Africa regions, where there are likely to be significantly more mini grids than what is captured in the table above.

6

Join the conversation on Twitter: @WBG_Energy @jamesknuckles #EndEnergyPoverty

WORLD BANK GROUP
Energy & Extractives

- Just focusing here on the installed mini grids by region, we see the most mini grids in South Asia followed by East Asia and the Pacific. It is important to note here that data were scarce for regions where there are likely to be more mini grids than we identified, including Latin America and the Caribbean, Europe and Central Asia, and the Middle East and North Africa.
- Mini grids in Asia provide electricity to more than 28 million people. Mini grids in Africa provide electricity to an additional 15 million people.
- The United States and Canada, and Europe and Central Asia account for about half of all installed mini grid capacity despite having only 6 percent of all installed mini grids globally. This is because mini grids in these regions tend to be much larger than mini grids in Asia and Africa.
- In addition, due in part to the large sizes of mini grids in the US and Canada, and Europe and Central Asia, these regions also had the largest total investment in mini grids.

Top Ten Lists for Installed Mini Grids

Rank	Number of mini grids	Millions of people (% population)
1	Afghanistan: 4,980	Afghanistan: 7.5 (21%)
2	Myanmar: 3,988	Philippines: 7.3 (7%)
3	India: 2,800	India: 6.2 (<1%)
4	Nepal: 1,519	Madagascar: 3.6 (14%)
5	China: 1,184	Tanzania: 3.0 (5%)
6	Philippines: 896	DRC: 2.6 (3%)
7	Indonesia: 583	Nepal: 1.7 (6%)
8	Russia: 501	Myanmar: 1.4 (3%)
9	United States: 391	Peru: 0.9 (3%)
10	Senegal: 272	China: 0.8 (<1%)
Total (% global)	**17,114 (89%)**	**35.0 (75%)**

7

Join the conversation on Twitter: @WBG_Energy @jamesknuckles #EndEnergyPoverty

WORLD BANK GROUP
Energy & Extractives

- It can be interesting to look at some “top 10” lists for various mini grid indicators.
- Five countries in our database have more than 1,000 installed mini grids: Afghanistan, Myanmar, India, Nepal, and China. Afghanistan has the most mini grids of any country in the database, with almost 5,000 installed mini grids.
- In Afghanistan, the typical mini grid is 11kW, serving 152 connections. In Myanmar, the typical mini grid is 15kW, serving 79 connections. In India, the typical mini grid has an installed capacity of 32kW and serves 123 connections.
- The top ten countries in terms of people connected to mini grids account for 75% of all people connected to mini grids globally. Mini grids provide electricity to 21 percent of Afghanistan’s population; in Mozambique, mini grids serve 14% of the population.

