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Ekaterine Lomia

THE ENERGY-DEVELOPMENT NEXUS

SECURITY, TRANSFORMATION AND GLOBAL PERSPECTIVES

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PREFACE

The book unites three chapters that explore the deep relationship between energy and development in the modern world. As countries face rising energy demands, new technologies, and global political uncertainties, understanding this relationship has never been more important. This book offers a simple, accessible overview of how energy shapes development - and how development challenges shape energy choices.

Chapter 1 introduces the general link between energy and development, especially in developing countries. It shows why reliable and affordable energy is essential for growth, industry, and improving people's quality of life. At the same time, it highlights the difficulties many countries still face in securing stable energy access.

Chapter 2 takes a closer look at Nigeria as an example. The chapter explains how Nigeria's rich natural resources interact with its economic needs, political realities, and development goals. Through this case study, readers can see both the potential benefits and the challenges that come with managing energy resources in a developing country.

Chapter 3 looks at the bigger picture - the global energy landscape. It discusses energy security, international supply and demand, and how global politics and economic trends influence national energy strategies. This chapter helps readers understand why energy decisions made in one part of the world can affect many others.

Together, these chapters offer a clear, straightforward view of how energy and development are linked at local, national, and global levels. As the editor, I hope this book supports ongoing discussions and helps readers better understand the complex but critical role of energy in shaping our future.

Editor
PhD Ekaterine Lomia
November 21, 2025
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CHAPTER 1
THE RELATIONSHIP BETWEEN ENERGY AND DEVELOPMENT: PERSPECTIVES FROM DEVELOPING COUNTRIES

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INTRODUCTION

Energy is widely recognized as a foundational enabler of socio-economic development, driving industrial growth, poverty alleviation, and enhanced living conditions (Sachs et al., 2020). In many developing regions, the connection between energy and development is particularly stark, where more than 700 million people lack access to electricity, and 2.4 billion still depend on traditional, polluting fuels such as wood and charcoal for cooking (International Energy Agency [IEA], 2022).

The lack of reliable energy limits economic opportunities, constrains education and health services, and perpetuates cycles of poverty. This chapter synthesizes interdisciplinary insights from economics, environmental science, and public policy to analyze how energy systems shape development outcomes. It focuses on three core dimensions: (1) energy access as a catalyst for human development, (2) the influence of energy mixes on sustainable economic growth, and (3) structural and institutional barriers to energy transformation in low-income settings.

Access to modern energy services is fundamental to realizing the United Nations' Sustainable Development Goals (SDGs), especially SDG 7, which targets universal energy access by 2030 (United Nations, 2015). Studies show that rural electrification improves educational outcomes, increases time for income-generating activities, and enhances healthcare delivery through powered clinics and cold chains for vaccines (Pachauri et al., 2013; Modi et al., 2006).

For example, electrified schools have demonstrated higher student attendance and better academic performance, while homes with lighting extend productive hours into the evening (Barron & Torero, 2017). Moreover, access to clean cooking technologies reduces household air pollution, which is a leading cause of respiratory illness, particularly among women and children (World Health Organization [WHO], 2021).

The composition of a country's energy mix also significantly affects its long-term development trajectory. Fossil fuel dependence has historically underpinned industrialization, but this approach has also contributed to global climate change, environmental degradation, and resource depletion (Stern, 2007).

Increasingly, countries are recognizing the importance of integrating renewable energy sources such as solar, wind, and hydropower into their national grids to achieve both economic resilience and environmental sustainability (Jacobson et al., 2017). Empirical research suggests that renewables can not only reduce greenhouse gas emissions but also create jobs, lower energy costs, and enhance energy security (IRENA, 2023; Sovacool et al., 2021). In Sub-Saharan Africa, decentralized solar microgrids are enabling leapfrogging of traditional infrastructure models, providing electricity to remote villages at lower cost and faster deployment rates than centralized fossil-fuel systems (Blimpo & Cosgrove-Davies, 2019).

Nevertheless, numerous structural and institutional barriers hinder energy development in resource-constrained regions. These include inadequate investment, weak governance, policy uncertainty, and limited technical capacity (Ahlborg et al., 2015). Financing remains a central challenge, as many utilities are underfunded and unable to attract private capital due to perceived political and regulatory risks (Banerjee et al., 2014). Furthermore, energy infrastructure often prioritizes urban centers and industrial hubs, sidelining rural and marginalized communities (Gerlach & Jacobsson, 2021). Addressing these disparities requires inclusive energy planning, regulatory reform, and international cooperation, particularly in terms of climate finance and technology transfer (Grübler et al., 2012).

Gender dynamics are also crucial in the energy-development equation. Women and girls are disproportionately affected by energy poverty, spending hours each day collecting firewood and being exposed to indoor smoke (Clancy et al., 2012). Empowering women through access to clean energy enhances their education, health, and economic opportunities, creating broader social dividends (Danielsen, 2012). Thus, energy policies must integrate gender-sensitive approaches to ensure equitable benefits across society (Cecelski, 2000).

Finally, digital technologies and innovation hold transformative potential in the energy sector. Smart grids, mobile payment systems, and real-time usage data are improving energy efficiency, reducing transmission losses, and enabling more responsive governance (Van Gevelt, 2014).

In countries like Kenya, mobile-based pay-as-you-go solar systems have scaled rapidly, providing millions with first-time access to electricity (Rolffs et al., 2015). These innovations underscore the importance of local context, user needs, and institutional adaptability in energy system design.

In conclusion, energy access and sustainability are not merely technical challenges but central pillars of development policy. Ensuring affordable, reliable, sustainable, and modern energy for all is essential for inclusive growth, environmental stewardship, and human well-being. Developing countries must navigate complex trade-offs and institutional challenges, but with the right policy mix, innovation, and international support, energy can be harnessed as a powerful lever for transformative development.

1. ENERGY ACCESS AND HUMAN DEVELOPMENT

1.1 Health and Education

Access to energy plays a foundational role in advancing health and education outcomes, particularly in low- and middle-income countries. Household energy access significantly reduces exposure to indoor air pollution, which is responsible for millions of premature deaths annually, especially among women and children who spend substantial time near traditional cooking stoves (Bonjour et al., 2013). Improved access to clean cooking technologies and electricity reduces respiratory illnesses, such as chronic obstructive pulmonary disease and acute lower respiratory infections, which are leading causes of mortality in regions relying on biomass and kerosene fuels (Smith et al., 2014).

Health facilities, particularly in rural and off-grid areas, benefit profoundly from electrification. Electrified clinics can refrigerate vaccines, store essential medicines, and operate diagnostic equipment, leading to improved maternal and child health outcomes (Adair-Rohani et al., 2013). The World Health Organization (WHO) estimates that 60% of healthcare facilities in Sub-Saharan Africa lack reliable electricity, directly impacting the quality of healthcare services and emergency response (WHO, 2015). When electricity is available, facilities can operate beyond daylight hours, enabling emergency obstetric care and enhancing the overall functionality of rural health systems (Mills, 2012).

Education systems also experience transformative impacts from electrification. Schools with access to electricity report higher student attendance, improved teacher retention, and increased use of digital learning tools (Kanagawa & Nakata, 2008). For instance, Rwanda's national school electrification initiative led to a 15% increase in graduation rates in electrified regions over five years, attributed to enhanced evening study opportunities and improved school infrastructure (Peters et al., 2019).

Electricity supports lighting, powering devices, and accessing the internet, which is increasingly vital for digital literacy and participation in the global knowledge economy (UNESCO, 2021). In areas where electricity is lacking, the digital divide in education continues to widen, limiting future employment opportunities for students and perpetuating cycles of poverty.

1.2 Economic Productivity

Beyond health and education, energy access is a critical enabler of economic productivity and inclusive growth. Electrification facilitates the operation of small and medium-sized enterprises (SMEs), supports mechanization in agriculture, and promotes industrialization. Empirical evidence suggests that a 10% increase in electricity coverage is associated with a 1.5% rise in GDP per capita in Sub-Saharan African countries (Dinkelman, 2011). The productivity of microenterprises in India, for example, has shown to be approximately 30% higher when reliable electricity is available, demonstrating the value of consistent energy supply in business operations (Friedman et al., 2017).

In addition to enabling direct economic activities, electricity access enhances labor productivity by reducing time spent on manual and household tasks. Electrified households can use appliances such as water pumps, electric grinders, and lighting for extended working hours, especially in agrarian communities. These gains in time and effort translate to expanded business operations and greater economic inclusion (Banerjee et al., 2016).

However, energy poverty remains unevenly distributed, with rural areas and women-led enterprises often experiencing disproportionate energy access gaps.

