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Review article

Lessons from the World Bank's solar home system-based rural electrification projects (2000–2020): Policy implications for meeting Sustainable Development Goal 7 by 2030

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A R T I C L E I N F O

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A B S T R A C T

The main objective of this review paper is to examine the lessons learnt from 16 solar home system (SHS)-based World Bank projects implemented between 2000 and 2020 in the remote rural areas of developing countries. This study emphasises the role of SHS as a technology option in providing electricity to the remaining 10% of the world's population without access to electricity. This study identifies three major internal factors and two external factors that may affect the successful implementation. The internal factors that emerge within the project and arise primarily during its design and implementation include financial barriers (barriers on subsidies and investment support, risk management and commercial viability, credit services and support, and partnerships with the local banking sector and micro-finance institutions), technical barriers (barriers on effective operation, maintenance and after-sales technical service, qualified technical entities and professionals, product quality assurance and monitoring, and the availability and feasibility of other complementary energy technology applications) and project design and implementation barriers (barriers on the monitoring, evaluation and sustainability of the project, the development of local capacity, and clearly defined project objectives). The external factors that have emerged outside the project and are already existing in the societal context include political and institutional barriers (barriers on the institutional framework and its sustainability, and political support and commitment from the community and local political leaders) and social and cultural barriers (barriers on building trust, relationships, confidence and partnerships among stakeholders, the sociocultural perceptions of SHSs, maintaining ongoing dialogues, coordination and cooperation among stakeholders, and adapting to changing international and local conditions). Subsequently, this study considers policy implications that are valuable for the current and upcoming challenges of rural electrification in achieving Sustainable Development Goal 7 – electricity for all – by 2030.

Contents

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1. Introduction

In the last 30 years, significant progress has been made in improving access to electricity, which has increased dramatically since 1970: from 49% in 1970 to 59% in 1990, 73% in 2000, 81% in 2010 and 90% in 2019 (IEA, 2002, 2004, 2012, 2022a). However, approximately 770 million people still lack access to electricity as of 2022 (IEA, 2022b). Sub-Saharan Africa (578 million or 75%) and Developing Asia (155 million or 20%) together account for 95% of the world's population without access to electricity (IEA, 2022a). Furthermore, compared to the 96% of the global urban population with access to electricity, only 85% of the rural population has access to electricity (IEA, 2022a). The proportion of the rural population with access to electricity in Africa and Sub-Saharan Africa is still considerably low, at only 37% and 29%, respectively (IEA, 2022a). Although improved access to electricity has benefited both the urban and rural areas of developing countries in the last 30 years, improving access to electricity in rural areas of the Saharan African region and some developing Asian countries remains a difficult problem to solve. Despite the greater prosperity and advanced energy technology of today, progress in improving access to electricity in these areas is slow and needs to be addressed specifically.

At the global level, the United Nations (UN) has become more proactive in tackling and addressing this problem. Notably, access to electricity has been, for the first time, included in the current development agenda, the Sustainable Development Goals (SDGs), which will be implemented from 2015 to 2030. SDG7, 'affordable and clean energy', aims to ensure that everyone has access to affordable, reliable, sustainable and modern energy services (United Nations, 2022a). As per SDG7.1, the goal's priority is to provide universal access to affordable, reliable and modern energy services by 2030 (United Nations, 2022a). The SDG7.1 target is measured using two indicators: the proportion of people who have access to electricity (SDG7.1.1) and the proportion of people who rely on clean fuels and technology as their primary source of energy (SDG7.1.2) (United Nations, 2022a). SDG7 establishes a clear timeline and specific target for facilitating poor people's access to electricity and regularly reviewing the progress thereof.

Since the inclusion of access to electricity in the UN's development goals, the rate of electrification has accelerated and more international attention has been drawn to reinforce concrete policy actions on the development issue of access to electricity, such as the World Bank rural electrification programmes and national rural electrification programmes in countries with low-electrification rates. According to the International Energy Agency's (IEA) scenario of 2010, the electrification rate and number of people without access to electricity in 2030 will be 85% and 1213 million, respectively (IEA, 2010). However, based on the current data, in 2019, the proportion of the global population with access to electricity increased to 90% and the number of people without access to electricity decreased to 770 million (IEA, 2022b). If more efforts and actions are made and taken, there is a higher chance of closing the 10% gap and achieving the UN's SDG7.1.1 of universal access to electricity by 2030. Nevertheless, progress remains slow because of the increased challenges of improving access to electricity for the remaining population, which typically relates to the low standard of living in remote and rural areas.

To accelerate the speed of electrification, grid or isolated grids can, without a doubt, be considered the first priority. However, the remaining 10% of the population is primarily concentrated in remote and rural areas, where grid or isolated grid access is likely too expensive for dispersed and poor households as well as for electricity providers. The use of locally available energy, such as solar energy, in combination with a cost-effective mechanism design, such as a solar home system-based (SHS-based) rural electrification programme, has more potential to close or minimise the 10% gap. In the last 30 years, some developing countries, developed countries and international organisations have implemented projects or programmes using SHSs in remote rural areas of developing countries with low-electrification rates. In collaboration with local governments and various actors, such as micro-finance institutions, small- and medium-sized enterprises (SMEs), non-governmental organisations (NGOs), social service institutions, community leaders and women in communities, these projects and programmes bring funds, technology and local capacity building to these areas.

The World Bank has been one of the most active funders of such development projects in the past 20 years, facilitating the process of improving rural households' access to electricity. Irrespective of the success of its SHS-based rural electrification projects, these projects provide valuable and insightful lessons that are helpful in addressing the current issue of improving access to electricity for remote rural households and areas. There is currently one study that has systematically reviewed the lessons learnt from the World Bank's various SHS-based rural electrification projects; however, it covers the years 1993–2001 (Martinot et al., 2001). Similarly, another study has investigated two of the World Bank's SHS-based projects in Sri Lanka and Indonesia with the approach of in-depth analysis; however, it only covered the regions of South Asia and Southeast Asia (Sovacool, 2018). There has been limited research on reviewing the lessons learnt from large-scale SHS-based rural electrification projects implemented by international development organisations such as the World Bank. However, the barriers that have hampered the successful implementation of the World Bank's SHS-based rural electrification projects, as gathered from the field experiences of the aforementioned studies, are particularly practical and useful for improving projects that are currently being implemented or will be implemented in remote rural areas in developing countries. To enhance the existing understanding of the lessons learnt from the World Bank's SHS-based rural electrification projects, the main objective of this study is to review and examine the lessons learnt from these projects over the last 20 years. This study aims to synthesise valuable lessons and their knowledge across 16 different projects and periods from 2000 to 2020. This study could bridge the gap and add new insights from the lessons summarised from these projects during this period. Although the different barriers can be seen individually or partly in the related published reports or papers, the overall analysis using the new framework of internal and external factors is a new and different way to categorise the findings.

Therefore, the purposes of this study are to (1) review the current state of access to electricity and consider the implications for achieving SDG7, (2) review the literature on SHS-based rural electrification and consider the implications for achieving SDG7 and access to electricity, (3) identify key barriers that hampered the successful implementation of the World Bank's SHS-based rural electrification projects from 2000 to 2020 and analyse the lessons learnt and (4) discuss the implications for achieving SDG7.

This study is organised into six sections. Section 2 introduces the research methodology and data sources used in the study. Subsequently, Section 3 reviews the current state of access to electricity and the literature on the lessons learnt from SHS-based rural electrification. Section 4 summarises the results of the lessons from the selected 16 World Bank SHS-based electrification projects implemented between 2000 and 2020. Section 5 discusses the policy implications of these lessons for meeting SDG7 by 2030. Finally, Section 6 presents the conclusions.

2. Data and methods

The electrification rate was calculated using data from the IEA's World Energy Outlook, its Access to Electricity Database (IEA, 2022a) and the World Bank's Access to Electricity Database (World Bank, 2022a). Data from various independent national data sources and national experts were used to validate the above information (Doll and Pachauri, 2010). The following keywords were used to search the literature for this study: access to electricity, rural electrification, solar home system, SHS and the World Bank. ScienceDirect, Springer, Taylor and Francis, EBSCOhost, SAGE, Wiley Online Library, College Publications, ResearchGate, Google Scholar and other databases were used to conduct the searches.

Review and analysis of the lessons learnt from the World Bank's SHS-based rural electrification projects here was based on the World Bank Project Database's Implementation Completion and Results Reports (World Bank, 2022b). All these projects were implemented in developing countries with low-electrification rates at the time, with the goal of increasing access to electricity through SHSs. The project search started with the Energy & Extractives sector and its subsector Renewable Energy Solar. As a result, 238 projects had been identified as of 1 March 2022, with 141 being completed implementation projects. Only the projects that had implemented SHS-based rural electrification, were completed between 2000 and 2020, had released official Implementation Completion and Results Reports and had analysed their lessons learnt in the field in the reports were selected. Therefore, 16 projects were chosen as cases in this study based on the aforementioned criteria (Table 1).

These projects were distributed, according to the IEA's classification of regions and countries (IEA, 2022a), in the following six regions (Table 2): South Asia (Sri Lanka and Bangladesh), East Asia (Mongolia), Southeast Asia (Lao, Philippines and Cambodia), South America (Argentina and Peru), West Africa (Mali, Burkina Faso, Guinea and Sierra Leone) and East Africa (Ethiopia, Uganda, Tanzania and Mozambique). A total of 11 of the 16 case countries were classified as least developed countries (LDCs) by the UN in 2022 based on the lowest threshold of the gross national income per capita, human assets index and economic and environmental vulnerability index (United Nations Department of Economic and Social Affairs, 2022). Despite the completion of the selected rural electrification projects, the electrification rate of the selected African countries in 2019 remains extremely low, particularly in rural areas.

Content analysis with latent coding was used to analyse the World Bank's SHS-based rural electrification projects. Latent coding refers to reviewing the lessons learnt from each project's Implementation Completion and Results Report and coding their underlying meaning (Babbie, 2013). Latent coding, unlike manifest coding, which involves counting specific words or terms that appear in a report (Babbie, 2013), is better suited for extracting the underlying meaning of the reports.

The limitations of the data used in the study are as follows: (1) Data analysis is constrained by the available data provided in the reports. The lack of further data or needed data for analysis may limit the understanding of real situations in the field or more in-depth analysis. The quantity of data provided by the reports also varies. To cope with the limitation, the approach of this study analyses the general barriers among projects, instead of in-depth analysis of each project implemented in each individual country. (2) The validity and reliability of the data lie in the quality of the reports. The validity and reliability of the data may affect the results and the further inference of implications. The World Bank's project reports have been published for decades and follow its internal standards and requirements. Compared to other sources of data, the validity and reliability of the data would be assumed to be of good quality. (3) The constraint of latent coding may affect the validity of the analysis and the accuracy of the results. The subjective judgement of the researcher who codes the data may jeopardise the accuracy of the coding if the researcher misunderstands the underlying meaning of the reports or selects data. However, such a constraint can be adjusted and

Table 1
Selected SHS-based World Bank rural electrification projects (2000–2020) (Compiled by the author based on World Bank, 2006, 2012a,b,c, 2013a,b,c,d,e,f, 2015a,b,c, 2017a,b, 2018a,b, 2022b).

Country	Project title	Project ID Nr.	Grant amount (USD, million)	Approval date (DD/MM/YY)	Closing date (DD/MM/YY)
Sri Lanka	Renewable Energy for Rural Economic Development Project	P076702	125.70	20/06/2002	31/12/2011
Bangladesh	Rural Electrification and Renewable Energy Development Project	P071794	290.10	25/06/2002	31/12/2012
Mongolia	Renewable Energy for Rural Electricity Access Project	P084766	18.00	19/12/2006	30/06/2012
Lao PDR	Rural Electrification Phase I Project of the Rural Electrification (APL) Programme	P075531	36.27	27/04/2006	31/03/2012
Philippines	Rural Power Project in Support of the First Phase of the Rural Power Development Programme	P113159	48.36	14/04/2009	15/01/2013
Cambodia	Rural Electrification and Transmission Project	P064844 P071591	4.96	16/12/2003	31/01/2012
Argentina	Renewable Energy in the Rural Market Project	P006043	120.50	30/03/1999	31/12/2012
Peru	Rural Electrification Project	P090116	100.00	07/03/2006	30/06/2013
Mali	Household Energy and Universal Access Project	P073036 P079440	49.85	04/11/2003	30/06/2012
Burkina Faso Guinea Sierra Leone	Energy Access Project Decentralised Rural Electrification Project Sierra Leone Energy Access Project	P078091 P077288 P126180	25.60 6.82 15.66	26/07/2007 07/02/2002 26/07/2007	31/10/2014 30/06/2013 31/10/2014
Ethiopia	Second Electricity Access (Rural) Expansion Project	P101556	130.0	03/07/2007	31/12/2014
Uganda Tanzania Mozambique	UG-Energy for Rural Transformation TZ-Energy Development & Access MZ-Energy Dev. & Access Project	P112334 P101645 P108444	82.07 134.58 71.67	06/04/2009 13/12/2007 04/02/2010	30/06/2016 29/09/2017 15/06/2017

Table 2
Selected SHS-based World Bank rural electrification projects in the region (Compiled by the author based on World Bank, 2022b; IEA, 2022a; United Nations Department of Economic and Social Affairs, 2022).