Top Ten Lists for Installed Mini Grids

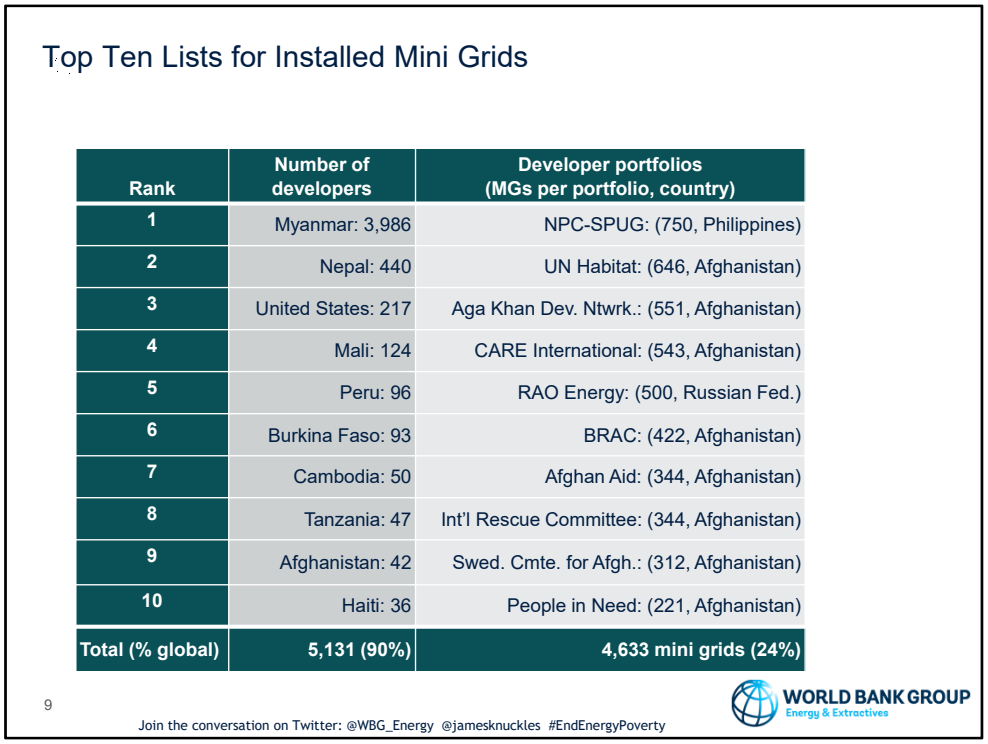
Rank	Median Capex (US$/kW)	Total capacity (MW)	Total investment (million US$)
1	Mexico: $1,456	United States: 1,594	United States: $6,332
2	Chile: $1,667	Russia: 671	Russia: $3,364
3	Afghanistan: $1,850	Canada: 558	Canada: $2,219
4	Kenya: $2,102	China: 472	China: $2,068
5	DRC: $2,320	Philippines: 397	Philippines: $2,035
6	Uganda: $2,435	Australia: 287	Madagascar: $1,167
7	Tanzania: $2,680	Japan: 219	Australia: $1,092
8	Myanmar: $2,707	Madagascar: 175	South Korea: $1,072
9	Cambodia: $2,986	Tanzania: 158	Japan: $958
10	Indonesia: $3,000	India: 138	Spain: $487
Total (% global)	**n.a.**	**4,668 (72%)**	**$20,794 (73%)**

