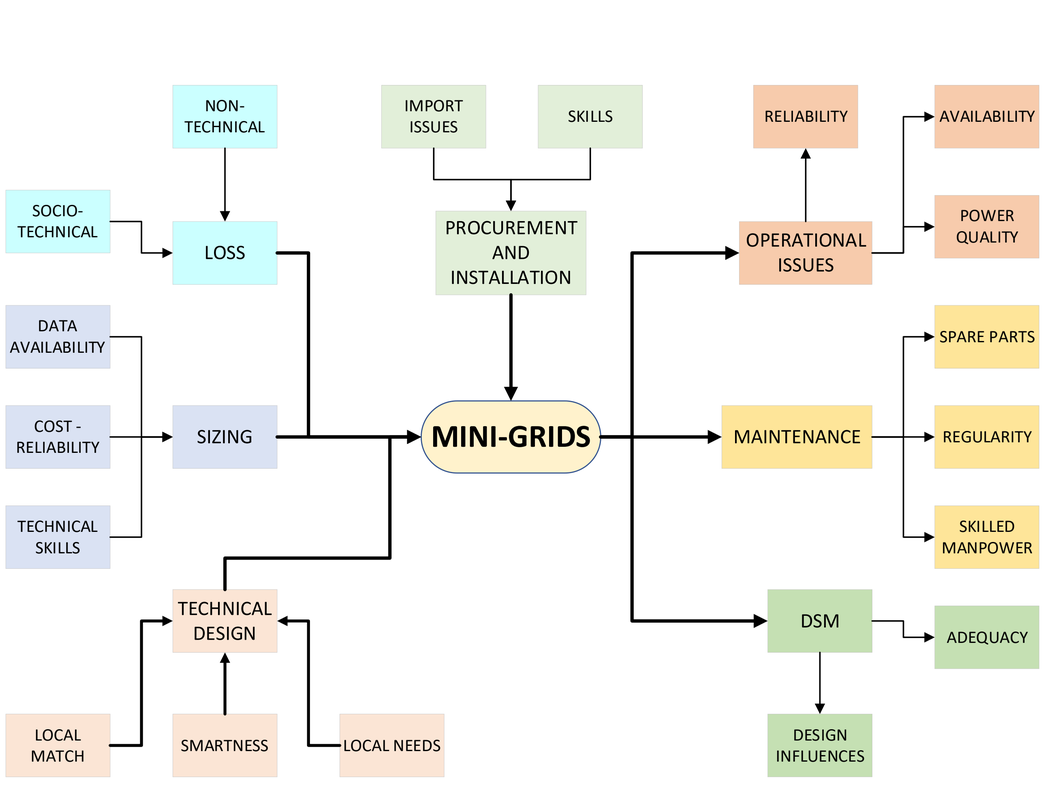
Sustainability, Inclusiveness and Governance of Mini-Grids in Africa (SIGMA) Project

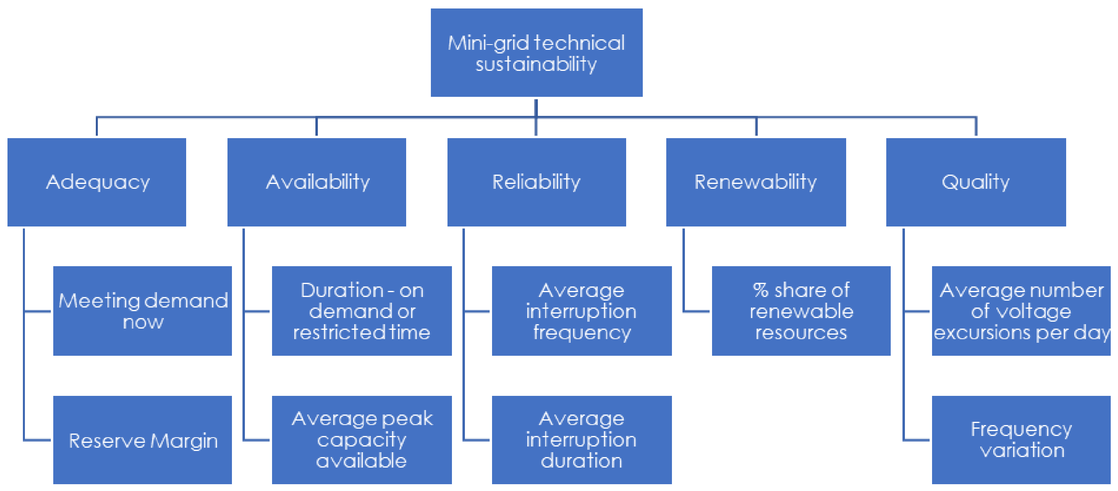
On the Technical Sustainability of Mini-Grids in Developing Countries—An Assessment Framework