Area	Region	Country	UN LDCs 2022	Electrification rate 2019 (%)		Population without access to electricity 2019 (million)
				National	Rural	
Asia (6)	South Asia	Sri Lanka		>99	99	<1
		Bangladesh	V	83	77	28
	East Asia	Mongolia		91	73	<1
	Southeast Asia	Lao	V	95	93	<1
		Philippines		96	93	4
		Cambodia	V	75	67	4
America (2)	South America	Argentina		99	85	<1
		Peru		97	86	<1
Africa (8)	West Africa	Mali	V	50	28	10
		Burkina Faso	V	22	2	16
		Guinea	V	46	24	7
		Sierra Leone	V	26	6	6
	East Africa	Ethiopia	V	47	34	60
		Uganda	V	29	17	32
		Tanzania	V	40	23	35
		Mozambique	V	35	22	20

verified by having other researchers and scientific communities review the report and verify the analysis again. All the data used for analysis in this study are from the Implementation Completion and Results Report, which can all be retrieved from the World Bank Project Database: https://projects.worldbank.org/en/projects-operations/projects-home.

3. Literature review

3.1. Access to electricity in geographic areas: Implications for SDG7

In 2019, approximately 1/10 of the world's population did not have access to electricity (IEA, 2022a). There are 771 million people who lack access to electricity, with the majority living in Africa (75%, 579 million), particularly Sub-Saharan Africa (75%, 578 million), and Developing Asia (20%, 155 million) (Table 3). In terms of population without access to electricity, the Developing Asia region has made the most significant progress in improving access to electricity. In the last 20 years, nearly 1 billion people have gained access to electricity. However, 155 million people still do not have access to electricity. In comparison to other regions, the rate of decrease in the number of people without electricity in Sub-Saharan Africa is far slower and remains nearly unchanged. In terms of geographic areas, improving access

Table 3
Electrification rate and population without electricity in 2000, 2010 and 2019 (Compiled by the author based on IEA, 2002, 2012, 2022a).

Area	2000 Electrification rate (%) Population without electricity (million)	2010 Electrification rate (%) Population without electricity (million)	2019 Electrification rate (%) Population without electricity (million)
World	**73%** **1645 million**	**81%** **1267 million**	**90%** **771 million**
Central and South America	87% 56 million	94% 29 million	97% 16 million
Middle East	91% 15 million	91% 18 million	92% 19 million
Developing Asia	67% 1041 million	81% 628 million	96% 155 million
Africa	34% 522 million	43% 590 million	56% 579 million
Sub-Saharan Africa	23% 509 million	32% 589 million	48% 578 million

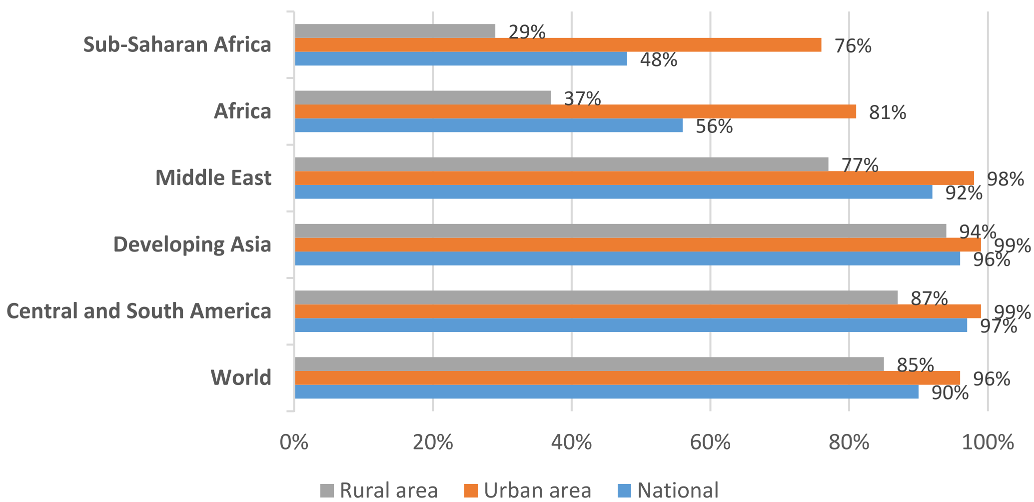

Fig. 1. Rural and urban electrification rates by region in 2019 (Compiled by the author based on IEA, 2022a).

to electricity in Sub-Saharan Africa and some developing Asian countries is critical to achieving SDG7.

3.2. Access to electricity in rural areas: Implications for SDG7

In 2019, nearly all households in Central and South America, the Middle East and Developing Asia had access to electricity (Fig. 1). The electrification rate in urban areas in Africa and Sub-Saharan Africa had also reached nearly 80%. Rural electrification rates were lower than urban electrification rates, except for Developing Asia, where the rate is 94%. The greatest disparity between urban and rural areas was found in Africa and Sub-Saharan Africa. Rural electrification rates in these two regions were only 37% and 29%, respectively. In terms of rural and urban areas, improving access to electricity requires a special focus on rural areas, particularly in Sub-Saharan African regions, to achieve SDG7.

3.3. Access to electricity in low-income countries, heavily indebted poor countries (HIPCs), LDCs, fragile and conflict-affected countries and pandemic-affected areas: Implications for SDG7

The World Bank's Access to Electricity Database groups countries by their characteristics, such as low-income countries, HIPCs, LDCs and fragile and conflict-affected countries (Fig. 2). This grouping has an electrification rate of 41%–54%, which is lower than the African region's 56%. The electrification rates in low-income countries (41%) and HIPCs (45%) are even lower than that in Sub-Saharan Africa (48%). The data show that poverty, human development and electrification are all linked.

Some studies have argued that there is a connection between electricity access and energy poverty as well as the potential effects on socioeconomic human development, particularly for the poor (Khanna et al., 2019; Nussbaumer et al., 2012; Pachauri and Spreng, 2011; Rao and Pachauri, 2017; Riva et al., 2018; Sagar, 2005; Sarkodie and Adams, 2020; Shyu, 2014, 2020). Although the actual causal relationship is difficult to establish empirically, improved access to electricity is thought to have a high probability of bringing about human development and poverty alleviation. A paragraph in the Poor People's Energy Outlook 2019 provides a local context for this argument: 'When electricity first came to the village of Amaguaya in Bolivia's Cordillera Real mountain range, a village leader said, ''Now we have a way, we have light, it is as if we are climbing the steps to a better and better life''. Beyond light, we hear from farmers about the benefits of solar-powered irrigation, women about the time saved by grinding and threshing machines and school teachers and health workers about the improved services they can provide. Electricity has the power to transform people's lives' (Practical Action, 2019).

Access to electricity in fragile and conflict-affected countries, such as Ukraine in 2022, Afghanistan in 2021, Yemen since 2014, Syria since 2011 and some African countries because of civil

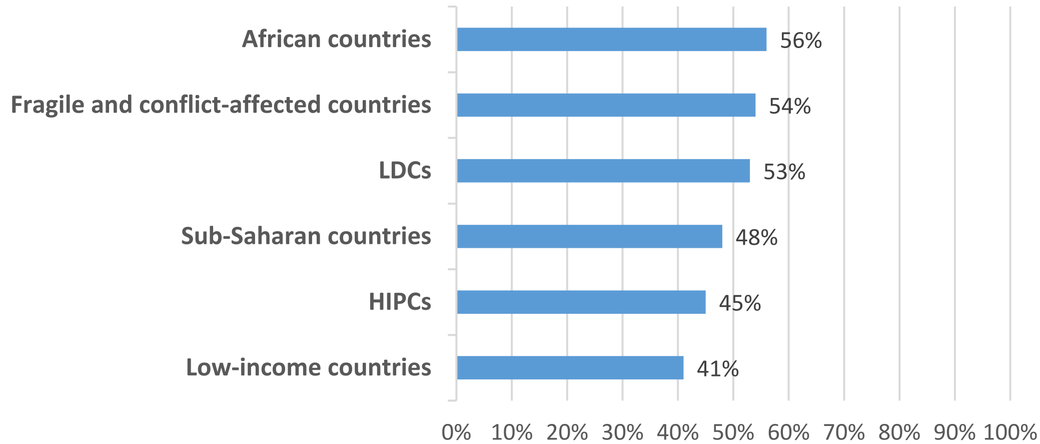

Fig. 2. Access to electricity in low-income countries, HIPCs, LDCs and fragile and conflict-affected countries in 2019 (Compiled by the author based on World Bank, 2022a; IEA, 2022a).

wars, requires special attention. Owing to wars or conflicts, the population without access to electricity in such affected areas may increase dramatically. It is necessary to address the lack of electricity in these affected areas and refugee camps. Other factors, such as the COVID-19 pandemic, which has been spreading since 2020, also pose unpredictably difficult challenges to improving access to electricity. The IEA (2022c) claimed that the COVID-19 pandemic continues to reverse previous progress in global access to electricity. According to some studies, access to electricity should be protected as a basic human right, which necessitates more policy actions, interventions and obligations at both the national and international levels (Bradbrook and Gardam, 2006; Bradbrook et al., 2008; Frigo et al., 2021; Hesselman et al., 2021; Ngai, 2012; Shyu, 2021; Tully, 2006a,b, 2008; Walker, 2015). Rural electrification must focus not only on the poor and least developed rural areas but also on fragile, conflict-affected and pandemic-affected areas if SDG7 is to be met.

3.4. Potential of SHS-based rural electrification programmes to improve access to electricity in remote rural areas and its implications for SDG7

In developing countries with low-electrification rates, power grids usually extend to urban areas and the nearby rural areas. Higher population densities and household incomes justify the implementation and investment of electrification programmes in and near urban areas. However, people living in remote and rural areas, where most of the remaining population without access to electricity is located, are hardly likely or unlikely to have access to electricity from power grids. Technology options for tackling access to electricity in rural areas include the extension of existing grids, creation of isolated mini-grid systems, or utilisation of stand-alone off-grid power generation systems (IEA, 2003, 2011). To achieve the SDG7.1.1 of electricity for all and close the gap of the remaining 10% of the world's population without access to electricity, relying only on the extension of existing grids or isolated mini-grid systems is not feasible and practical in reality. Decentralised stand-alone off-grid power generation systems using locally available indigenous energy resources such as solar, wind, hydro, biomass, and geothermal energy are viable electrification options in these areas. This type of rural electrification has been advocated by scholars, NGOs, international development organisations and national governments with policies and applied in numerous developing countries with low-electrification rates worldwide (AGECC, 2010; Asian Development Bank, 2005; Barnes, 2011; Bhattacharjee, 2002; Bhattacharyya, 2013; Flavin and Aeck, 2005; IEA, 2019; Kumar et al., 2022; Modi et al., 2005; Njoh et al., 2019; Practical Action, 2009, 2010, 2012, 2013, 2014, 2016, 2017, 2018, 2019; UNDP and WHO, 2009; World Bank, 2000, 2008; Yang, 2003; Zhou and Byrne, 2002).

Compared to other types of energy, solar energy is more widely available than wind or hydro energy. Consequently, international development organisations, NGOs and academics recommend SHS as a more practical stand-alone off-grid power generation system for improving access to electricity in remote rural areas of developing countries with low-electrification rates (Biswas et al., 2004; Ellegård et al., 2004; Friebe et al., 2013; IEA, 2010, 2014, 2017; Kamalapur and Udaykumar, 2011; Lemaire, 2009; Narayan et al., 2019; Zaman and Borsky, 2021). Based on case studies in Bangladesh, India, Kenya, Nepal, Peru, Togo and South Africa, Practical Action (2016, 2017, 2018, 2019) has recommended the potential of SHSs as a viable decentralised technology and approach considering remoteness, energy poverty and gender factors. Narayan et al. (2019) have investigated the SHS-based rural electrification and proposed an electricity access framework concerning the optimal SHS sizing for a five-tier household.