8

Join the conversation on Twitter: @WBG_Energy @jamesknuckles #EndEnergyPoverty

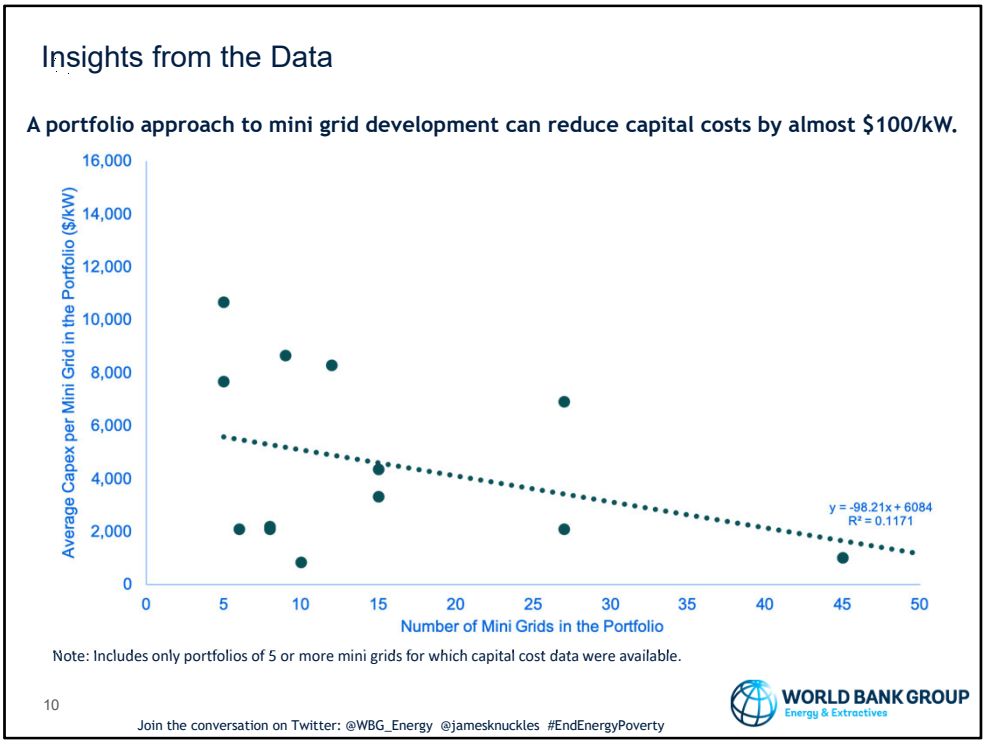
WORLD BANK GROUP
Energy & Extractives

- Mexico had the lowest **capital cost** mini grids of any other country, with US$1,456/kW. Nine other countries have capital costs at or below US$3,000/kW. The cost data from Mexico come from 40 solar-plus-storage mini grids built in remote communities as part of the World Bank's Integrated Energy Services Project.
- The United States has the highest **total capacity** of installed mini grids. There are almost 400 mini grids in the US, and each mini grid tends to have a relatively large capacity compared with mini grids in other countries. Nearly all of **Russia's** mini grid capacity is from 500 diesel-powered mini grids in remote areas operated by a regional utility company, RAO Energy. TANESCO in **Tanzania** operates a large number of relatively large mini grids, which is what puts Tanzania in the top 10 here.
- The US, Russia, Canada, and China are the four largest **markets** in terms of investment in installed mini grids, with a combined investment of US$14 billion. This is half of the global total.



Most of the **developers** we identified are in Myanmar and Nepal, with 3,986 and 440 developers, respectively. This reflects the large number of mini grids in these countries built by individual entrepreneurs as one-off projects.

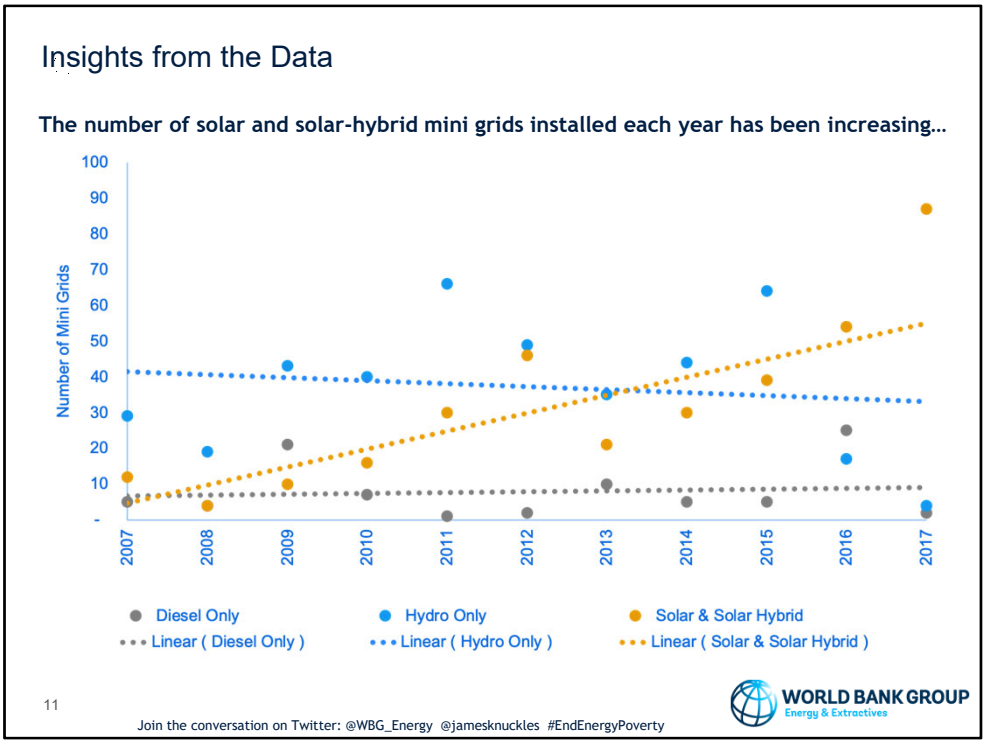
Meanwhile, the **Philippines** and **Afghanistan** are home to the largest **portfolios** of mini grids. In fact, 8 of the 10 largest mini grid portfolios are in Afghanistan – these are mostly portfolios of very small-scale solar-powered mini grids developed by NGOs. The largest developer, the National Power Corporation's Small Power Utility Group (NPC-SPUG), is the national utility in the Philippines. The other utility in the top ten list for portfolios is Russia's RAO Energy.



When we started to analyze the data, a few trends emerged.