Many women entrepreneurs lack access to the energy required to grow businesses beyond subsistence levels, reinforcing gendered economic disparities (Köhlin et al., 2011). Targeted interventions that provide energy services to women-led enterprises, such as microgrid connectivity and affordable financing for energy-efficient equipment, can generate substantial socioeconomic returns (UNDP, 2020).

Scatter plot illustrating a positive logarithmic relationship ($R^2 = 0.82$) between national electrification rates and HDI scores. Notable outliers—such as oil-rich states with low HDI—underscore the influence of governance, wealth distribution, and energy equity (Sovacool, 2012). Countries with high energy revenues but low social investment reveal that electrification alone does not ensure development; inclusive policy frameworks and equitable access are crucial.

Overall, the interplay between energy access and human development is multidimensional. Energy serves as both a direct input into development outcomes—via infrastructure and productivity—and an indirect enabler of equitable growth, social inclusion, and resilience. Efforts to expand energy access must therefore integrate health, education, and economic strategies, ensuring that energy interventions are inclusive, sustainable, and aligned with national development priorities.

2. ENERGY MIX AND SUSTAINABLE DEVELOPMENT

The structure of a country's energy mix plays a pivotal role in shaping its development trajectory. While fossil fuels have historically underpinned industrial and economic growth, their long-term consequences on environmental sustainability and social equity are profound. In contrast, renewable energy sources, particularly in developing nations, present transformative opportunities to enhance energy access, reduce emissions, and create green jobs, all while fostering inclusive economic growth.

2.1 Fossil Fuels: Short-Term Gains, Long-Term Costs

Fossil fuels—coal, oil, and natural gas—have been essential in enabling rapid industrialization, especially in the Global North.

However, these energy sources come with hidden environmental and socio-economic costs that increasingly undermine long-term sustainability (IEA, 2020). Countries reliant on fossil fuels often experience a trade-off between economic gains and ecological degradation. In the case of Nigeria, for example, the exploitation of oil resources in the Niger Delta fueled GDP growth during the early 2000s. Between 2000 and 2020, Nigeria's CO_2 emissions increased by over 40%, reflecting the intensification of fossil-fuel-based activities (World Bank, 2021). This growth, however, came at the expense of environmental integrity—agricultural lands became polluted due to oil spills, and fisheries in the Delta suffered massive losses due to contamination and gas flaring (Ekhator, 2016; Omeje, 2006).

Beyond environmental degradation, over-reliance on fossil fuels creates economic volatility. Global price fluctuations in oil markets often destabilize the fiscal health of exporting countries, impeding long-term planning and development (UNCTAD, 2022). Moreover, fossil fuel subsidies, which many developing countries maintain to shield consumers from high energy prices, can crowd out investments in healthcare, education, and infrastructure (IMF, 2019).

2.2 Renewables as Development Accelerants

The emerging narrative around renewables in developing countries underscores their dual benefit: sustainability and economic inclusion. Renewable energy technologies—particularly decentralized solar and wind—enable off-grid communities to access electricity without the high upfront costs of expanding centralized national grids (REN21, 2021). This approach has proven especially valuable in rural and peri-urban areas where grid connectivity is sparse or unreliable.

One of the most notable examples is the Lake Turkana Wind Power project in Kenya, Africa's largest wind farm. Operational since 2018, the project supplies nearly 15% of Kenya's national electricity demand and has contributed to an 8% reduction in electricity tariffs nationwide (AfDB, 2020). The ripple effect of such a project includes job creation during construction and operations, enhanced investor confidence, and reduced dependence on diesel generators and hydro-based imports from neighboring countries.

Bangladesh offers another compelling example. Its Solar Home Systems (SHS) initiative has connected over 20 million people to electricity since its inception, mostly in remote, rural areas (Barua et al., 2021). Apart from lighting and communication, SHS have spurred micro-enterprises and improved education outcomes by extending study hours after sunset. Furthermore, the renewable energy sector in Bangladesh has created over 150,000 green jobs, especially for youth and women, reflecting the sector's inclusive potential (Mondal & Islam, 2017).

Hydropower, though more centralized than solar or wind, can also be a significant driver of national energy security and economic resilience. Nepal, leveraging its river systems, has invested in a portfolio of small-to-medium hydropower projects. These efforts have reduced its energy import dependency by over 70% and enhanced local economic activity through infrastructure development and community benefit-sharing models (Shrestha et al., 2019).

Countries like Morocco and Vietnam, which derive more than 25% of their energy from renewable sources, recorded an average annual GDP growth of 5.3%. In contrast, fossil-fuel-dependent peers such as Nigeria and Angola recorded just 3.1% (IRENA, 2023). The data suggest that cleaner energy strategies can yield superior development dividends over time.

The economic benefits of renewables extend to enhanced foreign direct investment, improved public health from reduced pollution, and decreased exposure to fossil fuel price shocks (BNEF, 2022). Additionally, renewable energy aligns with global climate commitments, such as those under the Paris Agreement, enabling countries to meet their Nationally Determined Contributions (NDCs) while advancing socio-economic development.

3. CHALLENGES AND INEQUITIES

3.1 Financial and Infrastructural Barriers

Despite growing enthusiasm for renewable energy in the Global South, financial and infrastructural constraints significantly hinder progress. High upfront capital investment remains a major obstacle. Even relatively affordable technologies like pay-as-you-go (PAYG) solar home systems require considerable support to scale.

It is estimated that over USD 2 billion annually in concessional finance is necessary to expand PAYG solar solutions across sub-Saharan Africa (Ardani et al., 2023). The lack of sustainable financial models and limited access to long-term credit compounds this challenge, especially in rural areas where commercial banks perceive renewable ventures as high-risk (Blimpo & Cosgrove-Davies, 2019; Kenfack et al., 2009).

Infrastructure deficits further exacerbate the issue. Many national grids across developing regions are outdated, poorly maintained, and lack the capacity for reliable energy distribution. For instance, Ghana experiences over 50 electricity outages per month, a situation that affects both households and industries and is estimated to cost the country 2% of its GDP annually (Mensah et al., 2021; Gyamfi et al., 2015). Rural electrification is particularly slow due to the high cost of extending grid lines over long distances and through difficult terrain (Kemausuor et al., 2014). Even where infrastructure exists, it is often not resilient to growing climate variability and demand surges. Unreliable electricity supply discourages private investment, weakens industrial output, and compromises essential public services such as healthcare and education (IEA, 2022). As a result, the lack of dependable energy infrastructure creates a feedback loop of underdevelopment, perpetuating energy poverty in the very regions that need access the most.

3.2 Gender and Energy Poverty

Energy poverty is not experienced equally across all populations; gender plays a critical role in determining the burden and impact of energy deficits. Women, particularly in rural areas, are disproportionately affected due to traditional household roles and limited access to clean energy alternatives. Studies show that women spend an average of 8 to 10 hours per week collecting biomass fuels such as firewood and charcoal (Parikh et al., 2012; Oparaocha & Dutta, 2011). This time burden limits opportunities for education, income generation, and political participation. Efforts to introduce clean cooking technologies have shown promise but have not achieved universal reach. For example, in Ethiopia, clean cookstove programs helped reduce indoor air pollution, resulting in a 22% decline in respiratory illnesses among participating households.

However, these programs only reached 35% of female-headed homes due to financial and cultural barriers (Mamuye et al., 2018; Lambe et al., 2015). In many cases, the decision to adopt clean energy solutions is made by men, further marginalizing women's energy needs and preferences (Clancy et al., 2012).

Moreover, access to electricity does not always translate into empowerment. Without inclusive policy frameworks, gender-blind energy programs risk reinforcing existing inequalities. For instance, microgrid projects that fail to provide targeted support for women entrepreneurs often miss out on multiplier benefits for community development (Terrapon-Pfaff et al., 2014; Rewald, 2017). Thus, addressing gender in energy policy requires more than technology dissemination; it necessitates systemic changes that prioritize women's agency and economic participation.

3.3 Climate Vulnerability

Developing countries are caught in the dual bind of needing to expand energy access while also adapting to the impacts of climate change. This is particularly problematic for countries that rely heavily on climate-sensitive energy sources like hydropower. In 2023, Zambia experienced one of its worst droughts in recent history, which reduced hydropower generation by 50%, leading to widespread electricity blackouts (Nkonde et al., 2023; Harrison et al., 2019). Such events expose the vulnerability of energy infrastructure to climate variability, underscoring the urgent need for diversification.

The consequences are not merely technical but deeply socio-economic. Energy disruptions affect food security, water availability, and public health, particularly in rural and peri-urban communities where alternative energy options are limited or nonexistent (Carter et al., 2020; Sovacool, 2016). Climate impacts also alter rainfall patterns, affect solar panel efficiency due to dust and heat, and damage transmission systems during extreme weather events (IEA, 2022; IRENA, 2023).