However, compared to conventional technologies, for instance, the extension of grids and mini-grid systems, some studies have challenged the SHS as the most viable technology for rural electrification and development (Al-Ismaily and Probert, 1998; Bhattacharyya, 2006; Chaurey and Kandpal, 2010; Drennen et al., 1996; Ellegård et al., 2004; Wamukonya, 2007). Some critics have argued that there is insufficient evidence to support the development impact of SHS in rural areas of developing countries with low-electrification rates (Abu Saim and Khan, 2021; Azimoh et al., 2014, 2015; Chowdhury and Mourshed, 2016; Ellegård et al., 2004; Rahman and Ahmad, 2013; Schillebeeckx et al., 2012). However, these arguments are based on a comparison of grid extension and mini-grid systems with SHSs. Because of the limited amount of electricity that this type of power system can generate, the effects of SHS electrification are invariably small in scale, breadth and depth. In terms of time frame, the aforementioned studies were mainly conducted between 1996 and 2021, when grid extension and mini-grid systems were still more viable and better options for rural electrification for urban areas or more centralised rural areas in developing countries with low-electrification rates. However, with respect to closing the last 10% gap in terms of access to electricity and achieving the SDG7 electricity for all by 2030, the extension of grids and mini-grid systems for rural electrification will face increasing limitations for the remaining population without access to electricity. Thus, the role of SHSs for electrification will be critical in achieving the SDG7 in the remaining non-electrified remote rural areas.

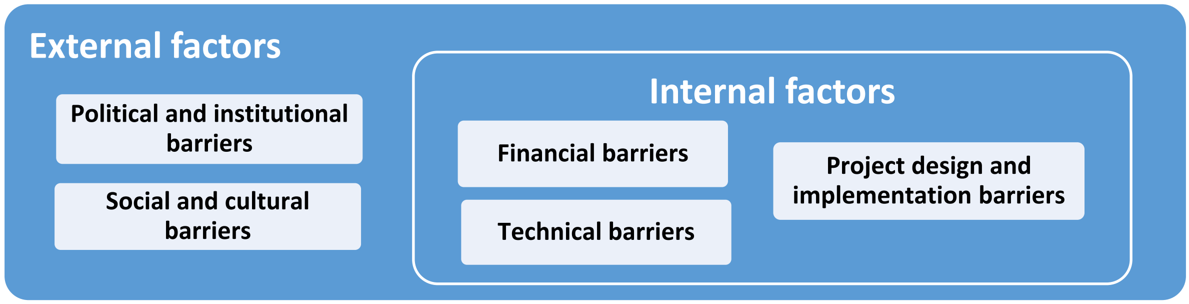

Fig. 3. Factors that may hinder the successful implementation of SHS-based rural electrification programmes in developing countries.

3.5. Lessons learnt from SHS-based rural electrification projects in remote rural areas

SHS-based rural electrification projects in the remote rural areas of developing countries have been investigated with their implications discussed in related published reports and papers. More in-depth investigations of one or two countries have been conducted (Aklin and Urpelainen, 2021; Balint, 2006; Fara et al., 1998; Newcombe and Ackom, 2017; Practical Action, 2018; Urmee et al., 2009; Wassie and Adaramola, 2021). Some researchers have focused on regional scales or developing countries (Barnes, 2011; López-Vargas et al., 2021; Practical Action, 2010, 2012, 2013, 2014; Sovacool and Drupady, 2012; Van der Vleuten et al., 2007). However, few studies have focused on the projects of international development organisations such as the World Bank (Martinot et al., 2001; Sovacool, 2018).

3.5.1. Country-focused studies

Fara et al. (1998) have investigated the technical, economic and social issues of implementing an SHS-based electrification project in Romania. Balint (2006) has considered the lessons learnt from two SHS-based projects for small NGOs in El Salvador, focusing on the following key factors: promoting local markets, adjusting all local stakeholders and developing alternative small-scale project models that combine market- and donor-based design. Following an analysis of the IDCOL renewable energy programme in Bangladesh and the Vunivau SHS-based programme in Fiji, Urmee et al. (2009) have identified some key factors that can help SHS-based rural electrification programmes succeed, including social, institutional, economic and policy ones. Newcombe and Ackom (2017) have analysed the lessons learnt from the SHS-based programmes in Myanmar and Bangladesh and proposed the following recommendations: an institutional framework, a national electrification plan, tariff/subsidy reviews, public–private partnerships (PPPs), micro-finance institutions and technical considerations. From the Nepal Rural Energy Development Programme 1996–2011 and South Africa's SHS-based decentralised electrification programmes, Practical Action (2018) identified several key factors that may have affected SHS-based decentralised electrification programmes in 1999–2018: government commitment, planning and budgeting and stakeholder coordination. Moreover, according to Aklin and Urpelainen (2021), population density, household income, government commitment and the most affordable distributed renewable energy technologies are some of the key factors that can be learnt from SHS-based rural electrification for lighting in rural India. Wassie and Adaramola have identified several critical challenges to rural electrification with SHSs in Ethiopia, including the high costs of quality-verified solar products, limited access to credit financing, poor market quality products and the lack of after-sales maintenance services (2021).

3.5.2. Region-focused studies

Lessons from SHS-based rural electrification programmes in Africa were discussed by Van der Vleuten et al. (2007), including self- or project-organised SHS-based programmes, the institutional capacity of donor programmes and PPP models to support dispersed projects. Sovacool and Drupady (2012) have identified four distinct types of challenges for small-scale renewable energy governance in Developing Asia: technical, economic, institutional and social challenges.

3.5.3. Developing country-focused studies

Barnes (2011) has proposed effective rural electrification solutions in developing countries based on lessons learnt from successful SHS-based rural electrification programmes. Based on their fieldwork in developing countries with low-electrification rates, Practical Action (2010, 2012, 2013, 2014) have suggested that a healthy energy access system included three critical dimensions: policy, finance and capacity. According to López-Vargas et al. (2021), one important factor that contributes to the success of SHS-based rural electrification programmes in developing regions is the lack of advanced mass scale monitoring, which may reduce the system's lifetime, increase the failure of operation and affect users' confidence in SHSs.

3.5.4. World bank project-focused studies

Martinot et al. (2001) have examined the outcomes and lessons learnt from 12 SHS-based World Bank projects implemented between 1993 and 2001: pilot private sector and NGO delivery models; pilot consumer credit delivery mechanisms; pay first-cost subsidies and offer affordable system sizes; support policy development and capacity; establish certification, testing and enforcement institutions; and conduct consumer awareness and marketing programmes. Sovacool (2018) has investigated two SHS-based World Bank projects in Sri Lanka and Indonesia with five lessons: financial institutions' polycentric involvement, flexibility in technological scope and geographic coverage, political harmonisation and support, capacity building and awareness and programmatic self-sufficiency.

4. Results

Based on the analysis of the lessons learnt from the 16 SHS-based World Bank rural electrification programmes in developing countries, the factors that hinder the successful implementation are categorised into two aspects: internal and external factors (Fig. 3). Internal factors refer to the barriers that emerge within the project and arise primarily during the project's design and implementation. External factors refer to barriers that already exist in the societal context or that emerge outside the project and its implementation. Compared to internal factors, external factors are more difficult to define and resolve because these factors

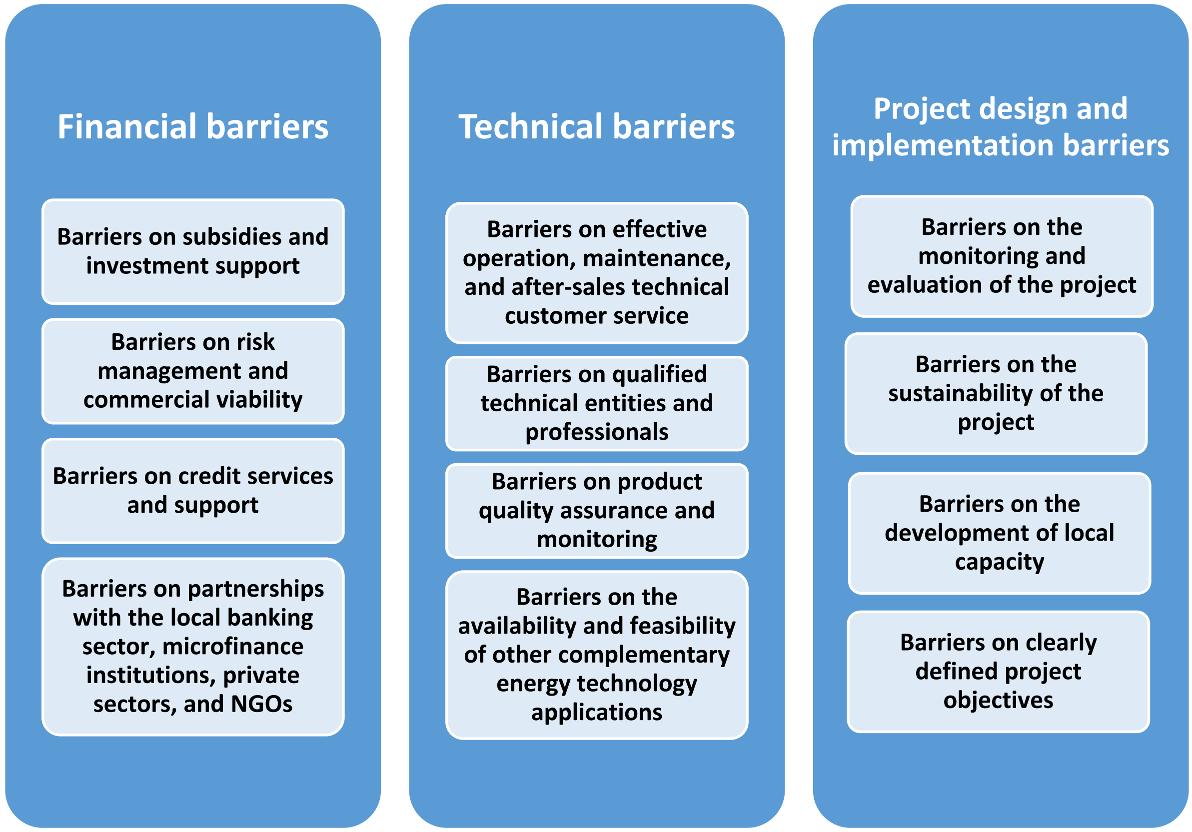

Fig. 4. Financial barriers, technical barriers and project design and implementation barriers that affect the successful implementation of the World Bank's SHS-based rural electrification programmes in developing countries.

are more complex, uncontrollable and unpredictable. Internal and external factors may interact at the local level, resulting in new, more complex and multilayered barriers, making a well-designed rural electrification programme more difficult in terms of implementing and achieving the desired policy effects, outcomes or impacts.

4.1. Internal factors

This study identifies three major internal factors that affect the successful implementation of the World Bank's SHS-based rural electrification programmes in developing countries: financial barriers, technical barriers and project design and implementation barriers (Fig. 4).

4.1.1. Financial barriers

Based on an analysis of the World Bank's Implementation Completion and Results Reports, the following four main financial barriers are identified as per the frequency mentioned: barriers on subsidies and investment support; barriers on risk management and commercial viability; barriers on credit services and support; and barriers on partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs (Fig. 4). See Appendix A for further information on the data and data analysis.

(a) Barriers on subsidies and investment support (11 projects): The results show that low household incomes, low electricity demand, and high investment costs characterise the dispersed rural markets of these SHS-based rural electrification projects. Therefore, it is vital to secure sustainable, effective, and timely government subsidies and investment to minimise uncertainties and ensure the sale and use of the SHSs, particularly for poor households. To ensure the successful implementation of such projects, subsidies and investment funded by secure sources, such as government funds, should also consider minimising economic distortions, such as the excessive subsidies of tariff policy, and maximising their performance, such as the productive uses of SHS.