First, the data support the hypothesis that building portfolios of mini grids leads to economies of scale. In this graph, the dots represent portfolios of 5 or more installed mini grids for which data are available on both the average capital cost for the portfolio's mini grids and the number of mini grids in the portfolio.

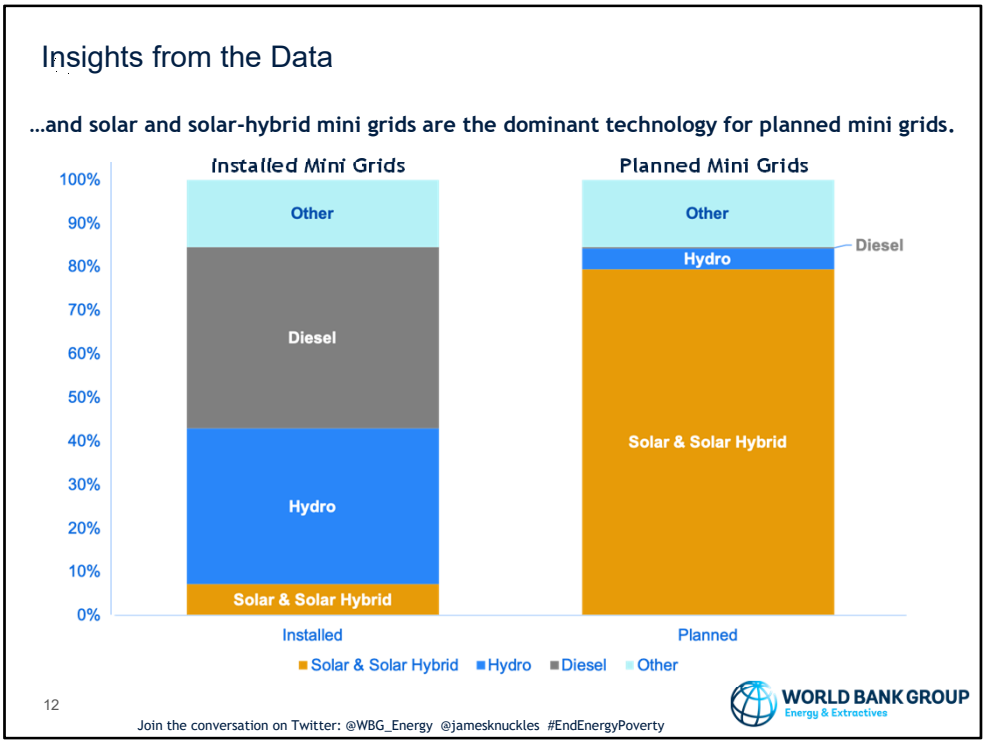
The trendline would suggest that building portfolios of mini grids leads to economies of scale that reduce mini grid capital costs by around US$100/kW for every additional mini grid added to the portfolio, although there are many other factors that impact capital costs.



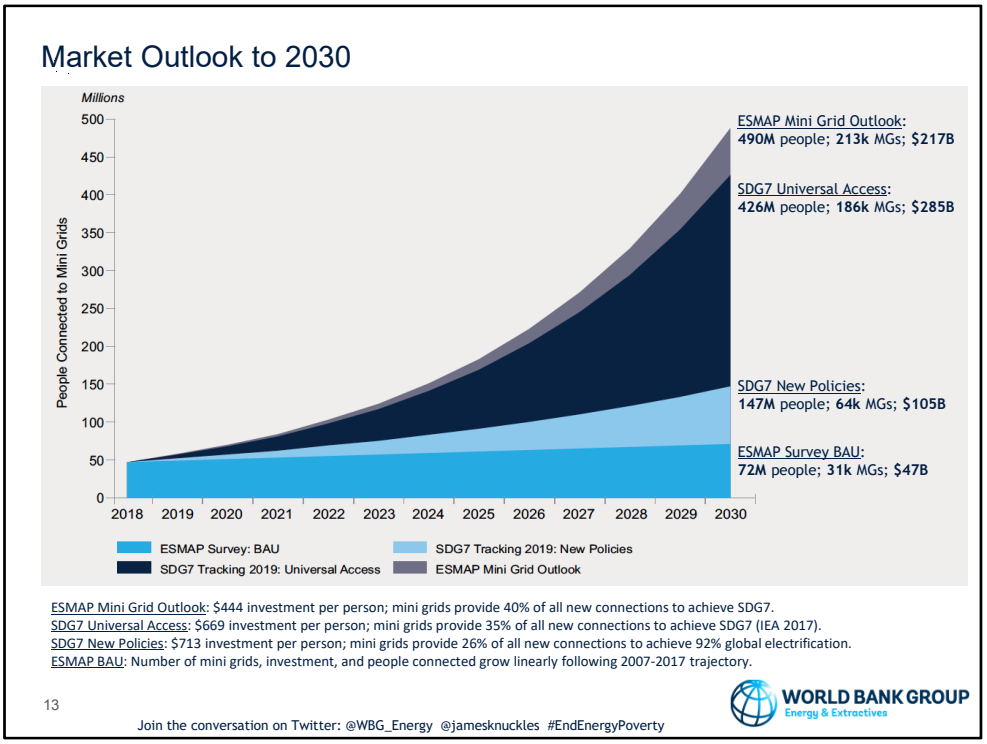
From a technology perspective, twice as many mini grids built between 2012 and 2017 incorporated solar PV than mini grids built between 2007 and 2012.