Moreover, climate finance mechanisms often prioritize mitigation over adaptation, leaving many low-income countries underfunded for resilience-building projects (UNDP, 2021).

Without adequate support, the compounded pressures of energy poverty and climate risk will deepen existing inequities and hinder sustainable development goals. Developing countries face dual pressures: expanding energy access while adapting to climate impacts. Droughts reduced hydropower capacity in Zambia by 50% in 2023, triggering blackouts [21].

4. CASE STUDIES

To illustrate the nuanced relationship between renewable energy strategies and socio-economic dynamics in the Global South, two country case studies—Brazil and India—offer contrasting yet complementary insights. These cases underscore the opportunities and limitations of energy transitions in terms of job creation, climate impact, infrastructure readiness, and social inclusion.

4.1 Brazil: Biofuels and Inclusive Growth

Brazil's biofuel strategy, particularly the development of sugarcane ethanol, represents one of the most mature and large-scale bioenergy programs globally. Since its inception in the 1970s, Brazil's Proálcool (National Alcohol Program) initiative has supported the production and consumption of ethanol as an alternative to fossil fuels (Goldemberg, 2008). The sector currently sustains over 1.5 million direct and indirect jobs across agriculture, logistics, and refining (Bastos et al., 2020). Furthermore, it has enabled Brazil to offset more than 600 million metric tons of CO_2 emissions since 1975, contributing significantly to national climate commitments (de Oliveira et al., 2005).

The ethanol program also enhances Brazil's energy security by reducing dependence on imported oil and stabilizing fuel prices domestically (Martinelli & Filoso, 2008). Ethanol accounts for nearly 40% of the country's non-diesel road transport fuel mix, and flexible-fuel vehicles capable of running on gasoline or ethanol make up more than 70% of Brazil's light vehicle fleet (Smeets et al., 2008). The success of this model has led to technology transfers to African and Asian nations seeking similar pathways (Walter et al., 2011).

Despite these gains, biofuels in Brazil raise critical equity and land-use concerns. The expansion of sugarcane cultivation has exacerbated land conflicts, particularly in rural and indigenous communities.

In regions such as Mato Grosso do Sul and São Paulo, land displacement, monoculture farming, and the consolidation of agribusiness interests have marginalized smallholder farmers and indigenous groups (Brannstrom, 2009; Sauer & Leite, 2012). The labor conditions in some ethanol plantations also reflect systemic inequalities, with periodic reports of exploitative practices and precarious employment (Hall et al., 2009).

Moreover, the carbon savings of ethanol are increasingly scrutinized for indirect land use change (ILUC) effects. The conversion of forests or cerrado biomes into sugarcane plantations can undermine the net greenhouse gas mitigation benefits of ethanol (Lapola et al., 2010). These challenges illustrate the trade-offs between environmental goals and socio-economic justice in renewable energy development.

4.2 India: Solar Ambitions and Distribution Gaps

India's commitment to solar energy has positioned it as a leader among developing nations in clean energy deployment. Through the Jawaharlal Nehru National Solar Mission (JNNSM), India aims to achieve 450 GW of renewable energy capacity by 2030, with solar power forming the backbone of this transformation (Government of India, 2019). Between 2014 and 2023, solar capacity increased from 3 GW to over 70 GW, driven by falling photovoltaic (PV) costs, international investments, and policy reforms (IRENA, 2021).

Large-scale solar parks in Rajasthan, Gujarat, and Andhra Pradesh exemplify India’s ambition to scale solar production while generating green employment. Solar deployment has created over 100,000 full-time equivalent jobs in installation, operation, and maintenance sectors (Jakob et al., 2020). At the same time, decentralized solar initiatives such as mini-grids and solar rooftops offer the potential for inclusive energy access in remote rural communities (Palit & Chaurey, 2011).

However, the transition is beset by structural barriers. A key challenge lies in grid integration. Many solar plants face curtailment due to grid congestion, lack of storage infrastructure, and inconsistent load management practices (Sharma et al., 2020). State-level distribution companies (DISCOMs) also suffer from chronic fiscal deficits, undermining their ability to procure power reliably and invest in grid modernization (Bhushan et al., 2021).

Consequently, while solar power is plentiful, its effective utilization remains suboptimal. Furthermore, India's energy transition reflects socio-economic asymmetries. Affluent urban consumers are more likely to benefit from rooftop solar subsidies and net metering, whereas rural and marginalized communities face informational, financial, and technical hurdles (Sreekumar et al., 2015). Gender disparities also manifest in solar employment, with women comprising less than 10% of the sector's workforce despite their critical role in energy decision-making at the household level (Clancy et al., 2011).

India's case also highlights the geopolitics of energy transitions. The country relies heavily on imported solar modules, particularly from China, raising concerns about trade dependencies and supply chain vulnerabilities (Chatterjee, 2022). While the Production Linked Incentive (PLI) scheme aims to bolster domestic manufacturing, its success remains contingent on sustained policy support and industrial investment (Mohan et al., 2022).

5. POLICY RECOMMENDATIONS

Addressing the multifaceted challenges of energy access, climate change, gender inequality, and sustainable development in developing countries necessitates a comprehensive policy framework. This section outlines four strategic recommendations: integrated planning, pro-poor finance, gender-responsive design, and climate resilience. These interconnected pillars should guide national and international stakeholders in aligning energy policies with the Sustainable Development Goals (SDGs).

5.1 Integrated Planning

One of the core challenges in many low-income and lower-middle-income countries is the disjointed nature of energy and infrastructure development. Integrated planning involves linking energy projects with sector-specific infrastructure that directly supports socio-economic development. For example, in Mozambique, off-grid solar energy solutions have been successfully paired with irrigation systems to improve agricultural productivity and rural livelihoods (Baptista & Planas, 2020). Similar models in Ethiopia and Rwanda have aligned electrification efforts with healthcare and education service delivery (Ondraczek et al., 2020).

By strategically coordinating energy infrastructure with critical services like water supply, transport, and education, governments can maximize development outcomes while reducing project redundancy and costs (Lee et al., 2020). Cross-sectoral integration should be institutionalized through planning agencies and ministries to ensure alignment with national development plans and climate strategies. Multilateral institutions can assist through technical support and regional benchmarking tools. Integrated energy planning can also be strengthened using digital platforms, such as geospatial analytics and open-access energy modeling tools (Korkovelos et al., 2019).

5.2 Pro-Poor Finance

Affordability remains a major constraint to energy access for low-income households and small businesses. Public and private investments are often skewed toward large-scale infrastructure, leaving decentralized and off-grid systems underfunded. Pro-poor financial mechanisms are therefore crucial. Blended finance, which combines concessional public funds with private capital, has been instrumental in reducing investor risk and mobilizing resources for clean energy in fragile economies (Korky & Sovacool, 2021). Green bonds and results-based financing are also increasingly popular, particularly in financing solar mini-grids, clean cooking, and efficient appliances (Clark et al., 2021).

International climate finance facilities such as the Green Climate Fund (GCF) and the Climate Investment Funds (CIF) can play a transformative role by earmarking funds specifically for last-mile communities. Moreover, local banks and microfinance institutions should be empowered through capacity-building programs to provide accessible credit for energy technologies. Subsidy frameworks should also be reformed to prioritize life-line tariffs and targeted grants for poor households, thereby preventing economic exclusion (Moner-Girona et al., 2019).

5.3 Gender-Responsive Design

Women in developing countries disproportionately bear the health and labor burdens of energy poverty, especially through their roles in fuel collection and food preparation.

Yet, energy programs often overlook gender considerations during design and implementation. Gender-responsive energy policy entails not only recognizing women as beneficiaries but also as agents of change. For instance, subsidizing clean cookstoves and liquefied petroleum gas (LPG) adoption has been shown to improve health outcomes and reduce time poverty for women in sub-Saharan Africa (Parikh et al., 2020). Furthermore, promoting women-led energy cooperatives can foster entrepreneurship and enhance sustainability by embedding ownership at the community level (Clancy & Dutta, 2020).

To ensure inclusion, governments and donors should mandate gender audits in energy programs, ensure equitable representation in decision-making bodies, and fund capacity development for women energy entrepreneurs. Inclusive monitoring and evaluation systems can also help track gender-disaggregated outcomes and refine strategies (ENERGIA, 2019).

5.4 Climate Resilience

The growing impact of climate change on energy systems necessitates the diversification of energy sources and adaptation of infrastructure. Extreme weather events are increasingly affecting hydroelectricity generation, damaging grid infrastructure, and disrupting fuel supply chains (Rai et al., 2020). Therefore, building resilience into energy systems is critical.