(b) Barriers on risk management and commercial viability (9 projects): The risks and commercial viability of SHS-based projects for the supply side include the following potential barriers during implementation (World Bank, 2012a, 2013a,b): (1) a large number of SHS vendors may enter the market as a result of grants or subsidies, causing the market to become overcrowded and resulting in low profits; (2) in a small and dispersed market, SHS vendors may face bankruptcy, cease operations or have no profit; (3) the price of new SHS modules may decrease significantly owing to technological advances or increased SHS efficiency, such as the introduction of LED bulbs if SHS vendors have too much inventory; (4) the market may shrink owing to grid connection and result in a massive withdrawal of SHSs; (5) the SHS vendors have to be responsive to new and changing market conditions, which may vary in different locations where electrification is low; and (6) prices and services may be regulated or affected by new policy interventions by governments or other institutions. For the demand side, the end-users may stop repaying SHS loans to credit institutions. To reduce purchase risks, the design of a buy-back scheme could reduce rural households' SHS purchase risks when they obtain grid electricity and the SHS is no longer needed (World Bank, 2013b). However, a World Bank project in

Bangladesh found that, despite having grid services, most rural households chose not to sell back their SHSs (World Bank, 2013b).

(c) Barriers on credit services and support (5 projects): For rural households to afford an SHS, it is necessary to provide affordable, reliable, and easy-to-access credit services. Flexibility and periodic reviews of credit market conditions should also be considered. If their SHSs stop working, rural households in developing countries are less likely to pay their SHS debts (World Bank, 2013b). SHS programmes can be made more sustainable by combining a credit system and after-sales services. When technicians from micro-finance institutions visit households to collect payments, they can also provide maintenance and after-sales services (World Bank, 2013b).

(d) Barriers on partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs (5 projects): The micro-finance model increased low-income rural households' willingness to use and pay for SHSs to access electricity and improve household lighting (World Bank, 2013b). At the local level, the institutional setup, outreach, and ongoing engagement of the banking sector, micro-finance institutions, the private sector, and NGOs can help build trust and contribute to large-scale and a higher uptake of SHSs (World Bank, 2013b,e). Furthermore, collaboration with local banks, micro-finance institutions, the private sector, and NGOs can strengthen or stimulate SHSs' productive energy use as well as the income-generating activities of rural households and SMEs at the local level to enhance their ability to afford and willingness to use SHSs (World Bank, 2013c).

4.1.2. Technical barriers

Based on an analysis of the World Bank's Implementation Completion and Results Reports, the following four main technical barriers are identified as per the frequency mentioned: barriers on effective operation, maintenance and after-sales technical customer service; barriers on qualified technical entities and professionals; barriers on product quality assurance and monitoring; and barriers on the availability and feasibility of other complementary energy technology applications (Fig. 4). See Appendix B for further information on the data and data analysis.

(a) Barriers on effective operation, maintenance and after-sales technical customer service (6 projects): The results indicate that, at the local level, the main challenge is to provide efficient, reliable and affordable operation, maintenance and related technical customer service in widely dispersed remote and rural areas. The provision of long-term after-sales technical services and warranty obligations can enhance the success of the SHS-based projects.

(b) Barriers on qualified technical entities and professionals (5 projects): Unqualified and/or undesirable private entities, such as local private vendors, SMEs, NGOs and community-based organisations, that lack the required technical capacity to provide after-sales services and warranty obligations may participate in the project because of grants, subsidies or investment, causing frustration and/or conflicts among stakeholders (World Bank, 2012a). A pre-technical qualification process for SHS equipment providers with the provision of guarantees must be introduced to reduce the number of private entities (World Bank, 2012a). Training of qualified local technicians for performing the SHS operation, maintenance and after-sales service is essential.

(c) Barriers on product quality assurance and monitoring (2 projects): The lack of regulation in ensuring SHS equipment's performance and minimum quality was not addressed in some World Bank projects (World Bank, 2013b,c). Therefore, establishing a quality assurance of product performance and conducting SHS quality monitoring, such as via a testing lab, random testing and random spot checks, is critical at the start of a project (World Bank, 2013b).

(d) Barriers on the availability and feasibility of other complementary energy technology applications (2 projects): Failure to consider the availability and feasibility of other complementary technology applications at the local level in some World Bank projects may result in a costly and time-consuming restructuring of rural electrification projects. From the lessons learnt in the World Bank projects, complementing grid extension, isolated mini-grid systems (Shyu, 2012, 2013), off-grid hybrid power systems (Mamaghani et al., 2016; Li et al., 2020) or other energy technology applications, such as wind energy (López-González et al., 2020; Leary et al., 2019), biomass (Demirci et al., 2022; Kumar and Channi, 2022) or geothermal energy (Lebbihiat et al., 2021; Hadjadj et al., 2021; Lebbihiat et al., 2022), with off-grid SHS options for remote rural areas is a cost-effective and reliable way to electrify rural areas.

4.1.3. Project design and implementation barriers

Based on an analysis of the World Bank's Implementation Completion and Results Reports, the following four main project design and implementation barriers are identified as per the frequency mentioned: barriers on the monitoring and evaluation of the project; barriers on the sustainability of the project; barriers on the development of local capacity; and barriers on clearly defined project objectives (Fig. 4). See Appendix C for further information on the data and data analysis.

(a) Barriers on monitoring and evaluation of the project (11 projects): SHS-based projects in rural areas should use a simple, easy, precise, flexible and robust monitoring and evaluation mechanism, such as an independent verification agent and a KPI, to track the project's implementation, detect any implementation flaws, assess the project's achievement, assess its social and environmental impact and ensure compliance with local social and environmental safeguards (World Bank, 2013c,d, 2017a, 2018a).

(b) Barriers on the sustainability of the project (4 projects): Delivering higher amounts of electricity for productive energy uses (World Bank, 2013c) and improving household living quality after having access to electricity for basic lighting and electric appliances is critical for the sustainability of SHS-based projects. Continuous project engagement is required for the following reasons (World Bank, 2012a): different stakeholders must grow into their roles in the projects; stakeholders need to have the capacity to identify problems; trust, relationships and networks need to be built among the various stakeholders; and emerging problems that typically appear several years later need to be addressed. As a result, developing a long-term and sustainable involvement scheme at the local level is crucial for the success of an SHS-based project.

(c) Barriers on the development of local capacity (3 projects): Building ownership, authority and responsibility of the implementing bodies and providing resources, tools and skills to various stakeholders to ensure the improvement of living conditions, livelihood and income-generating activities are critical to the success and sustainability of SHS-based rural electrification projects (World Bank, 2012a,c, 2013d).

(d) Barriers on clearly defined project objectives (2 projects): The effectiveness of short-term project design and political objectives in addressing long-term rural development challenges is questioned in some World Bank's SHS-based rural electrification projects (World Bank, 2013d). The objectives of an SHS-based project need to be clearly defined, with or without the inclusion of other political or rural development objectives. A first-come, first-served situation favoured some regions or areas that were institutionally stronger and might deviate from the project's objectives or the government's social and economic objectives, such as poverty reduction, as was the case in a project of the World Bank in Argentina (World Bank, 2013a).

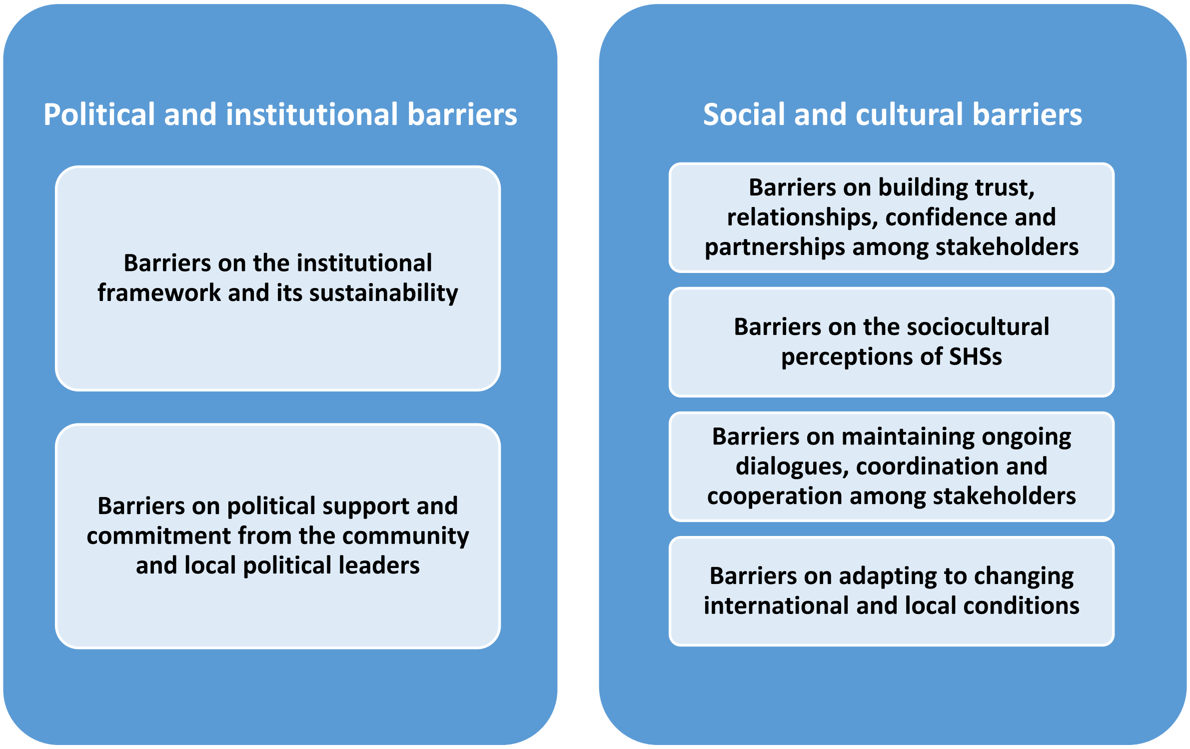

Fig. 5. Social and cultural barriers as well as political and institutional barriers that affect the successful implementation of the World Bank's SHS-based rural electrification programmes in developing countries.

4.2. External factors

This study identifies two major external factors that affect the successful implementation of the World Bank's SHS-based rural electrification programmes in developing countries: social and cultural barriers as well as political and institutional barriers (Fig. 5).

4.2.1. Political and institutional barriers

Based on an analysis of the World Bank's Implementation Completion and Results Reports, the following two main political and institutional barriers are identified as per the frequency mentioned: barriers on the institutional framework and its sustainability; and barriers on political support and commitment from the community and local political leaders (Fig. 5). See Appendix D for further information on the data and data analysis.

(a) Barriers on the institutional framework and its sustainability (8 projects): Rural electrification causes structural changes in the electricity market, necessitating a regulatory review or update as well as putting pressure on various local institutions (World Bank, 2013d). Furthermore, new or modified policy and regulatory frameworks are introduced to integrate SHS-based projects into the national energy sector policy, energy regulatory framework or tariff structure. As a result, the government must not only develop and facilitate an institutional framework for SHS-based projects but also ensure its long-term viability so that various implementation bodies at the national and local levels can work together (World Bank, 2006, 2012a, 2013e). A lack of recognition for the institutional framework and sustainability can lead to institutional inertia, inefficiency and ineffectiveness, all of which can hinder project implementation (World Bank, 2013a). Therefore, transparent, predictable, simple, effective, efficient and comprehensive institutional framework design and reform are required.

(b) Barriers on political support and commitment from the community and local political leaders (2 projects): In some projects, there are tensions between the long-term nature of rural SHS electrification and short-term political goals (World Bank, 2013d). The sustainable implementation of SHS-based projects in rural areas requires political support and commitment from the community and local political leaders. The community and local political leaders play an important role of organising and mobilising various actors, resources and institutions at the local level to develop and accelerate SHS-based projects.

4.2.2. Social and cultural barriers

Based on an analysis of the World Bank's Implementation Completion and Results Reports, the following four main social and cultural barriers are identified as per the frequency mentioned: barriers on building trust, relationships, confidence and partnerships among stakeholders; barriers on the sociocultural perceptions of SHSs; barriers on maintaining ongoing dialogues, coordination and cooperation among stakeholders; and barriers on adapting to changing international and local conditions (Fig. 5). See Appendix E for further information on the data and data analysis.