Over the same periods of time, new development of diesel-based mini grids remained about the same, while new development of hydro-powered mini grids slowly declined.

The steady rise of solar reflects the decline in component costs for solar and solar hybrid mini grids, most notably solar panels and batteries, which has incentivized developers to include solar PV in their generation mix.



Finally, more than 80 percent of planned mini grids will use solar PV, while about half of existing mini grids run only on diesel generators. Other capacity in this chart includes primarily wind and biomass.

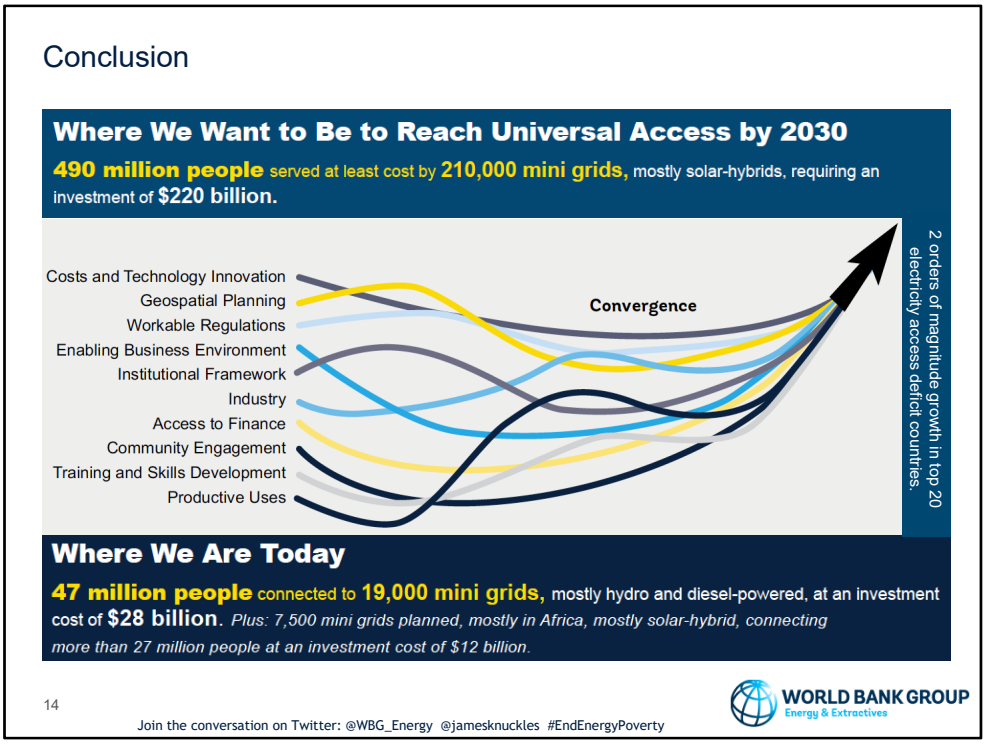


When we look ahead to 2030, we see mini grids as a core solution for reaching universal access to electricity. ESMAP estimates that achieving universal access by 2030 will require the construction of more than 210,000 mini grids, connecting 490 million people at an investment cost of almost $220 billion dollars. This is the grey area at the top of the graph.