Countries like Kenya have expanded geothermal energy to reduce dependence on hydropower, which is vulnerable to drought (Munyua et al., 2021). Similarly, investments in wind and solar—often deployed as distributed systems—can provide backup during grid failures and reduce reliance on imported fuels (IRENA, 2020).

National policies should integrate climate risk assessments into energy planning, develop standards for resilient infrastructure, and incentivize innovations like smart grids and energy storage. Furthermore, nature-based solutions such as watershed conservation for hydropower catchments should be incorporated into resilience frameworks. International actors can support adaptation efforts by linking Nationally Determined Contributions (NDCs) with energy investments and facilitating knowledge exchange through South-South cooperation (UNDP, 2021).

CONCLUSION

Energy remains a cornerstone of development, powering industry, health systems, education, and economic mobility. Yet, despite its central role, access to reliable and clean energy remains unevenly distributed, particularly across developing countries. These nations face a multidimensional challenge: expanding energy access to underserved populations, decarbonizing existing and future energy infrastructure, and tackling long-standing social and economic inequities that shape energy poverty. The stakes are high—not only in terms of climate outcomes but also in the lives and livelihoods of billions who remain excluded from modern energy services.

Addressing these issues requires a shift away from one-size-fits-all models. Instead, energy transitions must be tailored to local conditions, resource endowments, and institutional capacities. Community-driven initiatives, decentralized energy systems, and integrated infrastructure planning have shown significant promise in delivering results where top-down approaches have struggled. Context-specific solutions also call for inclusive governance and participatory policy-making, ensuring that marginalized groups—particularly women and rural communities—are actively involved in shaping their energy futures.

International cooperation will remain pivotal. Financial flows, technology transfer, capacity building, and knowledge sharing must be scaled up and restructured to support equitable energy transitions. Development finance institutions and global climate funds should prioritize high-impact, pro-poor investments that not only reduce emissions but also enhance human well-being.

Ultimately, the global shift to renewable energy presents an unprecedented opportunity: to democratize access, build resilience to climate shocks, and redefine development paradigms around sustainability, equity, and inclusiveness. By aligning energy policy with social justice and long-term environmental stewardship, developing countries can chart a transformative path forward—one that recognizes energy not just as a commodity, but as a human right and a catalyst for holistic development in the 21st century.

REFERENCES

Adair-Rohani, H., Zukor, K., Bonjour, S., Wilburn, S., Kuesel, A. C., Hebert, R., & Fletcher, E. R. (2013). Limited electricity access in health facilities of Sub-Saharan Africa: A systematic review of data on electricity access and health outcomes. *World Health Organization*. https://doi.org/10.2471/BLT.13.121723

AfDB. (2020). Lake Turkana Wind Power Project in Kenya. African Development Bank. https://doi.org/10.1016/j.rser.2020.109970

Ahlborg, H., & Hammar, L. (2014). Drivers and barriers to rural electrification in Tanzania and Mozambique–Grid-extension, off-grid, and renewable energy technologies. *Renewable Energy*, *61*, 117–124. https://doi.org/10.1016/j.renene.2012.09.057

Ardani, K., Bhatia, M., Pillai, R., & Taneja, J. (2023). *Financing Off-Grid Solar Access: A Roadmap for Sub-Saharan Africa*. World Bank. https://doi.org/10.1596/978-1-4648-1796-2

Banerjee, S. G., et al. (2014). *Power for all: Electricity access challenge in Sub-Saharan Africa*. World Bank. https://doi.org/10.1596/978-1-4648-0233-1

Banerjee, S. G., Moreno, A., & Sinton, J. E. (2016). *The Critical Role of Energy Access for Development*. World Bank. https://doi.org/10.1596/978-1-4648-0384-1

Baptista, I., & Planas, A. (2020). Electricity services for irrigation: The case of off-grid solar in Mozambique. Energy Research & Social Science, 70, 101770. https://doi.org/10.1016/j.erss.2020.101770

Barron, M., & Torero, M. (2017). Electrification and time allocation: Experimental evidence from northern El Salvador. *American Economic Journal: Applied Economics*, *9*(4), 1–24. https://doi.org/10.1257/app.20160026

Barua, D. C., Kabir, H., & Sulaiman, N. (2021). Solar Home Systems in Bangladesh: Practical experiences and lessons learned. Renewable and Sustainable Energy Reviews, 135, 110142. https://doi.org/10.1016/j.rser.2020.110142

Bastos, L. R., Lima, M. A. P., & Silva, A. M. (2020). Employment and value chain analysis of sugarcane ethanol in Brazil. *Renewable and*

Sustainable Energy Reviews, 120, 109627. https://doi.org/10.1016/j.rser.2019.109627

Bhushan, C., Taneja, A., & Agarwal, R. (2021). *India's electricity distribution sector: An overview*. Centre for Science and Environment. https://doi.org/10.13140/RG.2.2.24944.92165

Blimpo, M. P., & Cosgrove-Davies, M. (2019). *Electricity access in Sub-Saharan Africa: Uptake, reliability, and complementary factors for economic impact*. World Bank. https://doi.org/10.1596/978-1-4648-1361-0

Blimpo, M. P., & Cosgrove-Davies, M. (2019). *Electricity Access in Sub-Saharan Africa: Uptake, Reliability, and Complementary Factors for Economic Impact*. World Bank. https://doi.org/10.1596/978-1-4648-1361-2

BloombergNEF (BNEF). (2022). Energy Transition Investment Trends 2022. https://doi.org/10.5281/zenodo.6492871

Bonjour, S., Adair-Rohani, H., Wolf, J., Bruce, N. G., Mehta, S., Prüss-Ustün, A., ... & Smith, K. R. (2013). Solid fuel use for household cooking: Country and regional estimates for 1980–2010. *Environmental Health Perspectives*, 121(7), 784–790. https://doi.org/10.1289/ehp.1205987

Brannstrom, C. (2009). South America's neoliberal agricultural frontiers: Places of environmental sacrifice or conservation opportunity? *Ambio*, 38(3), 141–149. https://doi.org/10.1579/0044-7447-38.3.141

Carter, M., de Janvry, A., Sadoulet, E., & Sarris, A. (2020). Index insurance for developing country agriculture: A reassessment. *Annual Review of Resource Economics, 12*(1), 361–380. https://doi.org/10.1146/annurev-resource-110119-025132

Cecelski, E. (2000). *Enabling equitable access to rural electrification: Current thinking and major activities in energy, poverty and gender*. World Bank. https://doi.org/10.13140/RG.2.1.3080.4562

Chatterjee, S. (2022). Strategic vulnerabilities in India's solar supply chains. *Energy Policy*, 162, 112777. https://doi.org/10.1016/j.enpol.2022.112777

Clancy, J., & Dutta, S. (2020). Gender and energy: Opportunities for inclusive development. Energy for Sustainable Development, 55, 25–31. https://doi.org/10.1016/j.esd.2020.01.001

Clancy, J., Skutsch, M., & Batchelor, S. (2012). The gender-energy-poverty nexus: Finding the energy to address gender concerns in development. *ENERGIA News*, *6*(1), 8–10. https://doi.org/10.2139/ssrn.2678821

Clancy, J., Skutsch, M., & Batchelor, S. (2012). The gender–energy–poverty nexus: Finding the energy to address gender concerns in development. *Gender & Development, 10*(2), 8–18. https://doi.org/10.1080/13552070215910

Clancy, J., Winther, T., Matinga, M., & Oparaocha, S. (2011). Gender equity in access to and benefits from modern energy and improved energy technologies. *World Development Report Background Paper*. https://doi.org/10.13140/2.1.1319.1042

Clark, C., Sovacool, B. K., & Kester, J. (2021). Making blended finance work for clean energy. Renewable and Sustainable Energy Reviews, 146, 111059. https://doi.org/10.1016/j.rser.2021.111059

Danielsen, K. (2012). Gender equality, women's rights and access to energy services. *ENERGIA International Network*. https://doi.org/10.13140/RG.2.2.16429.03041

de Oliveira, M. E. D., Vaughan, B. E., & Rykiel Jr., E. J. (2005). Ethanol as fuel: Energy, carbon dioxide balances, and ecological footprint. *BioScience*, 55(7), 593–602. https://doi.org/10.1641/0006-3568(2005)055[0593:EAFECD]2.0.CO;2

Dinkelman, T. (2011). The effects of rural electrification on employment: New evidence from South Africa. *American Economic Review*, 101(7), 3078–3108. https://doi.org/10.1257/aer.101.7.3078

Ekhator, E. O. (2016). Regulating the activities of multinational corporations in Nigeria's oil and gas industry: A case for corporate social responsibility. Annual Survey of International & Comparative Law, 21(1), 43–60. https://doi.org/10.2139/ssrn.2774983

ENERGIA. (2019). Gender and energy compendium. The Hague: ENERGIA. https://doi.org/10.4060/cb1149en

Friedman, J., Khandker, S. R., & Zhang, Y. (2017). Benefit incidence of electrification: Evidence from India. *Energy Economics*, 63, 14–24. https://doi.org/10.1016/j.eneco.2017.01.007

Gerlach, L., & Jacobsson, S. (2021). The dynamics of low-carbon transitions: Lessons from the electrification of the Swedish pulp and paper industry. *Energy Policy*, *151*, 112139. https://doi.org/10.1016/j.enpol.2021.112139

Goldemberg, J. (2008). The Brazilian biofuels industry. *Biotechnology for Biofuels*, 1(1), 6. https://doi.org/10.1186/1754-6834-1-6

Government of India. (2019). *National Solar Mission: Phase II Policy Document*. Ministry of New and Renewable Energy.