(a) Barriers on building trust, relationships, confidence and partnerships among stakeholders (7 projects): The results indicate that the bottom-up approach to SHS-based project engagement of various local stakeholders is more likely to be successful and meet local needs than the top-down approach of foreign private operators and investors (World Bank, 2013c). Building partnerships or alliances, cultivating good relationships and trust and empowering stakeholders among community leaders, social service institutions and women in the community could help achieve

greater sustainability (World Bank, 2012a, 2013d). The cultural and historical presence of micro-finance institutions, NGOs, private vendors, SMEs and local leaders leads to a greater level of familiarity and trust among rural consumers, resulting in a higher SHS uptake (World Bank, 2013b). The stakeholder consultation necessitates soft sociocultural skills that can help spread SHSs in practice (World Bank, 2012a).

(b) Barriers on sociocultural perceptions of SHSs (4 projects): In some projects, low community and household interest in SHSs is owing to a limited electricity generation capacity that cannot meet the communities' and households' electricity demands (World Bank, 2013c). The sociocultural perception of SHSs may influence individuals' willingness to use it, limiting its ability to generate income or improve living conditions. The dissemination of SHS practices and benefits among interested parties, such as local governments, community social service institutions, household, SMEs and NGOs, is critical to inform various stakeholders about the potential benefits of SHSs, which could result in a positive change in their living conditions and livelihood.

(c) Barriers on maintaining ongoing dialogues, coordination and cooperation among stakeholders (3 projects): In some projects, regular meetings and visits could strengthen stakeholder groups and make an SHS project successful by maintaining ongoing dialogue, efficient coordination and effective cooperation among various stakeholders and beneficiaries (World Bank, 2012a). It is also crucial to ensure that this coordination and cooperation network among various stakeholders and beneficiaries can function and remain stable after the project is completed. Furthermore, having conversations with various stakeholders and beneficiaries to discuss project closure and help them prepare for it can ensure that they understand and are aware that there will be no further follow-up of the projects (World Bank, 2012a).

(d) Barriers on adapting to changing international and local conditions (2 projects): Changes in international and local conditions, such as political and economic crises, international or internal conflicts, wars and pandemics, may hamper the implementation of SHS-based rural electrification projects in some developing countries with low rural electrification rates. To adjust to these changes, projects that have been designed rigidly and with little room for flexibility are likely to face significant delays and additional costs (World Bank, 2013a). Therefore, the design of SHS-based projects should be flexible to adapt to changing international conditions as well as local conditions that may arise, such as the government's policy orientation, national rural development goals and local economic, social and cultural conditions (World Bank, 2006, 2013a).

5. Discussion: Policy implications and recommendations for meeting SDG7 by 2030

5.1. External factors are key to the success of electrification programmes in remote rural areas

The success of the World Bank's SHS-based rural electrification projects is highly influenced by external factors such as political, institutional, social and cultural barriers, which are complex, uncontrollable and difficult to predict and resolve. The findings suggest that rural electrification for the remaining population without access to electricity should not be limited to the project's internal factors, such as those concerning the finance, technology and project aspects, which are commonly addressed and emphasised. The rural electrification programme is not a panacea to ensure the desired policy outcomes. To ensure the sustainability of electrification, the design and implementation of SHS-based rural electrification programmes for the remaining remote rural areas of developing countries with varying local conditions requires the implementation body and stakeholders to have a combination of social, political and cultural knowledge and skills.

5.2. Securing affordability for the remaining population without access to electricity

When measured on a per capita basis, the LDCs, particularly in Sub-Saharan Africa, received far less international public funding in support of clean and renewable energy than the global average (IEA, 2022d). The current population of people who do not have access to electricity is frequently the poorest in society. For them, a long-term financing plan at the local level is essential. Whether using government or international subsidies, private investments, donor funds, end-user micro-finance, tariff and pricing structures, local markets, entrepreneurial skills or a combination of these financial resources and tools, the design of such a scheme must be innovative, sustainable, bottom-up and adaptable to local conditions. More international public funding in support of improving access to electricity in low-electrification countries also needs to be allocated and secured to achieve SDG7 by 2030.

5.3. Balancing SHSs with possible future grid extension, mini-grid distribution systems or other complementary energy technology applications while planning

The possibility of a grid connection could significantly impact SHS-based rural electrification programmes. When planning, it is important to include the possibility of a future grid extension, mini-grid distribution system development or other complementary energy technology applications. The key to a successful SHS-based rural electrification programme is balancing grid extensions, mini-grid distribution systems and stand-alone SHSs in a timely and cost-effective manner (Practical Action, 2016). Solar systems are becoming more affordable, making mini-grid electricity more competitive with grid extensions, such as solar or solar-diesel hybrid mini-grids (Practical Action, 2016). Even if these remote rural areas have grid access, according to the results, power outages, interruptions and insufficient power are likely to occur frequently. SHSs can still play an important role as a backup power source regularly or daily according to the results.

5.4. Including multi-stakeholders at the local level with a service-based approach rather than a supply-based approach

Integrating rural electrification with the actual needs of the energy-poor and women at the household and community level as well as providing space and support for the stakeholders involved is critical (Practical Action, 2013, 2014, 2016). Having access to electricity via SHSs does not always imply a significant improvement in socioeconomic conditions (Shyu, 2013). To provide poor rural communities with sustainable access to electricity, household electricity needs must be respected and integrated into their daily lives and livelihoods. How electricity is used and for what purposes at the local level as well as with what impact on people's lives comprise a central issue. A service-based approach, rather than a supply-based approach (Practical Action, 2013, 2014; 2015; 2016), can increase the sustainability of SHS-based rural electrification programmes.

5.5. Adopting a holistic approach that involves not only SDG7 but also other SDGs and national development plans

Electrification programmes for a population without access to electricity in the remaining remote rural areas bring not only electricity to the people but also the potential effects of elec-

Table A.1

Project	Lessons cited or summarised from the World Bank *Implementation Completion and Results Reports*	Identified financial barriers
Sri Lanka **Renewable Energy for Rural Economic Development Project (2002–2011)**	Performance-based subsidies to SHS vendors work well (World Bank, 2012a)	Subsidy and investment support
	Risk analysis should be carried out during implementation (World Bank, 2012a)	Risk management and commercial viability
Bangladesh **Rural Electrification and Renewable Energy Development Project (2002–2012)**	Providing a minimal subsidy per SHS allowed poor rural households to purchase SHSs (World Bank, 2013b)	Subsidies and investment support
	The outreach of micro-finance institutions and NGOs can contribute to large-scale and a greater uptake of SHSs (World Bank, 2013b)	Partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs
	Flexibility in adapting to changing market needs is crucial to the success of an SHS project (World Bank, 2013b)	Risk management and commercial viability
	Consumer buy-back scheme reduced rural households' SHS purchase risks when the households received grid electricity, and the SHS might become unnecessary (World Bank, 2013b)	
	Selling systems on credit can be important for system maintenance (World Bank, 2013b)	Credit services and support
Mongolia **Renewable Energy and Rural Electricity Access Project (2006–2012)**	Ensure financial sustainability, market development, subsidies, and reliable credit services (World Bank, 2006) Balance between cost recovery and affordability with smart subsidies (World Bank, 2012b)	Subsidies and investment support Risk management and commercial viability Credit services and support
Lao PDR **Rural Electrification Phase I Project (2006–2012)**	The government developed a financing mechanism, e.g., subsidy and tariff policies, to ensure the achievement of the targets in a timely and effective manner (World Bank, 2013e)	Subsidies and investment support
	Continuous bank engagement is essential for the lasting impact of rural electrification programmes (World Bank, 2013e)	Partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs
	The SHS programme must be reevaluated in terms of the unprecedented success of grid extension, which may result in the mass withdrawal of SHSs, market shrinking, and increased cost of services (World Bank, 2013e)	Risk management and commercial viability
Philippines **Rural Power Project (2003–2012)**	Demand-driven, upstream, and flexible credit operations and periodic reviews of credit market conditions are needed (World Bank, 2013f)	Credit services and support
	Commercial viability owing to the limited economies of density and high cost of services in some remote areas of the Philippines (World Bank, 2013f)	Subsidies and investment support Risk management and commercial viability
Cambodia **Rural Electricity and Transmission Project (2005–2012)**	Subsidies, financing, grants, investment, customer affordability, and customised support for productive uses should be in place with a demand base, instead of purely commercial principles (World Bank, 2012c) Service providers should be allowed to recover their costs through a combination of government support and tariffs (World Bank, 2012c)	Subsidies and investment support Credit services and support
Argentina **Renewable Energy in the Rural Market Project (1999–2012)**	Subsidies are necessary for dispersed rural markets (World Bank, 2013a)	Subsidies and investment support
Peru **Rural Electrification Project (2006–2013)**	Reliable funding for subsidies and investment support (World Bank, 2013d)	Subsidies and investment support
Mali **Household Energy and Universal Access Project (2003–2012)**	Partnerships with the local banking sector must be strengthened to stimulate income-generating activities after electrification (World Bank, 2013c)	Partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs
Guinea **Decentralised Rural Electrification Project (2002–2013)**	High capital costs, greater demands, and risks on operators (World Bank, 2015c)	Subsidies and investment support Risk management and commercial viability
	Private financial institutions play a significant role during implementation, and aligning the incentives of the institution is important (World Bank, 2015c)	Partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs

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trification, which can alter the lives of people, household and communities in terms of human, economic and social development. Other SDGs can also benefit from the spill-over effects of SHS-based rural electrification programmes, including poverty reduction (SDG1), food production and security (SDG2), essential healthcare services (SDG3), equitable quality education (SDG4), improvement of gender inequality (SDG5), generation of local economic activities and employment (SDG8), reduction of inequality within and among countries (SDG10), safe and sustainable human settlements (SDG11) and climate change mitigation (SDG13) (United Nations, 2022b). Rural electrification programmes that incorporate innovative SDGs and national development plans can multiply the effects of electrification and human

Table A.1 (*continued*).

Project	Lessons cited or summarised from the World Bank *Implementation Completion and Results Reports*	Identified financial barriers
Ethiopia **Electricity Access (Rural) Expansion Project (2007–2014)**	Business model, financial incentives, customer affordability, subsidy policies, financing mechanism, and feed-in tariffs must be addressed (World Bank, 2015b)	Subsidies and investment support Risk management and commercial viability Credit services and support
	Risk-sharing mechanisms must be addressed (World Bank, 2015b)	Risk management and commercial viability
Uganda **Energy for Rural Transformation Project (2009–2016)**	Lack of involvement and interest of the private sector (World Bank, 2017a)	Partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs
Tanzania **Energy Development & Access Expansion (2007–2017)**	SHS market relied heavily on government procurement and was not sufficiently adaptable to changing dynamic market circumstances (World Bank, 2018b)	Subsidies and investment support Risk management and commercial viability

Table B.1

Project	Lessons cited or summarised from the World Bank *Implementation Completion and Results Reports*	Identified technical barriers
Sri Lanka **Renewable Energy for Rural Economic Development Project (2002–2011)**	After-sales services and warranty obligations are not respected (World Bank, 2012a)	Effective operation, maintenance, and after-sales customer service
	Unqualified and/or undesirable private entities are drawn by grants (World Bank, 2012a)	Qualified technical entities and professionals
Bangladesh **Rural Electrification and Renewable Energy Development Project (2002–2012)**	It is crucial to establish a quality assurance of product performance at the beginning of a project, and quality monitoring is essential (World Bank, 2013b)	Product quality assurance and monitoring
Mongolia **Renewable Energy and Rural Electricity Access Project (2006–2012)**	After-sale service must be accessible to a dispersed population (World Bank, 2012b)	Effective operation, maintenance, and after-sales customer service
Lao PDR **Rural Electrification Phase I Project (2006–2012)**	Complementing grid extension with off-grid SHS options for remote rural areas (World Bank, 2013e)	Availability and feasibility of other complementary energy technology applications
Cambodia **Rural Electricity and Transmission Project (2005–2012)**	Local private developers may not have the capacity and technical support for post-installation operation, and maintenance arrangements are critical (World Bank, 2012c)	Effective operation, maintenance, and after-sales customer service
	The choice of an appropriate SHS size should be based on a robust upfront analysis of varying household needs and suitable delivery approaches (World Bank, 2012c)	Availability and feasibility of other complementary energy technology applications
Argentina **Renewable Energy in the Rural Market Project (1999–2012)**	Promote the use of local resources in terms of technical qualifications to develop an effective renewable energy system market and achieve sustainable operation (World Bank, 2013a)	Qualified technical entities and professionals
	Sustainability of the operation needs effective maintenance and affordable customer service in a market owing to technical complexity (World Bank, 2013a)	Effective operation, maintenance, and after-sales customer service
Peru **Rural Electrification Project (2006–2013)**	Assurances to service providers and distribution companies (World Bank, 2013d)	Effective operation, maintenance, and after-sales customer service
Mali **Household Energy and Universal Access Project (2003–2012)**	The performance of equipment must be improved, and the lack of regulation in ensuring the minimum quality of the equipment must be addressed (World Bank, 2013c)	Product quality assurance and monitoring
Sierra Leone **Energy Access Project (2013–2017)**	The lack of technical know-how and technical capacity (World Bank, 2018a)	Qualified technical entities and professionals
Ethiopia **Electricity Access (Rural) Expansion Project (2007–2014)**	The need to establish a technically qualified private network of energy service delivery companies or small local organisations (World Bank, 2015b) Special attention on training local technicians in the installation of an SHS is required (World Bank, 2015b)	Qualified technical entities and professionals
Tanzania **Energy Development & Access Expansion (2007–2017)**	Technical assistance and building technical capacity play an important role (World Bank, 2018b)	Effective operation, maintenance, and after-sales customer service Qualified technical entities and professionals

development on people and communities. International cooperation of SHS-based rural electrification programmes also facilitates the achievement of SDG17 for strengthening the means of implementation and revitalising global partnerships for sustainable development (United Nations, 2022b).