For this scenario, we used the World Bank's latest estimate that reaching universal access will require 1.2 billion people being connected between now and 2030. Due to cost declines for solar and solar hybrid mini grids, the ESMAP scenario has mini grids as the least cost option for **40 percent** of all new connections.

The SDG7 Universal Access scenario – which is the large dark area in the graph – uses the IEA's estimate that **35 percent** of all new connections will come from mini grids. The difference is that the IEA's estimate uses a higher per-customer cost than what we see in our database of planned mini grid projects.

ESMAP's business-as-usual scenario – the blue area at the bottom of the graph – assumes that the current pace of mini grid development continues unchanged. This scenario would see just over 31,000 mini grids serving 72 million people, at a total investment cost of $47 billion by 2030.



So, how do we get from where we are today – which is 47 million people connected to 19,000 mini grids – to where we want to be to reach universal access by 2030, which is 490 million people connected to 210,000 mini grids?

To be clear, this would represent a 2-orders of magnitude increase in the number of mini grids deployed in each of the 20 countries with the highest electricity access deficit per year – from 10 mini grids per country per year today to 500 per year by 2025 to 1,500 per country per year by 2030.

Achieving this scale will require 10 building blocks to be in place in each country in order to achieve this 2-orders of magnitude increase. These building blocks are: (i) solar-hybrid technology and costing, (ii) geospatial portfolio planning, (iii) income-generating uses of electricity, (iv) community engagement, (v) local and international industry, (vi) access to finance, (vii) training and skills building, (viii) institutional framework, (ix) workable regulations, and (x) enabling business environments.

Thank you, and I will be happy to take your questions.

Annex

WORLD BANK GROUP
Energy & Extractives

Data Sources

The ESMAP mini grid database consists of projects and project data from many sources. The main sources that provided data for mini grids in multiple countries are as follows:

- **Interviews and desk research** conducted by Navigant and ESMAP for more than 50 countries
- **Navigant Research proprietary database** of renewable energy microgrid projects globally;
- **Bloomberg New Energy Finance proprietary database** of renewable energy microgrid projects globally with a capacity greater than 100 kW;
- **A proprietary research report by Infinergia** published in 2018 entitled Mini-grid for Village Electrification: Industry and African & Asian Markets;
- **A 2016 survey report of mini grids in West Africa by ECREEE** (ECOWAS Centre for Renewable Energy and Energy Efficiency) entitled Mapping & Assessment of Existing Clean Energy Mini-Grid Experiences in West Africa, available online: http://www.ecreee.org/sites/default/files/mapping_and_assessment_of_existing_clean_energy_mini-grid_experiences_in_west_africa_ecreee.pdf;
- **An open-access database of around 2,000 mini grid projects from CLUB-ER** (African Association for Rural Electrification), available online: http://club-er.org/library/techno-economic-databases-324.html;
- **A 2015 report from IRENA** (International Renewable Energy Agency) entitled Off-Grid Renewable Energy Systems: Status and Methodological Issues, available online: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2015/IRENA_Off-grid_Renewable_Systems_WP_2015.pdf;
- **World Bank surveys of mini grid operators** in Myanmar, Nepal, and Cambodia;

Methods

Modeling to Fill Data Gaps

In general, median values were used instead of averages to avoid skewing effects of very large or very small mini grids. When carrying out the modeling, the following four-step cascading process was applied:

1. Whenever possible, and particularly for countries with relatively few projects, real-time desk research was conducted to try to find missing data, particularly on costs and number of connections or people.
2. If information specific to that mini grid could not be found, median values from other mini grids in the same country were used to minimize the impact of variations across countries, so long as a sufficient number of projects in that country had data for that metric.
3. In the absence of a sufficient number of data points for other mini grids in that same country, median values for mini grids in the same region were used.
4. In the rare case where no data existed at the regional level, median values at the global level were used.

