

Chad

National Electrification Rate [1]

- National: 12%
 - Urban: 42%
 - Rural: 3%
-

Population

- Total: 16.4 million [2]
- Urban ratio: 23.5% [2]

Population growth

- Medium population growth: 2.8% [2]
-

Average household size, urban: 5.1 people [3]

Average household size, rural: 5.6 people [3]

Average electricity consumption per

- Household: 333 kWh/year
- Capita: 62 kWh/year (Tier 3) [1], [4]

Low demand target⁸: U3-R1

High demand target: U4-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): 0.134 \$/kWh
- Expected on-grid cost (high): 0.2 \$/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: ~7 MW/year

Grid connection limit: ~2.5% population/year

⁸ 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] United Nations Statistics Division, "2016 Energy Balances." [Online]. Available: <https://unstats.un.org/unsd/energy/balance/default.htm>. [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.

Note! The Medium Voltage (MV) lines is the modelling output of Gridfinder , a modified version of Facebook's open source Pathfinder algorithm. This approach was adopted in the absence of actual, mapped and publicly available data for the country (at the time of publication). The modelled MV lines have been visually inspected and curated using existing HV lines. Modelled MV lines more than 100 km away from existing HV lines have been abstracted and not used in the electrification model. While the 100 km buffer is a well-educated estimate, is yet an assumption. Therefore, we warmly welcome your feedback and we would be glad to update the results with new, better datasets in case those exist.