6. Conclusions

This study emphasises the critical role of technology options, SHS, in achieving SDG7 by 2030 by providing electricity to the world's remaining population without access to electricity. Based

Table C.1

Project	Lessons cited or summarised from the World Bank *Implementation Completion and Results Reports*	Identified project design and implementation barriers
Sri Lanka **Renewable Energy for Rural Economic Development Project (2002–2011)**	Long-term involvement is essential (World Bank, 2012a)	Sustainability of the project
	The implementing body needs to have ownership, authority, responsibility to function independently and resolve issues on its own (World Bank, 2012a)	Development of local capacity
Lao PDR **Rural Electrification Phase I Project (2006–2012)**	It takes far longer than one project cycle to influence energy sector policies and institutional capacity building. Sustainability of an SHS programme requires long-term attention and strategy during and beyond the project life (World Bank, 2013e)	Sustainability of the project
	The government developed a monitoring mechanism to ensure the achievement of the targets in a timely and effective manner (World Bank, 2013e) Management of the social and environmental impact of the project implementation (World Bank, 2013e)	Monitoring and evaluation of the project
	The government set clear targets for electricity access to ensure the achievement of the targets (e.g., targeting the gender and extreme poverty dimensions of rural electrification) in a timely and effective manner (World Bank, 2013e)	Clearly defined project objectives
Philippines **Rural Power Project (2003–2012)**	Ensure sustainability in different ways (World Bank, 2013f)	Sustainability of the project
Cambodia **Rural Electricity and Transmission Project (2005–2012)**	A well-designed M&E framework is essential, and sector-level goals should be included (World Bank, 2012c)	Monitoring and evaluation of the project
	Decision-makers should equip key sector participants, including permitting bodies, financing institutions, developers, regulatory entities, etc., with necessary resources, tools, and skills (World Bank, 2012c)	Development of local capacity
Argentina **Renewable Energy in the Rural Market Project (1999–2012)**	The effectiveness of short-term instruments in addressing long-term rural development challenges (World Bank, 2013a)	Sustainability of the project
	Identification of project areas, regions, and population in line with government's policy orientation (World Bank, 2013a)	Clearly defined project objectives
	Effective identification of the social and environmental impact of the projects to safeguard the implementation of the projects (World Bank, 2013a)	Monitoring and evaluation of the project
Peru **Rural Electrification Project (2006–2013)**	Potential conflict between the long-term nature of rural electrification and short-term political objectives requires a sustained commitment and understanding by the authorities to avoid distortions in the programme's design and implementation (World Bank, 2013d)	Clearly defined project objectives
	Effective identification of social and environmental impact (World Bank, 2013d) Effective monitoring and evaluation of the project needs precise key performance indicators (KPIs) (World Bank, 2013d)	Monitoring and evaluation of the project
	Building the capacity of communities, individuals, and NGOs to improve livelihoods through the use of electricity (World Bank, 2013d)	Development of local capacity
Mali **Household Energy and Universal Access Project (2003–2012)**	Simple and robust monitoring for project implementation (World Bank, 2013c)	Monitoring and evaluation of the project
Burkina Faso **Energy Access Project (2007–2014)**	Early detection of implementation weakness and the monitoring and evaluation of the project, such as tender design, procurement procedures, mixing objectives (electricity and fuel wood substitution), too many institutions, human resources of agencies, financial management, safeguard guidelines, and beneficiary survey, can prevent implementation delays (World Bank, 2015a)	Monitoring and evaluation of the project
Guinea **Decentralized Rural Electrification Project (2002–2013)**	Social and economic consequences within the beneficiary communities must be (World Bank, 2015c) A well-designed M&E framework should be in place and allow for the uncertainties of financing, technology, and approach aspects (World Bank, 2015c)	Monitoring and evaluation of the project
Sierra Leone **Energy Access Project (2013–2017)**	Compliance with social and environmental safeguards are essential in fragile environments (World Bank, 2018a) Adequate M&E and compliance with social and environmental safeguards are essential for effective supervision in fragile environments (World Bank, 2018a)	Monitoring and evaluation of the project

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on the field experiences of the 16 SHS-based World Bank electrification projects that were implemented in the remote rural areas of developing countries with low-electrification rates from 2000 to 2020, this work identifies three major internal factors and two external factors that may affect the successful implementation.

The internal factors that emerge within the project and arise primarily during its design and implementation include the following: (1) financial barriers: barriers on subsidies and investment support; barriers on risk management and commercial viability; barriers on credit services and support; and barriers on

Table C.1 (*continued*).

Project	Lessons cited or summarised from the World Bank *Implementation Completion and Results Reports*	Identified project design and implementation barriers
Ethiopia **Electricity Access (Rural) Expansion Project (2007–2014)**	Project implementation was affected by extensive delays and unanticipated risks (World Bank, 2015b)	Monitoring and evaluation of the project
Uganda **Energy for Rural Transformation Project (2009–2016)**	Effectiveness of independent verification agents plays a key role in achieving the project objectives and monitoring the progress of the project implementation (World Bank, 2017a)	Monitoring and evaluation of the project
Mozambique **Energy Development and Access Project (2010–2017)**	Project objectives must be clearly defined (World Bank, 2017b)	Clearly defined project objectives
Tanzania **Energy Development & Access Expansion (2007–2017)**	Social and environmental safeguards aspects must be systematically addressed and dealt with (World Bank, 2018b)	Monitoring and evaluation of the project

Table D.1

Project	Lessons cited or summarised from the World Bank *Implementation Completion and Results Reports*	Identified political and institutional barriers
Mongolia **Renewable Energy and Rural Electricity Access Project (2006–2012)**	Ensure a rural electrification programme's institutional sustainability and integrate the programme into energy sector policy, energy regulatory framework, and tariff structure (World Bank, 2006) Focus is needed on institutional aspects to avoid institutional deficiencies that threaten long-term sustainability (World Bank, 2012b)	Institutional framework and its sustainability
Lao PDR **Rural Electrification Phase I Project (2006–2012)**	There are multiple implementers of electrification projects at both national and provincial levels (World Bank, 2013e) Donor support is united in a single programme and operated based on the same operational guidelines to maximum efficiency (World Bank, 2013e)	Institutional framework and its sustainability
Cambodia **Rural Electricity and Transmission Project (2005–2012)**	The basic policy and enabling regulatory environment should be simple, transparent, and predictable (World Bank, 2012c)	Institutional framework and its sustainability
Argentina **Renewable Energy in the Rural Market Project (1999–2012)**	Rural electrification entails structural changes in the electricity market that require a revision or update of the regulatory regime (World Bank, 2013a)	Institutional framework and its sustainability
Peru **Rural Electrification Project (2006–2013)**	Potential conflict between the long-term nature of rural electrification and short-term political objectives requires a sustained commitment and understanding of authorities to avoid distortions in the programme's design and implementation (World Bank, 2013d)	Political support and commitment from the community and local political leaders
Mali **Household Energy and Universal Access Project (2003–2012)**	Active and sustained participation of community leaders (World Bank, 2013c)	Political support and commitment from the community and local political leaders
Sierra Leone **Energy Access Project (2013–2017)**	Changes in policies and energy sector (World Bank, 2018a)	Institutional framework and its sustainability
Ethiopia **Electricity Access (Rural) Expansion Project (2007–2014)**	Government commitment is needed to ensure longer-term sustainability (World Bank, 2015b)	Political support and commitment from the community and local political leaders
	A strong and clear institutional and policy framework for the planning and implementation of off-grid electrification is important (World Bank, 2015b)	Institutional framework and its sustainability
Tanzania **Energy Development & Access Expansion (2007–2017)**	Transparent, comprehensive, and stable government policies and regulatory framework (World Bank, 2018b)	Institutional framework and its sustainability
Mozambique **Energy Development and Access Project (2010–2017)**	The lengthy and unclear approval process of large contracts and disbursement systems can affect project implementation (World Bank, 2017b) Lack of understanding of the government's large contract clearance procedures and the lengthy approval process affects project implementation (World Bank, 2017b) Government accounts and systems caused delays in project implementation, particularly flow-of-funds and disbursement system (World Bank, 2017b)	Institutional framework and its sustainability

partnerships with the local banking sector, micro-finance institutions, private sectors and NGOs; (2) technical barriers: barriers on effective operation, maintenance and after-sales technical customer service; barriers on qualified technical entities and professionals; barriers on product quality assurance and monitoring; and barriers on the availability and feasibility of other complementary energy technology applications; (3) project design and implementation barriers: barriers on the monitoring and evaluation of the project; barriers on the sustainability of the project; barriers on the development of local capacity; and barriers on clearly defined project objectives.

The external factors that emerge outside the project and are already existing in the societal context include the following: (1) political and institutional barriers: barriers on the institutional framework and its sustainability; and barriers on political support

Table E.1

Project	Lessons cited or summarised from the World Bank *Implementation Completion and Results Reports*	Identified social and cultural barriers
Sri Lanka **Renewable Energy for Rural Economic Development Project (2002–2011)**	Building trust and maintaining ongoing dialogue among various stakeholders (World Bank, 2012a)	Building trust, relationships, confidence and partnerships among stakeholders Maintaining ongoing dialogues, coordination and cooperation among stakeholders
Bangladesh **Rural Electrification and Renewable Energy Development Project (2002–2012)**	Culture and historical presence of microfinance institutions and NGOs leads to greater trust and larger uptake of SHSs (World Bank, 2013b)	Building trust, relationship, confidence and partnership among stakeholders
Mongolia **Renewable Energy and Rural Electricity Access Project (2006–2012)**	Consumers are willing to pay for good quality and reliable products and services if they are well informed (World Bank, 2012b) Consumers can have access to SHS-related information, instructions, sample items, and assistance for purchase (World Bank, 2006)	Sociocultural perceptions of SHSs
	Rural energy programmes must maximise the private sector, e.g., SMEs, social service institutions, communities, and stakeholders' participation, and build partnerships (World Bank, 2006)	Building trust, relationships, confidence and partnerships among stakeholders
	Transfer of international experience must be customised to suit local conditions and the flexibility to change must be based on evidence on the ground (World Bank, 2012b) Take an integrated approach to link rural electricity services with rural development, income-generating activities, and livelihood support (World Bank, 2006)	Adapting to changing international and local conditions
Lao PDR **Rural Electrification Phase I Project (2006–2012)**	Electricité du Laos has been a key and keen facilitator and front-line partner in implementing electrification programmes (World Bank, 2013e) Importance of partnerships for the national electrification programme (World Bank, 2013e)	Building trust, relationships, confidence and partnerships among stakeholders
Philippines **Rural Power Project (2003–2012)**	Effective coordination of different government and donor initiatives, including government, donor, and private sector solar PV initiatives, targeting the same issue to avoid overlapping efforts and resource waste (World Bank, 2013f)	Maintaining ongoing dialogues, coordination and cooperation among stakeholders
Argentina **Renewable Energy in the Rural Market Project (1999–2012)**	Importance of dissemination (World Bank, 2013a)	Sociocultural perceptions of SHSs
	Project design should be flexible enough to adapt to changing external and internal conditions that may arise (World Bank, 2013a)	Adapting to changing international and local conditions
Peru **Rural Electrification Project (2006–2013)**	Building alliances with and empowering local governments, distribution utilities, and other local/regional stakeholders could be an effective way to achieve greater sustainability (World Bank, 2013d) Actively involving a considerable number of women (World Bank, 2013d)	Building trust, relationships, confidence and partnerships among stakeholders
	Improving the relationship between the client and the electricity company (World Bank, 2013d)	Maintaining ongoing dialogues, coordination and cooperation among stakeholders
	Helping create an awareness of project activities (World Bank, 2013d)	Sociocultural perceptions of SHSs
Mali **Household Energy and Universal Access Project (2003–2012)**	Low interest from the community for SHSs owing to the limited electricity generation capacity, which cannot meet the electricity demand (World Bank, 2013c)	Sociocultural perceptions of SHSs
	Partnership with the local banking sector must be strengthened to stimulate income-generating activities after electrification (World Bank, 2013c) Bottom-up approach of engagement of local private operators was successful (World Bank, 2013c)	Building trust, relationships, confidence and partnerships among stakeholders
Ethiopia **Electricity Access (Rural) Expansion Project (2007–2014)**	Potential roles of the banking institutions, private sector, rural cooperatives, and PPP must be specified (World Bank, 2015b)	Building trust, relationships, confidence and partnerships among stakeholders

and commitment from the community and local political leaders; (2) social and cultural barriers: barriers on building trust, relationships, confidence and partnerships among stakeholders; barriers on the sociocultural perceptions of SHSs; barriers on maintaining ongoing dialogues, coordination and cooperation among stakeholders; and barriers on adapting to changing international and local conditions.