Indicator	Formula for Estimation	Rationale
Number of mini grids	None—all data are from known projects and/or country totals from reputable sources	This approach resulted in a high degree of confidence that at least "X" number of installed and planned mini grids exist in the world today.
Number of connections	Median capacity per connection of other projects in that country or at the regional level, times total capacity	Using this formula instead of median capacity per mini grid x number of mini grids results in estimations less likely to be skewed by large single mini grids with many customers.
Number of people	Number of connections, times average household size for that country	While imperfect because it does not capture people at certain connections like schools or community centers, this method is both efficient and tailored to each country's household demographics.
Median capital cost	Based on available data for total project cost/total capacity or existing cost-per-capacity data	Cost data are not readily available for most projects, so whatever cost data were available, either total upfront project cost or cost per capacity, were collected.

Mini Grid Characteristics

Totals calculated	Mini grids per portfolio	People per mini grid	Connections per mini grid	Capacity per connection (watts)	Capacity per mini grid (kW)
Global totals: installed (excluding Afghanistan)					
Median	4	539	117	223	50
Average	16	2,034	490	1,656	1,349
Number of Observations (N)	146 portfolios	2,836 MGs	3,159 MGs	3,113 MGs	13,845 MGs
Global totals: planned					
Median	32	1,000	200	150	30
Average	122	1,966	403	567	565
N	22	3,611	4,002	3,091	6,013
Grand total					
Median	5	1,000	174	135	23
Average	48	1,472	285	629	613
N	202	11,190	11,904	9,908	23,774

19

WORLD BANK GROUP
Energy & Extractives

In Afghanistan, the median mini grid size is 11kW of installed capacity, serving 152 connections.

Top Ten Lists for Planned Mini Grids

Rank	Number of mini grids	Millions of people (% population)
1	India: 1,905	Philippines: 11.6 (11%)
2	Senegal: 1,217	India: 7.8 (<1%)
3	Nigeria: 879	Angola: 5.0 (17%)
4	Indonesia: 506	D. R. Congo: 3.1 (4%
5	Tanzania: 301	Nigeria: 2.0 (1%)
6	Rwanda: 236	Tanzania: 1.5 (3%)
7	Kenya: 228	Indonesia: 1.3 (<1%)
8	Bangladesh: 215	Cameroon: 1.3 (5%)
9	Mali: 184	Senegal: 0.8 (6%)
10	Russia: 180	Mauritania: 0.6 (14%)
Total (% global)	**5,636 (75%)**	**35,065,716 (90%)**

WORLD BANK GROUP
Energy & Extractives

Top Ten Lists for Planned Mini Grids

Rank	Median Capex (US$/kW)	Total capacity (MW)	Total investment (million US$)
1	Kenya: $2,320	Philippines: 641	Philippines: $3,554
2	Russia: $2,397	Tanzania: 457	Tanzania: $1,982
3	United States: $3,696	Angola: 299	Angola: $1,296
4	Mali: $4,116	India: 174	India: $821
5	Malawi: $4,279	Russia: 147	D. R. Congo: $613
6	Nigeria: $4,400	D. R. Congo: 141	Nigeria: $492
7	Argentina: $4,444	Nigeria: 112	Russia: $353
8	Bangladesh: $4,725	Cameroon: 64	Australia: $326
9	Australia: $5,543	Australia: 59	Cameroon: $275
10	Niger: $8,357	Rwanda: 53	Rwanda: $231
Total (% global)	**n.a.**	**2,146 (81%)**	**$9,943 (80%)**

WORLD BANK GROUP
Energy & Extractives

Top Ten Lists for Planned Mini Grids

Rank	Number of developers	Developer portfolios (MGs per portfolio, country)
1	Myanmar: 171	OMC: (996, India)
2	Burkina Faso: 18	PLN: (500, Indonesia)
3	Bangladesh: 15	Tiger Power: (500, India)
4	Haiti: 10	RAO Energy: (178, Russia)
5	Tanzania: 9	Husk Power Systems: (175, India)
6	India, US, Indon.: 7	AT2ER: (108, Togo)
7	Madagascar: 6	Eskom: (100, South Africa)
8	Cameroon: 5	Henri Frasier Fils & Cie: (100, Madagascar)
9	Austral., Maurita., Niger: 4	Powerhive: (100, Kenya)
10	Malawi: 3	Freyr Energy: (50, India)
Total (% global)	**270 (84%)**	**2,807 mini grids (37% of all planned MGs)**

WORLD BANK GROUP
Energy & Extractives