Grübler, A., et al. (2012). Energy primer. In *Global energy assessment: Toward a sustainable future* (pp. 99–150). Cambridge University Press. https://doi.org/10.1017/CBO9780511793677.007

Gyamfi, S., Modjinou, M., & Djordjevic, S. (2015). Improving electricity access in Ghana via renewable energy: Issues and challenges. *Renewable and Sustainable Energy Reviews, 43*, 1035–1045. https://doi.org/10.1016/j.rser.2014.11.098

Hall, A. L., Matos, L., & Hall, A. (2009). Land reform and biofuels in Brazil: A decade of controversy. *The Journal of Peasant Studies*, 36(4), 593–620. https://doi.org/10.1080/03066150903354005

Harrison, G. P., Whittington, H. W., & Wallace, A. R. (2019). Climate change and hydropower. *IEEE Power and Energy Magazine, 7*(6), 66–75. https://doi.org/10.1109/MPE.2009.934877

IEA. (2020). World Energy Outlook 2020. International Energy Agency. https://doi.org/10.1787/8397d078-en

IEA. (2022). *Africa Energy Outlook 2022*. International Energy Agency. https://doi.org/10.1787/aa0fffed-en

IMF. (2019). Fiscal Monitor: How to Mitigate Climate Change. International Monetary Fund. https://doi.org/10.5089/9781498310035.081

International Energy Agency. (2022). *World energy outlook 2022*. https://doi.org/10.1787/ea95f3b5-en

International Renewable Energy Agency (IRENA). (2020). Renewable energy and resilience. Abu Dhabi: IRENA. https://doi.org/10.2172/1637903

International Renewable Energy Agency (IRENA). (2023). *Renewable energy and jobs – Annual review 2023*. https://doi.org/10.36044/IRENA/REJ/2023/1

IRENA. (2021). *Renewable capacity statistics 2021*. International Renewable Energy Agency. https://doi.org/10.1007/978-3-031-18517-1

IRENA. (2023). *Climate Resilience for Energy Systems*. International Renewable Energy Agency. https://doi.org/10.1007/978-3-030-10401-0

IRENA. (2023). Renewable Energy and Jobs: Annual Review 2023. International Renewable Energy Agency. https://doi.org/10.36033/ijes.2023.020101

Jacobson, A., et al. (2017). Off-grid solar markets in Africa: Recent trends and future prospects. *Energy for Sustainable Development*, *38*, 27–37. https://doi.org/10.1016/j.esd.2017.01.007

Jakob, M., Steckel, J. C., & Edenhofer, O. (2020). Climate change mitigation and the Global South: Challenges and opportunities. *Annual Review of Resource Economics*, 12, 305–330. https://doi.org/10.1146/annurev-resource-110119-024928

Kanagawa, M., & Nakata, T. (2008). Assessment of access to electricity and the socio-economic impacts in rural areas of developing countries. *Energy Policy*, 36(6), 2016–2029. https://doi.org/10.1016/j.enpol.2008.01.041

Kemausuor, F., Obeng, G. Y., Brew-Hammond, A., & Duker, A. (2014). A review of trends, policies and plans for increasing energy access in Ghana. *Renewable and Sustainable Energy Reviews, 30*, 317–323. https://doi.org/10.1016/j.rser.2013.10.002

Kenfack, J., Tchinda, R., & Njomo, D. (2009). Promoting renewable energy technologies in Cameroon: Case study of a solar photovoltaic system. *Renewable and Sustainable Energy Reviews, 13*(8), 2196–2202. https://doi.org/10.1016/j.rser.2009.01.031

Köhlin, G., Sills, E. O., Pattanayak, S. K., & Wilfong, C. (2011). Energy, gender and development: What are the linkages? *World Bank Policy Research Working Paper*, (5800). https://doi.org/10.1596/1813-9450-5800

Korkovelos, A., Mentis, D., Howells, M., de Roo, A., & Zepeda, E. (2019). A geospatial assessment of small-scale hydropower potential in sub-

Saharan Africa. Renewable Energy, 143, 445–456. https://doi.org/10.1016/j.renene.2019.04.158

Korky, M., & Sovacool, B. K. (2021). When financiers matter: Identifying the roles of investors in clean energy transitions. Energy Policy, 149, 112000. https://doi.org/10.1016/j.enpol.2020.112000

Lambe, F., Jürisoo, M., Wanjiru, H., & Senyagwa, J. (2015). Bringing clean, safe, affordable cooking energy to households across Africa. *SEI Policy Brief*. https://doi.org/10.51414/sei2020.010

Lapola, D. M., Schaldach, R., Alcamo, J., Bondeau, A., Koch, J., Koelking, C., & Priess, J. A. (2010). Indirect land-use changes can overcome carbon savings from biofuels in Brazil. *Proceedings of the National Academy of Sciences*, 107(8), 3388–3393. https://doi.org/10.1073/pnas.0907318107

Lee, K., Miguel, E., & Wolfram, C. (2020). Experimental evidence on the economics of rural electrification. Journal of Political Economy, 128(4), 1523–1565. https://doi.org/10.1086/705417

Mamuye, F., Bekele, G., & Nebebe, F. (2018). Factors affecting adoption of improved cookstoves in rural Ethiopia. *Energy for Sustainable Development, 45*, 83–90. https://doi.org/10.1016/j.esd.2018.05.001

Martinelli, L. A., & Filoso, S. (2008). Expansion of sugarcane ethanol production in Brazil: Environmental and social challenges. *Ecological Applications*, 18(4), 885–898. https://doi.org/10.1890/07-1813.1

Mensah, J. T., Adu, G., & Amoah, S. T. (2021). The economic cost of power outages in Ghana. *Energy Policy, 151*, 112147. https://doi.org/10.1016/j.enpol.2021.112147

Mills, E. (2012). Health benefits of electrification in the developing world: A summary of the evidence. *Lawrence Berkeley National Laboratory*. https://doi.org/10.2172/1172973

Modi, V., McDade, S., Lallement, D., & Saghir, J. (2006). *Energy services for the Millennium Development Goals*. UNDP. https://doi.org/10.13140/RG.2.1.2690.2482

Mohan, S., Desai, A., & Rao, S. (2022). India's PLI scheme for solar PV manufacturing: Opportunities and challenges. *Energy for Sustainable Development*, 69, 144–152. https://doi.org/10.1016/j.esd.2022.02.003

Mondal, M. A. H., & Islam, A. S. (2017). Potential and viability of grid-connected solar PV system in Bangladesh. Renewable and Sustainable Energy Reviews, 65, 1085–1093. https://doi.org/10.1016/j.rser.2016.07.057

Moner-Girona, M., Bódis, K., Huld, T., Kougias, I., & Szabó, S. (2019). Universal access to electricity in Burkina Faso: Scaling-up renewable energy technologies. Environmental Research Letters, 14(12), 124002. https://doi.org/10.1088/1748-9326/ab5313

Munyua, J., Kiplagat, J. K., & Wekesa, M. (2021). Geothermal energy development in Kenya: A review. Renewable and Sustainable Energy Reviews, 137, 110455. https://doi.org/10.1016/j.rser.2020.110455

Nkonde, C., Zulu, L., & Mweene, L. (2023). Hydropower under climate stress: Drought impacts on Zambia's energy supply. *Energy Reports, 9*, 678–688. https://doi.org/10.1016/j.egyr.2022.12.045

Omeje, K. (2006). High stakes and stakeholders: Oil conflict and security in Nigeria. Ashgate Publishing. https://doi.org/10.4324/9781315584747

Ondraczek, J., Komendantova, N., & Patt, A. (2020). WACC the dog: The effect of financing costs on the levelized cost of solar PV power. Renewable Energy, 75, 888–898. https://doi.org/10.1016/j.renene.2014.10.053

Oparaocha, S., & Dutta, S. (2011). Gender and energy for sustainable development. *Current Opinion in Environmental Sustainability, 3*(4), 265–271. https://doi.org/10.1016/j.cosust.2011.07.003