The policy implications from these lessons provide valuable practical knowledge and insights into the ongoing and upcoming challenges to achieving SDG7—universal access to electricity: (1) for an electrification programme in a remote rural area to succeed, external factors such as political, institutional, social and cultural barriers must be overcome; (2) affordability for the remaining population without access to the electricity needs to be secured; (3) balancing SHSs with possible future grid extensions, mini-grid distribution systems or other complementary energy technology applications must be considered while planning; (4) the inclusion of multi-stakeholders at the local level with a service-based approach rather than a supply-based approach needs to be considered; and (5) a holistic approach that involves not only SDG7 but also other SDGs and national development plans needs to be adopted.

According to the findings, the World Bank projects have succeeded in increasing access to electricity but encountered various internal and external barriers and challenges that may limit their effects and impacts. For individuals with pre-existing socioeconomic disadvantages, it is even more important to address the deep inequalities in electricity access that significantly affect human development and worsen with a disproportionate impact during this research period in the era of the COVID-19 pandemic and increasing conflicts around the world.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

All the data used for analysis in this study can be retrieved from the World Bank Project Database:https://projects.worldbank.org/en/projects-operations/projects-home.

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Ethical statement

The author read, understood, and complied with *Elsevier's Terms & Conditions*, *Ethical Guidelines*, and *Ethics in Publishing*.

Appendix A. Financial barriers of the World Bank's SHS-based rural electrification programmes in developing countries (Compiled by the author based on World Bank, 2006, 2012a,b,c, 2013a,b,c,d,e,f, 2015b,c, 2017a, 2018b)

See Table A.1.

Appendix B. Technical barriers of the World Bank's SHS-based rural electrification programmes in developing countries (Compiled by the author based on World Bank, 2012a,b,c, 2013a,c,d,e, 2015b, 2018a,b)

See Table B.1.

Appendix C. Project design and implementation barriers of the World Bank's SHS-based rural electrification programmes in developing countries (Compiled by the author based on World Bank, 2012a,c, 2013a,c,d,e,f, 2015a,b,c, 2017a,b, 2018a,b)

See Table C.1.

Appendix D. Political and institutional barriers of the World Bank's SHS-based rural electrification programmes in developing countries (Compiled by the author based on World Bank, 2006, 2012b,c, 2013a,c,d,e, 2015b, 2017b, 2018a,b)

See Table D.1.

Appendix E. Social and cultural barriers of the World Bank's SHS-based rural electrification programmes in developing countries (Compiled by the author based on World Bank, 2006, 2012a,b,c, 2013a,b,c,d,e, 2015b)

See Table E.1.

References

Abu Saim, Md., Khan, I., 2021. Problematizing solar energy in Bangladesh: Benefits, burdens, and electricity access through solar home systems in remote islands. Energy Res. Soc. Sci. 74.
AGECC (The Secretary-General's Advisory Group on Energy and Climate Change), 2010. Energy for a Sustainable Future, the Secretary-General Advisory Group on Energy and Climate Change: Summary Report and Recommendations. United Nations, New York.
Aklin, M., Urpelainen, J., 2021. The evolving role of solar-based lighting solutions in rural India: Global lessons for distributed renewables. Energy Sustain. Dev. 63, 113–118.
Al-Ismaily, H.A., Probert, D., 1998. Photovoltaic electricity prospects in oman. Appl. Energy 59 (2–3), 97–124.
Asian Development Bank, 2005. Technical Assistance to People's Republic of China: Alternative Energy Supply for Rural Poor in Remote Areas. Asian Development Bank, Manila.
Azimoh, C.L., Klintenberg, P., Wallin, F., Karlsson, B., 2015. Illuminated but not electrified: an assessment of the impact of Solar Home System on rural households in South Africa. Appl. Energy 155, 354–364.
Azimoh, C.L., Wallin, F., Klintenberg, P., Karlsson, B., 2014. An assessment of unforeseen losses resulting from inappropriate use of solar home systems in South Africa. Appl. Energy 136, 336–346.
Babbie, E., 2013. The Practice of Social Research, thirteenth ed. Wadsworth, Cengage Learning, London.
Balint, P.J., 2006. Bringing solar home systems to rural El Salvador: lessons for small NGOs. Energy Policy 34 (6), 721–729.
Barnes, D.F., 2011. Effective solutions for rural electrification in developing countries: Lessons from successful programs. Curr. Opin. Environ. Sustain. 3 (4), 260–264.
Bhattacharjee, C.R., 2002. Socio-economic aspects of an odd-grid SPV power supply system in an island village in India. Int. J. Environ. Sustain. Dev. 1 (4), 397–402.
Bhattacharyya, S.C., 2006. Renewable energies and the poor: niche or nexus? Energy Policy 34 (6), 659–663.
Bhattacharyya, S.C., 2013. Financing energy access and off-grid electrification: A review of status, options and challenges. Renew. Sustain. Energy Rev. 20, 462–472.
Biswas, W.K., Diesendorf, M., Bryce, P., 2004. Can photovoltaic technologies help attain sustainable rural development in Bangladesh? Energy Policy 32 (10), 1199–1207.
Bradbrook, A.J., Gardam, J.G., 2006. Placing access to energy services within a human right framework. Hum. Rights Q. 28, 389–415.
Bradbrook, A.J., Gardam, J.G., Cormier, M., 2008. A human dimension to the energy debate: Access to modern energy services. J. Energy Natl. Resour. Law 26, 526–552.
Chaurey, A., Kandpal, T.C., 2010. A techno-economic comparison of rural electrification based on solar home systems and PV microgrids. Energy Policy 38 (6), 3118–3129.
Chowdhury, S.A., Mourshed, M., 2016. Off-grid electrification with solar home systems: An appraisal of the quality of components. Renew. Energy 97, 585–598.
Demirci, I., Akar, O., Ozturk, Z., 2022. Technical-environmental-economic evaluation of biomass-based hybrid power system with energy storage for rural electrification. Renew. Energy 195, 1202–1217.
Doll, C.N.H., Pachauri, S., 2010. Estimating rural populations without access to electricity in developing countries through night-time light satellite imagery. Energy Policy 38, 5661–5670.
Drennen, T.E., Erickson, J.D., Chapman, D., 1996. Solar power and climate change policy in developing countries. Energy Policy 24 (1), 9–16.
Ellegård, A., Arvidson, A., Nordström, M., Kalumiana, O.S., Mwanza, C., 2004. Rural people pay for solar: Experiences from the Zambia PV-ESCO project. Renew. Energy 29 (8), 1251–1263.
Fara, S., Finta, D., Micu, G., 1998. Problems of village electrification based on PV systems in Romania: Individual solar home systems for settlements in the Cerna Valley. Renew. Energy 15 (1–4), 519–522.
Flavin, C., Aeck, M.H., 2005. Energy for development: The potential role of renewable energy in meeting the millennium development goals. In: Paper Prepared for the Renewable Energy Policy Network for the 21st Century. The World Watch, Washington, D.C.