In the context of access to electricity, mini-grids have emerged as an electrification strategy in the developing world. However, various technical, economic, sociopolitical and governance issues militate against the sustainability of mini-grids. Sustainability here is defined as the ability of mini-grids – specifically, those powered wholly or partly by renewable sources - to meet present and future needs for domestic and productive energy uses in a reliable, accessible, efficient and cost-effective manner. The purpose of this paper is to critically review and synthesise the available literature on the technical sustainability of mini-grids with a special emphasis on Sub-Saharan Africa (SSA), and highlight lessons for mini-grid projects in the region

Scope element	Inclusion criteria	Exclusion criteria	Comments
Electricity systems	Mini-grids	Centralised, on-grid electricity; Decentralised electricity through stand-alone systems e.g. solar home systems, diesel generators or solar lanterns	Mini-grids are defined as "localised power networks, distributing electricity to a defined area, which can consist of just a few customers in a remote settlement, or hundreds of thousands of customers in a town". The search included mini-grids from all generation sources, including renewable energy technologies, a combination of renewables and fossil fuels (hybrid-mini-grids), and fossil fuels. Articles that compared the performance of different types of mini-grids were included.
Geographical scope	Low and middle-income countries	High-income countries	While studies from Sub-Saharan Africa were given higher priority, the review also drew from a wide evidence base in other developing countries.
Publication date	2000 onwards	Pre-2000 studies	The literature about access to electricity mini-grids before this date is virtually non-existent
Publication format	Journal articles, working papers, evaluations, institutional reports, specialised news outlets.	Other (books, book chapters, student papers, dissertations, unpublished works)	Specialist news outlets can capture the current performance and constraints of mini-grids faster than academic and institutional literature. This allowed us to take the pulse of the sector alongside robust peer reviewed studies.
Methodological approach	Primary and empirical studies that employ quantitative or qualitative data to address our research questions.	Secondary, theoretical, simulations or conceptual studies	The quality of the evidence provided by the literature reviewed was assessed according to the framework presented in Section 5.
Aims of the study	The literature addresses one or several of our research questions and sub-questions	Other (i.e. technical design of mini-grids; least cost electrification planning or other planning studies; sizing of mini-grids)	
Publication language	English and French	Other	English and French are spoken in many Sub-Saharan African countries, and literature about the sub-region is expected to be mainly available in one of both languages.



This review of technical sustainability indicates that technical sustainability is multi-dimensional, and while a wide range of indicators have been considered, several issues remain. First, the ability of the indicators to measure the desired effect is not always clear. For example, the comparison of consumption with the regional average used in Rahmann et al. (2016) or the prescriptive thresholds for different tiers used in the MTF framework are difficult to justify. Second, data availability limits the application of very data intensive frameworks. A framework that can provide a reasonable picture of the technical sustainability need not be too complex or impose too much demand on data. Third, the framework must consider long-term perspectives and respect renewability and future demand growth. Fourth, the framework should be easy to use and interpret and should allow comparison across different mini-grids at a specific time and at different points in time. A simple index is suggested below. Five weighted indicators are used in the framework, namely adequacy, availability, reliability, renewability and quality.



Measures	Indicators	Weight	Base (=1)	Standard (=3)	High (=5)
Adequacy	Ability to meet demand now	60%	Barely meeting the demand	Meeting most of the time	Always meeting the demand
	Reserve margin	40%	0-5% margin	10-20% margin	25% margin
Availability	Duration	50%	Only for limited or restricted time	Available during specified hours	On demand (anytime)
	Peak capacity	50%	Basic lighting and phone charging	Supply to support commonly used appliances	Supply to support aspirational needs
Reliability	Average number of interruptions	40%	<1 per week	<1 per month	<2 per year
	Average duration of interruption	60%	<10 % of time	<5% of the time	<1% of time
Renewability	% of renewable supply	100%	<50%	50-80%	80-100%
Quality	Average number of voltage excursions	50%	<10 per day	<5 per day	<1 per day
	Frequency variations	50%	+/- 2Hz	+/- 1 Hz	+/- 0.5 Hz

Bukari, D ; Hatamimarbini, A ; Bhattacharyya, SC ; Kerr, D ; Baker, L ; Onsongo, E ; Sesan T , Sawe, E.N. and, Pueyo, A (2023) On the technical sustainability of mini-grids in developing countries: A comprehensive review of literature. Sustainability, Inclusiveness and Governance of Mini-Grids in Africa (SIGMA) Project, Working paper 2.
Rahmann, C., Nunez, O., Valencia, F., Arrechea, S., Sager, J. and Kammen, D. (2016) Methodology for monitoring sustainable development of isolated mini-grids in rural communities. Sustainability, 8, 1163, doi:10.3390/su8111163.
ESMAP (2015) Beyond connections: Energy access redefined. Technical Report 08/15, Energy Sector Management Assistance Program, World Bank, Washington, D.C., https://openknowledge.worldbank.org/bitstream/handle/10986/24368/Beyond0connect0d000technical0report.pdf?sequence=1&isAllowed=y

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