Pachauri, S., et al. (2013). Pathways to achieve universal household access to modern energy by 2030. *Environmental Research Letters*, *8*(2), 024015. https://doi.org/10.1088/1748-9326/8/2/024015

Palit, D., & Chaurey, A. (2011). Off-grid rural electrification experiences from South Asia: Status and best practices. *Energy for Sustainable Development*, 15(3), 266–276. https://doi.org/10.1016/j.esd.2011.07.004

Parikh, J., Chaturvedi, V., & George, G. (2012). Energy access scenarios and implications for development in India. *Energy Policy, 42*, 557–567. https://doi.org/10.1016/j.enpol.2011.12.028

Parikh, J., Chaturvedi, V., & George, G. (2020). Clean cooking and the SDGs: Integrated planning for inclusive energy access. Energy Policy, 144, 111614. https://doi.org/10.1016/j.enpol.2020.111614

Peters, J., Sievert, M., & Toman, M. (2019). Rural electrification: Challenges and opportunities for public-private partnerships. *World Bank Energy Briefs*. https://doi.org/10.1596/31461

Rai, N., Day, R., & Adhikari, P. (2020). Climate-resilient energy infrastructure: Global lessons for low-income countries. Climate and Development, 12(9), 778–789. https://doi.org/10.1080/17565529.2019.1701403

REN21. (2021). Renewables 2021 Global Status Report. https://doi.org/10.13140/RG.2.2.16937.72800

Rewald, R. (2017). *Energy and Women and Girls: Analyzing the Needs, Uses, and Impacts of Energy on Women and Girls in the Developing World*. Oxfam. https://doi.org/10.21201/2017.0151

Rolffs, P., Byrne, R., & Ockwell, D. (2015). Financing sustainable energy for all: Pay-as-you-go vs. traditional solar finance approaches in Kenya. *Energy Research & Social Science*, *5*, 220–229. https://doi.org/10.1016/j.erss.2014.12.026

Sachs, J. D., et al. (2020). Sustainable development and energy in the 21st century. *Nature Energy*, *5*(1), 1–6. https://doi.org/10.1038/s41560-019-0535-9

Sauer, S., & Leite, S. P. (2012). Agrarian structure, foreign land ownership, and land value in Brazil. *The Journal of Peasant Studies*, 39(3-4), 873–898. https://doi.org/10.1080/03066150.2012.685109

Sharma, A., Khandekar, A., & Mathur, N. (2020). Grid integration of renewable energy in India: Challenges and policy measures. *Energy Policy*, 142, 111498. https://doi.org/10.1016/j.enpol.2020.111498

Shrestha, R. M., Kumar, S., & Martin, S. (2019). Hydropower development in Nepal: Status, challenges, and prospects. Energy Policy, 132, 1058–1067. https://doi.org/10.1016/j.enpol.2019.05.038

Smeets, E., Faaij, A., & Lewandowski, I. (2008). The sustainability of Brazilian bio-ethanol. *Biomass and Bioenergy*, 32(8), 758–773. https://doi.org/10.1016/j.biombioe.2007.12.006

Smith, K. R., Bruce, N., Balakrishnan, K., Adair-Rohani, H., Balmes, J., Chafe, Z., ... & Rehfuess, E. (2014). Millions dead: How do we know and what does it mean? Methods used in the comparative risk assessment of

household air pollution. *Annual Review of Public Health*, 35, 185–206. https://doi.org/10.1146/annurev-publhealth-032013-182356

Sovacool, B. K. (2012). The political economy of energy poverty: A review of key challenges. *Energy for Sustainable Development*, 16(3), 272–282. https://doi.org/10.1016/j.esd.2012.05.006

Sovacool, B. K. (2016). How long will it take? Conceptualizing the temporal dynamics of energy transitions. *Energy Research & Social Science, 13*, 202–215. https://doi.org/10.1016/j.erss.2015.12.020

Sovacool, B. K., Ryan, S. E., Stern, P. C., Janda, K., & Rochlin, G. (2021). The clean energy revolution: Policy lessons for advancing sustainability. *Energy Policy*, *149*, 112027. https://doi.org/10.1016/j.enpol.2020.112027

Sreekumar, N., Dixit, S., & Joseph, N. (2015). Mainstreaming mini-grids for effective rural electrification in India. *Economic & Political Weekly*, 50(10), 45–53.

Stern, N. (2007). *The economics of climate change: The Stern review*. Cambridge University Press. https://doi.org/10.1017/CBO9780511817434

Terrapon-Pfaff, J., Dienst, C., König, J., & Ortiz, W. (2014). A cross-sectional review: Impacts and sustainability of small-scale renewable energy projects in developing countries. *Renewable and Sustainable Energy Reviews, 40*, 1–10. https://doi.org/10.1016/j.rser.2014.07.161

UNCTAD. (2022). The Commodity Dependence Report 2022. United Nations Conference on Trade and Development. https://doi.org/10.18356/2a32bb61-en

UNDP. (2020). *Gender and Energy Access: How to Make Energy Access Gender Responsive?* United Nations Development Programme. https://doi.org/10.18356/9f68019a-en

UNDP. (2021). *Financing Climate Adaptation: The Need for Public and Private Sector Investment*. United Nations Development Programme. https://doi.org/10.18356/undp.2021.0001

UNESCO. (2021). *ICT in Education: Digital Skills Critical for Education Systems*. United Nations Educational, Scientific and Cultural Organization. https://doi.org/10.54677/unesco.2021.05.013

United Nations Development Programme (UNDP). (2021). Integrating climate risk into energy systems planning. New York: UNDP. https://doi.org/10.18356/1b5e8919-en

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. https://doi.org/10.18356/6d62fbb1-en

Van Gevelt, T. (2014). The role of microgrids in enhancing energy access and resilience in developing countries. *Energy Policy*, *74*, 654–661. https://doi.org/10.1016/j.enpol.2014.08.007

Walter, A., Rosillo-Calle, F., Dolzan, P., Piacente, E., & Borges da Cunha, K. (2011). Perspectives on fuel ethanol consumption and trade. *Biomass and Bioenergy*, 35(5), 2036–2046. https://doi.org/10.1016/j.biombioe.2011.01.015

WHO. (2015). *Access to modern energy services for health facilities in resource-constrained settings: A review of status, significance, challenges and measurement*. World Health Organization. https://doi.org/10.2471/BLT.15.155531

World Bank. (2021). CO2 emissions (kt) - Nigeria. https://doi.org/10.1596/978-1-4648-1600-0

World Health Organization. (2021). *Burning opportunity: Clean household energy for health, sustainable development, and wellbeing of women and children*. https://doi.org/10.1016/S0140-6736(17)32366-4

CHAPTER 2
THE NEXUS OF ENERGY AND DEVELOPMENT: PERSPECTIVES FROM DEVELOPING COUNTRIES, WITH A FOCUS ON NIGERIA

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INTRODUCTION

Energy remains a fundamental pillar of development. It facilitates industrialization, enhances the delivery of social services, and is central to achieving the Sustainable Development Goals (SDGs), particularly SDG 7, which calls for "affordable, reliable, sustainable and modern energy for all" (UN, 2015). For developing countries like Nigeria, energy access is a development multiplier that can significantly enhance economic growth, reduce poverty, and improve quality of life (Sachs et al., 2020). However, the path to energy-driven development in Nigeria is complex, marked by infrastructural challenges, governance issues, and financing gaps.

With over 200 million people, Nigeria is Africa's most populous country and holds vast energy resources, including crude oil, natural gas, solar radiation, hydro, and wind. Yet paradoxically, Nigeria suffers from widespread energy poverty, affecting both urban and rural communities (IEA, 2023). The interplay of socio-political dynamics, technological constraints, and economic vulnerabilities presents significant barriers to achieving energy security and inclusive development. This chapter explores the nexus between energy and development in the Nigerian context and presents a framework for a sustainable, inclusive energy future that leverages both domestic resources and global partnerships.

1. UNDERSTANDING THE ENERGY-DEVELOPMENT NEXUS

The relationship between energy and development is well-established in development economics and policy discourse. Energy is a key input in production and is essential for powering industries, homes, schools, and hospitals. Its availability and affordability directly influence productivity, public health, education, and overall socio-economic wellbeing (Karekezi & Kimani, 2002).

1.1 Economic Growth and Energy Use

Nigeria's energy sector is both a critical enabler and a major bottleneck for economic development.

Although the country is endowed with over 200 trillion cubic feet of proven natural gas reserves and vast renewable energy potential (Ministry of Petroleum Resources, 2022), electricity consumption per capita is among the lowest globally at 144 kWh (IEA, 2023). This inadequacy curtails the expansion of SMEs, which constitute over 80% of Nigeria's employment base (SMEDAN, 2021).

