

Botswana

National Electrification Rate [1]

- National: 65%
 - Urban: 81%
 - Rural: 28%
-

Population

- Total: 2.4 million [2]
- Urban ratio: 70.9% [2]

Population growth

- Medium population growth: 1.5% [2]
-

Average household size, urban: 1.7 people [3]

Average household size, rural: 2.1 people [3]

Average electricity consumption per

- Household: 1235 kWh/year
- Capita: 650 kWh/year (Tier 4) [1], [4]

Low demand target³: U4-R1

High demand target: U5-R3

Off-grid technology cost [5]–[12]:

- Expected Hydro mini-grid cost: ~3000 \$/kWp
 - Expected hybrid mini-grid component costs:
 - o PV panels: 503 \$/kWp
 - o Batteries: 139 \$/kWh
 - o Inverter: 80 \$/kWp
 - o Charge controller: 142 \$/kW
 - o Diesel generator: 261 \$/kW
 - o Wind turbine: 2800 \$/kW
 - Expected PV stand-alone (or SHS) costs:
 - o ~9620 \$/kWp if kW < 0.02
 - o ~8780 \$/kWp if 0.02 < kW < 0.05
 - o ~6380 \$/kWp if 0.05 < kW < 0.1
 - o ~4470 \$/kWp if 0.1 < kW < 1
 - o ~6950 \$/kWp if kW > 1
-

Grid generating cost [13]–[15]

- Expected on-grid cost (low): 0.038 \$/kWh
- Expected on-grid cost (high): 0.051 \$/kWh

T&D costs [16], [17] [18], [19] [8], [20]–[25]:

- HV line (69-132 kV): ~53000 \$/km
- MV line (11-33 kV): ~7000 \$/km
- LV line (0.2 – 0.4 kV): ~4250 \$/km
- HV to MV substation (1000 kVA): ~25000 \$/unit
- MV to V substation (400 kVA): ~10000 \$/unit
- Service transformer (50 kVA): ~4250 \$/unit

Grid generation capacity cap per year: ~105 MW/year

Grid connection limit: ~2.5% population/year

³ U: Urban households; R: Rural households; 1-5: Electrification Tiers as defined by ESMAP's Multitier framework

References

- [1] The International Energy Agency (IEA), "Energy access database." 2017.
 - [2] United Nations | DESA Population Division, "World Population Prospects - Population Division - United Nations." <https://esa.un.org/unpd/wpp/> (accessed Jan. 18, 2019).
 - [3] D. Mentis et al., "Lighting the World: the first application of an open source, spatial electrification tool (OnSSET) on Sub-Saharan Africa," *Environ. Res. Lett.*, vol. 12, no. 8, 2017.
 - [4] IEA, "World Energy Balances." [Online]. Available: <https://www.iea.org/statistics/balances/>. [Accessed: 3-May-2019].
 - [5] International Renewable Energy Agency, "Renewable Power Generation Costs in 2017," IRENA, Abu Dhabi, UAE, 2018. doi: ISBN: 978-92-9260-040-2.
 - [6] IRENA, *Innovation Outlook: Renewable Mini-Grids*. 2016.
 - [7] IRENA, "Solar PV in Africa: Costs and Markets," 2016.
 - [8] A. Korkovelos et al., "The Role of Open Access Data in Geospatial Electrification Planning and the Achievement of SDG7. An OnSSET-Based Case Study for Malawi," *Energies*, vol. 12, no. 7, p. 1395, Apr. 2019, doi: 10.3390/en12071395.
 - [9] A. Korkovelos et al., "A Geospatial Assessment of Small-Scale Hydropower Potential in Sub-Saharan Africa," *Energies*, vol. 11, no. 11, p. 3100, Nov. 2018, doi: 10.3390/en11113100.
 - [10] Energy Sector Management Assistance Program, *Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers*. World Bank, 2019. doi: 10.1596/31926.
 - [11] J. Agenbroad, K. Carlin, K. Ernst, and S. Doig, "Minigrids in the Money: Six Ways to Reduce Minigrad Costs by 60% for Rural Electrification," Rocky Mountain Institute. [Online]. Available: <https://rmi.org/wp-content/uploads/2018/12/rmi-seeds-minigrad-report.pdf>
 - [12] R. M. Johannsen, P. A. Østergaard, and R. Hanlin, "Hybrid photovoltaic and wind mini-grids in Kenya: Techno-economic assessment and barriers to diffusion," *Energy Sustain. Dev.*, vol. 54, pp. 111–126, Feb. 2020, doi: 10.1016/j.esd.2019.11.002.
 - [13] C. Taliotis et al., "An indicative analysis of investment opportunities in the African electricity supply sector - Using TEMBA (The Electricity Model Base for Africa)," *Energy Sustain. Dev.*, vol. 31, pp. 50–66, 2016.
 - [14] I. Pappis, "Electrified Africa – Associated investments and costs," 2016.
 - [15] World Bank Electricity Planning Model (EPM): Mathematical Formulation World Bank Electricity Planning Model, World Bank 2018
 - [16] Energy Sector Management Assistance Program (ESMAP), "Model for Electricity Technology Assessment (META)." The World Bank, Washington D.C, 2014.
 - [17] R. Karhammer et al., "Sub-Saharan Africa: Introducing Low Cost Methods in Electricity Distribution Networks," *ESMAP Tech. Pap.* 10406, no. October, 2006.
 - [18] World Bank, "Reducing the cost of grid extension for rural electrification," Washington, D.C, Feb. 2000.
 - [19] B. J. van Ruijven, J. Schers, and D. P. van Vuuren, "Model-based scenarios for rural electrification in developing countries," *Energy*, vol. 38, no. 1, pp. 386–397, 2012, doi: 10.1016/j.energy.2011.11.037.
 - [20] D. Mentis et al., "Lighting the World: the first application of an open source, spatial electrification tool (OnSSET) on Sub-Saharan Africa," *Environ. Res. Lett.*, vol. 12, no. 8, 2017, doi: 10.1088/1748-9326/aa7b29.
 - [21] F. F. Nerini, O. Broad, D. Mentis, M. Welsch, M. Bazilian, and M. Howells, "A cost comparison of technology approaches for improving access to electricity services," *Energy*, vol. 95, pp. 255–265, 2016, doi: 10.1016/j.energy.2015.11.068.
 - [22] A. Korkovelos, M. Bazilian, D. Mentis, and M. Howells, "A GIS approach to planning electrification in Afghanistan," Washington D.C, 2017.
 - [23] The International Energy Agency (IEA), "Energy Access Outlook 2017: From Poverty to Prosperity," International Energy Agency, Paris, France, 2017.
 - [24] J. F. Kappen, "Project Information Document-Integrated Safeguards Data Sheet - Madagascar - Least-Cost Electricity Access Development Project - LEAD - P163870," 2019.
 - [25] KTH division of Energy Systems Analysis & SNV, "Electrification pathways for Benin - A spatial electrification analysis based on the Open Source Spatial Electrification Tool (OnSSET)," Stockholm, Sweden, 2018.
-