Friebe, C.A., von Flotow, P., Täube, F.A., 2013. Exploring the link between products and services in low-income markets—Evidence from solar home systems. Energy Policy 52, 760–769.
Frigo, G., Baumann, M., Hillerbrand, R., 2021. Energy and the good life: Capacities as the foundation of the right to access energy services. J. Hum. Dev. Capab. http://dx.doi.org/10.3917/eufor.378.0026.
Hadjadj, A., Atia, A., Ben, B., Arıcı, M., Naili, N., Kaddour, A., 2021. Energy and exergy analyses of a helicoidal water to air geothermal heat exchanger for arid regions. Energy Sources A http://dx.doi.org/10.1080/15567036.2021.1970859.
Hesselman, M., Varo, A., Guyet, R., Thomson, H., 2021. Energy poverty in the COVID-19 era: Mapping global responses in light of momentum for the right to energy. Energy Res. Soc. Sci. 81, 102246.
IEA (International Energy Agency), 2002. World Energy Outlook 2002. International Energy Agency, Paris.
IEA (International Energy Agency), 2003. World Energy Outlook 2003. International Energy Agency, Paris.
IEA (International Energy Agency), 2004. World Energy Outlook 2004. International Energy Agency, Paris.
IEA (International Energy Agency), 2010. Energy Poverty: How to Make Modern Energy Access Universal?. International Energy Agency, Paris.
IEA (International Energy Agency), 2011. World Energy Outlook 2011. International Energy Agency, Paris.
IEA (International Energy Agency), 2012. World Energy Outlook 2012. International Energy Agency, Paris.
IEA (International Energy Agency), 2014. Africa Energy Outlook: A Focus on Energy Prospects in Sub-Saharan Africa. International Energy Agency, Paris.
IEA (International Energy Agency), 2017. Energy Access Outlook 2017: From Poverty to Prosperity. International Energy Agency, Paris.
IEA (International Energy Agency), 2019. Africa Energy Outlook 2019. International Energy Agency, Paris.
IEA (International Energy Agency), 2022a. Access to electricity database. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity (Accessed 7 2022).
IEA (International Energy Agency), 2022b. Access to electricity. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity (Accessed 10 2022).
IEA (International Energy Agency), 2022c. Covid-19 continues to reverse electricity access progress. https://www.iea.org/reports/sdg7-data-and-projections/access-to-electricity (Accessed 10 2022).
IEA (International Energy Agency), 2022d. Least developed countries receive only a fraction of international financing for renewable energy. https://unstats.un.org/sdgs/report/2021/goal-07/ (Accessed 10 2022).
Kamalapur, G.D., Udaykumar, R.Y., 2011. Rural electrification in India and feasibility of photovoltaic solar home systems. Int. J. Electr. Power Energy Syst. 33 (3), 594–599.
Khanna, R.A., Li, Y., Mhaisalkar, S., Kumar, M., Liang, L.J., 2019. Comprehensive energy poverty index: Measuring energy poverty and identifying micro-level solutions in South and Southest Asia. Energy Policy 132, 379–391.
Kumar, R., Channi, H.K., 2022. A PV-biomass off-grid hybrid renewable energy system (HRES) for rural electrification: Design, optimization and techno-economic-environmental analysis. J. Clean. Prod. 349, 131347.
Kumar, P., Pal, N., Sharma, H., 2022. Optimization and techno-economic analysis of a solar photo-voltaic/biomass/diesel/battery hybrid off-grid power generation system for rural remote electrification in eastern India. Energy 247.
Leary, J., Schaube, P., Clementi, L., 2019. Rural electrification with household wind systems in remote high wind regions. Energy Sustain. Dev. 52, 154–175.
Lebbihiat, N., Atia, A., Arıcı, M., Meneceur, N., 2021. Geothermal energy use in Algeria: A review on the current status compared to the worldwide, utilization opportunities and countermeasures. J. Clean. Prod. 302, 126950.
Lebbihiat, N., Atia, A., Arıcı, M., Meneceur, N., Hadjadj, A., Chetioui, Y., 2022. Thermal performance analysis of helical ground-air heat exchanger under hot climate: In situ measurement and numerical simulation. Energy 254, 124429.
Lemaire, X., 2009. Fee-for-service companies for rural electrification with photovoltaic systems: The case of Zambia. Energy Sustain. Dev. 13 (1), 18–23.
Li, J., Liu, P., Li, Z., 2020. Optimal design and techno-economic analysis of a solar-wind-biomass off-grid hybrid power system for remote rural electrification: A case study of west China. Energy 208, 118387.
López-González, A., Ranaboldo, M., Domenech, B., Ferrer-Martí, L., 2020. Evaluation of small wind turbines for rural electrification: Case studies from extreme climatic conditions in venezuela. Energy 209, 118450.
López-Vargas, A., Fuentes, M., Vivar, M., 2021. Current challenges for the advanced mass scale monitoring of solar home systems: A review. Renew. Energy 163, 2098–2114.
Mamaghani, A.H., Escandon, S.A.A., Najafi, B., Shirazi, A., Rinaldi, F., 2016. Techno-economic feasibility of photovoltaic, wind, diesel and hybrid electrification systems for off-grid rural electrification in Colombia. Renew. Energy 97, 293–305.
Martinot, E., Cabraal, A., Mathur, S., 2001. World bank/GEF solar home system projects: experiences and lessons learned 1993–2001. Renew. Sustain. Energy Rev. 5 (1), 39–57.
Modi, V., MaDade, S., Lallement, D., Saghir, J., 2005. Energy services for the millennium development goals. In: Energy Sector Management Assistance Programme, United Nationals Development Programme, UN Millennium Project. World Bank, New York.
Narayan, N., Chamseddine, A., Vega-Garita, V., Qin, Z., Popovic-Gerber, J., Bauer, P., Zeman, M., 2019. Exploring the boundaries of Solar Home Systems (SHS) for off-grid electrification: Optimal SHS sizing for the multi-tier framework for household electricity access. Appl. Energy 240, 907–917.
Newcombe, A., Ackom, E.K., 2017. Sustainable solar home systems model: Applying lessons from Bangladesh to Myanmar's rural poor. Energy Sustain. Dev. 38, 21–33.
Ngai, J.S., 2012. Energy as a human right in armed conflict: A question of universal need, survival, and human dignity. Brooklyn J. Int. Law 37, 579–622.
Njoh, A.J., Etta, S., Ngyah-Etchutambe, I.B., Enomah, L.E.D., Tabrey, H.T., Essia, W., 2019. Opportunities and challenges to rural renewable energy projects in Africa: Lessons from the Esaghem Village, Cameroon solar electrification project. Renew. Energy 131, 1013–1021.
Nussbaumer, P., Bazilian, M., Modi, V., 2012. Measuring energy poverty: Focusing on what matters. Renew. Sustain. Energy Rev. 16 (1), 231–243.
Pachauri, S., Spreng, D., 2011. Measuring and monitoring energy poverty. Energy Policy 39 (12), 7497–7504.
Practical Action, 2009. Energy Poverty: The Hidden Energy Crisis. Practical Action Publishing, Rugby, UK.
Practical Action, 2010. Poor People's Energy Outlook 2010: Total Energy Access. Practical Action Publishing, Rugby, UK.
Practical Action, 2012. Poor People's Energy Outlook 2012: Energy for Earning a Living. Practical Action Publishing, Rugby, UK.
Practical Action, 2013. Poor People's Energy Outlook 2013: Energy for Community Services. Practical Action Publishing, Rugby, UK.
Practical Action, 2014. Poor People's Energy Outlook 2014: Key Messages on Energy for Poverty Alleviation. Practical Action Publishing, Rugby, UK.
Practical Action, 2016. Poor People's Energy Outlook 2016: National Energy Access Planning from the Bottom Up. Practical Action Publishing, Rugby, UK.
Practical Action, 2017. Poor People's Energy Outlook 2017: Financing National Energy Access a Bottom-Up Approach. Practical Action Publishing, Rugby, UK.
Practical Action, 2018. Poor People's Energy Outlook 2018: Achieving Inclusive Energy Access At Scale. Practical Action Publishing, Rugby, UK.
Practical Action, 2019. Poor People's Energy Outlook 2019 – Enabling Energy Access: From Villages to Nations. Practical Action Publishing, Rugby, UK.
Rahman, S.M., Ahmad, M.M., 2013. Solar home system (SHS) in rural Bangladesh: Ornamentation or fact of development? Energy Policy 63, 348–354.
Rao, N.D., Pachauri, S., 2017. Energy access and living standards: Some observations on recent trends. Environ. Res. Lett. 12 (2).
Riva, F., Ahlborg, H., Hartvigsson, E., Pachauri, S., Colombo, E., 2018. Electricity access and rural development: Review of complex socio-economic dynamics and causal diagrams for more appropriate energy modelling. Energy Sustain. Dev. 43, 203–223.
Sagar, A.D., 2005. Alleviating energy poverty for the world's poor. Energy Policy 33 (11), 1367–1372.
Sarkodie, S.A., Adams, S., 2020. Electricity access, human development index, governance and income inequality in Sub-Saharan Africa. Energy Rep. 6, 455–466.
Schillebeeckx, S.J.D., Parikh, P., Bansal, R., George, G., 2012. An integrated framework for rural electrification: Adopting a user-centric approach to business model development. Energy Policy 48, 687–697.
Shyu, C.-W., 2012. Rural electrification program with renewable energy sources: An analysis of China's Township Electrification Program. Energy Policy 51, 842–853.
Shyu, C.-W., 2013. End-users' experiences with electricity supply from stand-alone mini-grid solar PV power stations in rural areas of western China. Energy Sustain. Dev. 17 (4), 391–400.
Shyu, C.-W., 2014. Ensuring access to electricity and minimum basic electricity needs as a goal for the post-MDG development agenda after 2015. Energy Sustain. Dev. 19, 29–38.
Shyu, C.-W., 2020. Energy poverty alleviation in Southeast Asian countries: policy implications for improving access to electricity. J. Asian Public Policy 9, 7–121.
Shyu, C.-W., 2021. A framework for 'right to energy' to meet UN SDG7: Policy implications to meet basic human energy needs, eradicate energy poverty, enhance energy justice, and uphold energy democracy. Energy Res. Soc. Sci. 79, 102199.
Sovacool, B., 2018. Success and failure in the political economy of solar electrification: Lessons from world bank solar home system (SHS) projects in Sri Lanka and Indonesia. Energy Policy 123, 482–493.

Sovacool, B., Drupady, I., 2012. Energy Access, Poverty, and Development: The Governance of Small-Scale Renewable Energy in Developing Asia. Ashgate Publishing, Farnham, UK.
Tully, S., 2006a. The human right to access electricity. Electr. J. 19, 30–39.
Tully, S., 2006b. The contribution of human rights to universal energy access. Northwestern J. Int. Hum. Rights 4, 518–548.
Tully, S., 2008. The human right to access clean energy. J. Green Build. 3, 140–148.
United Nations Development Programme (UNDP), World Health Organization (WHO), 2009. The Energy Access Situation in Developing Countries: A Review Focusing on the Least Developed Countries and Sub-Saharan Africa. United Nations Development Programme (UNDP), New York.
United Nations, 2022a. Sustainable Development Goal 7 - Ensure Universal Access To Affordable, Reliable and Modern Energy Services. Sustainable Development Goal Knowledge Platform. United Nations, https://sdgs.un.org/goals/goal7 (Accessed 25 2022).
United Nations, 2022b. The 17 goals. In: Sustainable Development Goal Knowledge Platform. United Nations, New York, https://sdgs.un.org/goals (Accessed 25 2022).
United Nations Department of Economic and Social Affairs, 2022. Least developed countries (LDCs) database. https://www.un.org/development/desa/dpad/least-developed-country-category.html (Accessed 25 2022).
Urmee, T., Harries, D., Schlapfer, A., 2009. Issues related to rural electrification using renewable energy in developing countries of Asia and Pacific. Renew. Energy 34 (2), 354–357.
Van der Vleuten, F., Stam, N., van der Plas, R., 2007. Putting solar home system programmes into perspective: What lessons are relevant? Energy Policy 35 (3), 1439–1451.
Walker, G., 2015. The right to energy: meaning, specification and the politics of definition. L'Eur. Form. 378, 26–38. http://dx.doi.org/10.3917/eufor.378.0026.
Wamukonya, N., 2007. Solar home system electrification as a viable technology option for Africa's development. Energy Policy 35 (1), 6–14.
Wassie, Y.T., Adaramola, M.S., 2021. Socio-economic and environmental impacts of rural electrification with solar photovoltaic systems: Evidence from southern Ethiopia. Energy Sustain. Dev. 60, 52–66.
World Bank, 2000. Energy Service for the World's Poor. World Bank, Washington, D.C.
World Bank, 2006. Implementation Completion and Results Report on Renewable Energy and Rural Electricity Access Project (Mongolia). World Bank, Washington, D.C.
World Bank, 2008. The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits, an Independent Evaluation Group (IEG) Impact Evaluation. World Bank, Washington, D.C.
World Bank, 2012a. Implementation Completion and Results Report on Renewable Energy for Rural Economic Development Project (Sri Lanka). World Bank, Washington, D.C.
World Bank, 2012b. Implementation Completion and Results Report on Renewable Energy and Rural Electricity Access Project (Mongolia). World Bank, Washington, D.C.
World Bank, 2012c. Implementation Completion and Results Report on Rural Electricity and Transmission Project (Cambodia). World Bank, Washington, D.C.
World Bank, 2013a. Implementation Completion and Results Report on Renewable Energy in the Rural Market Project (Argentine). World Bank, Washington, D.C.
World Bank, 2013b. Implementation Completion and Results Report on Rural Electrification and Renewable Energy Development (Bangladesh). World Bank, Washington, D.C.
World Bank, 2013c. Implementation Completion and Results Report on Household Energy and Universal Access Project (Mali). World Bank, Washington, D.C.
World Bank, 2013d. Implementation Completion and Results Report on Rural Electrification Project (Peru). World Bank, Washington, D.C.
World Bank, 2013e. Implementation Completion and Results Report on Rural Electrification Phase I Project of the Rural Electrification (APL) Program (Lao). World Bank, Washington, D.C.
World Bank, 2013f. Implementation Completion and Results Report on Rural Power Project in Support of the First Phase of the Rural Power Development Program (Philippines). World Bank, Washington, D.C.
World Bank, 2015a. Implementation Completion and Results Report on Energy Access Project (Burkina Faso). World Bank, Washington, D.C.
World Bank, 2015b. Implementation Completion and Results Report on Second Electricity Access (Rural) Expansion Project (Ethiopia). World Bank, Washington, D.C.
World Bank, 2015c. Implementation Completion Report (ICR) Review on Decentralized Rural Electrification Project (Guinea). World Bank, Washington, D.C.
World Bank, 2017a. Implementation Completion Report (ICR) Review on Energy for Rural Transformation Project (Uganda). World Bank, Washington, D.C.
World Bank, 2017b. Implementation Completion Report (ICR) Review on Energy Development and Access Project (Mozambique). World Bank, Washington, D.C.
World Bank, 2018a. Implementation Completion Report (ICR) Review on Energy Access Project (Sierra Leone). World Bank, Washington, D.C.
World Bank, 2018b. Implementation Completion Report (ICR) Review on Energy Development & Access Expansion (Tanzania). World Bank, Washington, D.C.
World Bank, 2022a. Access to electricity database. https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS (Accessed 7 2022).
World Bank, 2022b. World Bank Project database. https://projects.worldbank.org/en/projects-operations/projects-home (Accessed 7 2022).
Yang, M., 2003. China's rural electrification and poverty reduction. Energy Policy 31 (3), 283–295.
Zaman, R., Borsky, S., 2021. The impact of supply structure on solar home system installations in rural off-grid areas. Environ. Innov. Soc. Transit. 40, 625–644.
Zhou, A., Byrne, J., 2002. Renewable energy for rural sustainability: Lessons from China. Bull. Sci. Technol Soc. 22 (2), 123–131.