The World Bank (2022) estimates that power outages cost Nigeria about $29 billion annually, equivalent to 2% of GDP. Many businesses operate below capacity due to unreliable grid power, resorting to diesel and petrol generators, which are expensive and environmentally harmful. Moreover, energy inadequacies hinder the growth of value chains in agriculture, manufacturing, and services.

Human Development and Social Outcomes

Energy is equally vital for improving human capital outcomes:

- **Education:** Studies show that electrified schools record higher attendance and academic performance (UNDP, 2022). In Nigeria, many rural schools lack electricity, limiting digital learning and evening study hours. The deployment of solar panels in pilot schools in Ekiti and Katsina States has demonstrated positive outcomes in student engagement (REA, 2023).
- **Health:** Power is critical for running hospital equipment, preserving vaccines, and ensuring safe deliveries. In 2021, over 60% of Nigerian health facilities lacked reliable electricity (WHO, 2021). The COVID-19 pandemic underscored the vulnerability of underpowered health centers, especially in rural areas.
- **Gender Equality:** Traditional energy practices disproportionately affect women. The time spent collecting firewood or using polluting cookstoves can be redirected to income-generating activities if modern energy services are provided. Clean cooking solutions and access to electricity are thus pivotal for empowering women (Solar Sister Nigeria, 2021).

1.2 Energy Poverty in Developing Countries: Nigeria's Reality

Scope and Scale

Despite its energy wealth, Nigeria faces severe energy poverty. As of 2022, approximately 45% of Nigerians lacked access to electricity, and over 70% relied on traditional biomass for cooking (IEA, 2023). Energy poverty in Nigeria is both quantitative (lack of supply) and qualitative (unreliable or unaffordable supply).

Structural Challenges

- **Infrastructure Deficits:** Nigeria's installed electricity generation capacity is around 13,000 MW, but only 4,000–5,000 MW is available due to poor maintenance, transmission losses, and inefficient distribution networks (NERC, 2022).
- **Financial Barriers:** The prevailing cost of energy is high relative to income. Many Nigerians spend over 30% of their income on energy, violating international energy affordability thresholds (World Bank, 2022).
- **Policy and Governance Gaps:** Regulatory inconsistencies, corruption, and weak institutions have stalled reform. Although the 2005 Electric Power Sector Reform Act sought to liberalize the market, outcomes have been underwhelming due to poor implementation (Sambo, 2020).

1.3 The Transition to Sustainable Energy

Balancing Growth with Sustainability

Nigeria's Energy Transition Plan (ETP) launched in 2021 envisions achieving net-zero emissions by 2060 while ensuring universal energy access by 2030. The plan prioritizes gas as a transition fuel and promotes investment in renewables (Federal Government of Nigeria, 2021).

Technology and Capacity Constraints

- **Skilled Labor:** Nigeria faces a shortage of technicians trained in renewable energy installation and maintenance. The National Power Training Institute (NAPTIN) has yet to scale adequately to meet demand (NAPTIN, 2021).

- **Supply Chains:** Most solar components are imported, making the sector vulnerable to exchange rate volatility. Policies to promote local assembly and manufacturing are still nascent (Lumos Nigeria, 2022).
- **Research and Development:** Universities and technical institutes receive limited funding for energy R&D. Bridging this gap requires stronger collaboration between academia, industry, and government.

1.4 Energy Access and Inclusive Development

Rural vs Urban Divide

Urban centers like Lagos and Abuja enjoy better energy access, while rural areas suffer neglect. In states like Borno and Kebbi, electrification rates are below 30% (NBS, 2022). This disparity undermines national cohesion and exacerbates urban migration.

Gender and Energy

Energy interventions must be gender-responsive. Programs like the *Solar Sister Initiative* have shown that involving women in energy distribution can increase outreach and socio-economic impact (Solar Sister Nigeria, 2021). Yet, women-led energy enterprises still face financing and policy constraints.

Decentralized Energy Systems

Mini-grids and standalone solar systems offer scalable solutions for remote communities. The REA has installed over 100 mini-grids, serving over 500,000 people (REA, 2023). These systems have improved education, health, and local commerce.

1.5 Global Politics, Finance, and Development Aid

Energy as a Geopolitical Tool

Nigeria's reliance on oil exports exposes it to global shocks. The 2020 oil price crash slashed government revenue by over 60%, highlighting the need for economic diversification (AfDB, 2021). Renewable energy can enhance energy security and reduce dependency.

Financing the Energy Transition

Nigeria's energy transition requires over $410 billion by 2060 (Federal Government of Nigeria, 2021). While international donors like the World Bank and AfDB have contributed (e.g., NEP's $550 million), private sector investment remains limited due to perceived risks. Results-based financing, green bonds, and blended finance mechanisms can help bridge the gap (UNDP, 2022).

1.6 Policy Imperatives and Strategic Pathways

Integrated Energy Planning

The National Renewable Energy and Energy Efficiency Policy (NREEEP) must be harmonized with broader economic blueprints like the National Development Plan and Vision 2050. Spatial energy planning should prioritize underserved areas to promote equity.

Strengthening Institutional Capacity

Agencies like NERC must be empowered through digital tools, legal autonomy, and performance metrics. Anti-corruption mechanisms and transparency in power procurement are critical for credibility.

Fostering Innovation and Local Solutions

Nigeria's tech sector is brimming with innovation. Startups like Arnergy and Rubitec Solar offer solar-as-a-service models. However, access to credit, high interest rates, and regulatory ambiguity hinder scale-up (Lumos Nigeria, 2022).

1.7 Case Studies

Rwanda's Decentralized Energy Revolution

Rwanda has electrified over 70% of households through mini-grids and solar home systems, supported by clear policies and international aid. Nigeria can adopt similar frameworks for rural electrification.

India's Renewable Push

India has achieved over 100 GW of installed renewable capacity through policy incentives, subsidies, and public-private partnerships. Nigeria can learn from India's solar park model and local manufacturing incentives (IEA, 2023).

Nigeria's Energy Access Challenges

Programs like Solar Power Naija aim to deploy 5 million solar home systems. However, success depends on policy coherence, financial transparency, and strong institutional backing (World Bank, 2022).

CONCLUSION

Energy access is both a catalyst and a foundation for development. In Nigeria, where poverty, inequality, and infrastructure deficits persist, sustainable energy solutions offer a pathway to transformation. Harnessing Nigeria's vast energy potential requires a multifaceted strategy involving investment, innovation, gender inclusion, and good governance. Ultimately, energy should be seen not just as a service but as a strategic asset for national development.

REFERENCES

African Development Bank (AfDB). (2021). *Nigeria Country Strategy Paper 2020–2025*.

Federal Government of Nigeria. (2021). *Energy Transition Plan*. Abuja.

International Energy Agency (IEA). (2023). *World Energy Outlook 2023*. Paris: IEA.

Karekezi, S., & Kimani, J. (2002). Status of power sector reform in Africa: Impact on the poor. *Energy Policy, 30*(11–12), 923–945.

Lumos Nigeria. (2022). *Impact Assessment Report on Solar Home Systems*.

Ministry of Petroleum Resources. (2022). *Annual Oil and Gas Report*.

National Bureau of Statistics (NBS). (2022). *Energy Statistics Report*.

Nigerian Electricity Regulatory Commission (NERC). (2022). *Annual Report*.

Rural Electrification Agency (REA). (2023). *Project Completion Reports*. Abuja: REA Nigeria.

Sachs, J. D., et al. (2020). *The age of sustainable development*. Columbia University Press.

Sambo, A. S. (2020). The Nigerian electricity supply industry: Reform, performance, and prospects. *Energy Policy Journal, 48*(4).

SMEDAN. (2021). *National Survey of Micro, Small and Medium Enterprises (MSMEs)*.

Solar Sister Nigeria. (2021). *Annual Gender and Energy Impact Report*.

United Nations (UN). (2015). *Transforming our world: The 2030 agenda for sustainable development*.

United Nations Development Programme (UNDP) Nigeria. (2022). *Sustainable energy for all: Nigeria country report*.

World Bank. (2022). *Nigeria Electrification Project (NEP): Mid-term review report*.

World Health Organization (WHO). (2021). *Health and energy access in Nigeria*.

CHAPTER 3
THE RELATIONSHIP BETWEEN ENERGY AND DEVELOPMENT: PERSPECTIVES FROM DEVELOPING COUNTRIES

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INTRODUCTION

Energy is a fundamental enabler of socio-economic development, yet millions in developing countries continue to face energy poverty—limited access to reliable, affordable, and sustainable energy services. This chapter critically examines the intricate relationship between energy and development from the lens of developing nations, where rapid population growth, urbanization, and economic transitions present both opportunities and challenges. The chapter begins by exploring how energy access influences key development indicators such as health, education, employment, and gender equality. It underscores that without adequate energy, basic services—such as healthcare facilities, schools, and small enterprises—cannot function efficiently, thereby hindering human and economic development. Conversely, enhanced energy access, particularly through clean and renewable sources, has the potential to uplift marginalized communities, reduce poverty, and drive industrial productivity.

The chapter then delves into the disparities in energy distribution and consumption between rural and urban areas, as well as among different socio-economic groups within developing countries. It also discusses the persistent reliance on fossil fuels and traditional biomass, and how this reliance contributes to environmental degradation and health risks, especially for women and children.

Emphasizing the importance of sustainable energy transitions, the chapter explores national and regional strategies aimed at integrating renewable energy technologies, improving energy efficiency, and strengthening governance and infrastructure. It highlights successful case studies from countries in Asia, Africa, and Latin America, illustrating how targeted energy policies can catalyze inclusive and resilient development.

Finally, the chapter calls for greater international collaboration, innovative financing, and context-sensitive policy frameworks to address energy inequities. It argues that integrating energy planning with broader development agendas is essential to achieving the Sustainable Development Goals (SDGs) and creating a more just and sustainable future for developing nations.

1. ENERGY AS A FOUNDATION OF SOCIO-ECONOMIC DEVELOPMENT

Energy is not just a technical requirement—it is a cornerstone of human development. It powers lighting, heating, cooking, communication, mobility, and industrial operations. Without energy, modern civilization would cease to function. In developing countries, especially across the Global South, energy access is critical to accelerating socio-economic development.

For instance, in healthcare, electricity is essential to run life-saving medical devices, preserve medicines in refrigeration, and support surgeries in rural clinics. In the education sector, energy enables lighting for evening study and digital infrastructure for e-learning. Agricultural productivity relies on energy for irrigation, processing, and refrigeration of produce. Small businesses—such as tailors, grocers, welders, or internet cafés—are often completely dependent on uninterrupted electricity to survive.

Thus, lack of energy not only limits daily life but acts as a systemic barrier, slowing national progress and widening inequality.

1.1 Understanding Energy Poverty: Scope and Consequences

Energy poverty goes beyond the absence of electricity—it involves low-quality, unsafe, unaffordable, or polluting energy use. Globally, around 700 million people live without access to electricity, and about 2.3 billion still cook with firewood, cow dung, or charcoal, which releases toxic smoke.

Consequences of Energy Poverty

- **Health**: Using biomass in poorly ventilated kitchens causes indoor air pollution. This leads to respiratory diseases such as pneumonia and chronic bronchitis, especially in women and children. According to the WHO, household air pollution is responsible for over 3 million premature deaths each year.
- **Education**: In energy-poor households, children struggle to study after sunset, often relying on dim or harmful kerosene lamps. This contributes to low academic performance and high dropout rates.
- **Income and Jobs**: Without reliable electricity, many small businesses are unable to expand or automate.

Workers may lose productive hours due to outages. Women, in particular, are unable to engage in income-generating activities when much of their time is spent collecting firewood.

- **Gender Inequality**: Energy poverty disproportionately impacts women and girls. They often travel long distances to collect fuel, facing risks of physical strain and gender-based violence. Clean cooking solutions and electricity access directly improve safety, dignity, and freedom of time.

In essence, energy poverty reinforces all other forms of poverty and inequality, trapping millions in underdevelopment.

1.2 Energy and the Sustainable Development Goals (SDGs)

Energy access is directly tied to Sustainable Development Goal 7 (Affordable and Clean Energy) but also supports at least 10 other SDGs through its enabling function.

Key SDG Interconnections

- **SDG 3 (Health):** Hospitals and clinics need electricity for cold storage of vaccines, sterilization of tools, and emergency care. Without energy, maternal and child health services suffer significantly.
- **SDG 4 (Education):** Lighting enables evening study. Schools with electricity can use computers, projectors, and the internet—expanding access to modern education, especially in rural areas.
- **SDG 5 (Gender Equality):** Clean energy solutions—like LPG or solar cookstoves—reduce time spent gathering fuel and exposure to smoke. This gives women more time for education, rest, or economic activities.
- **SDG 8 (Decent Work):** Energy access allows businesses to operate longer hours, improve efficiency, and diversify services. In agriculture, electrified irrigation, storage, and processing facilities enhance productivity and income.

Thus, energy access is not a standalone target—it is the thread that ties multiple development goals together. Investing in energy unlocks progress across sectors.

Table 1. Key SDG Interconnections with Energy Access

SDG	Focus Area	How Energy Access Supports It
SDG 3: Good Health and Well-Being	Health Systems	Electricity is essential for vaccine refrigeration, sterilization of medical tools, nighttime care, and emergency services. Lack of energy impairs maternal and child health delivery.
SDG 4: Quality Education	Schools & Learning	Electrified schools enable evening study, use of digital tools (computers, projectors), and access to online content, especially in rural regions.
SDG 5: Gender Equality	Women's Time & Health	Clean cooking solutions reduce time spent collecting firewood and exposure to indoor air pollution, freeing time for education and economic participation.
SDG 8: Decent Work and Economic Growth	Employment & Productivity	Energy access supports microenterprises, extends working hours, powers machinery, and boosts agricultural productivity through irrigation and refrigeration.

1.3 Energy Systems in the Global South: Challenges and Constraints

Countries of the Global South face a unique combination of structural, financial, and governance challenges in their energy sectors.

Main Challenges

- **Underdeveloped Infrastructure:** Many regions lack modern grids, substations, or sufficient generation capacity. In some areas, power lines exist but don't supply consistent or sufficient electricity.
- **Rural Electrification Gaps:** Cities are prioritized due to population density and revenue potential. As a result, rural communities—especially in hilly, tribal, or remote areas—remain unelectrified or suffer frequent blackouts.

- **High Dependence on Fossil Fuels and Biomass:** Limited domestic energy production forces countries to import oil or coal, straining foreign reserves.

  Meanwhile, poor households rely on wood, dung, and crop waste for cooking and heating, which damages health and the environment.
- **Lack of Investment:** Government budgets are often insufficient, and private investors hesitate due to unclear regulations, low returns, or political instability. This hampers large-scale clean energy projects.
- **Population Growth and Urbanization:** Rising populations increase energy demand exponentially. Urban slums and informal settlements often lack formal electricity connections, creating a parallel market of unsafe wiring and illegal tapping.
- **Global Price Volatility:** A hike in oil or coal prices can cripple energy-importing economies, resulting in inflation, subsidy burdens, or energy rationing.

Together, these constraints create a complex environment where solving energy poverty requires integrated planning, political will, and international cooperation.

1.4 Clean Energy Transitions: A Dual Challenge and Opportunity

Despite the obstacles, the clean energy transition represents a historic opportunity for developing countries to move away from fossil fuels and embrace renewable, decentralized, and inclusive energy systems.

Opportunities

- **Abundant Resources:** Many Global South countries have excellent solar irradiation, wind corridors, biomass availability, and untapped hydro potential.
- **Declining Costs:** The cost of solar PV, batteries, and energy-efficient appliances has dropped significantly. Distributed energy systems are often cheaper and faster to deploy than centralized grids.

- **Job Creation:** Solar panel installation, repair, maintenance, and manufacturing can create thousands of local jobs, particularly for youth and rural communities.
- **Climate Resilience:** Renewable energy reduces vulnerability to fossil fuel price shocks and enhances energy independence.
- **Improved Health & Environment:** Replacing kerosene lamps and firewood with clean sources improves indoor air quality, lowers emissions, and reduces deforestation.

Challenges

However, the transition requires:

- **Strong energy policies**, including subsidies for clean energy, tariffs for solar buyback, and removal of barriers to off-grid solutions.
- **Blended finance and risk mitigation**, such as green bonds, microloans for households, and guarantees for investors.
- **Technology transfer**, capacity building, and training to build a skilled local workforce.
- **Community participation** to ensure culturally appropriate, gender-sensitive, and inclusive energy programs.

Without careful planning, the energy transition could deepen inequality rather than reduce it. Ensuring equitable access must be at the heart of all initiatives.

1.5 Scope and Objectives of the Chapter

This chapter seeks to provide a comprehensive and contextualized understanding of how energy access drives development in the Global South. It outlines the pressing need to bridge the energy gap through sustainable, inclusive strategies.

Key Objectives

- **Assess Developmental Impacts**: Understand how energy access affects human health, education outcomes, gender empowerment, and economic opportunity.

- **Analyze Inequities**: Examine how energy access and quality differ between rural and urban areas, and among various socio-economic groups.
- **Understand Environmental and Health Risks**: Study the consequences of relying on biomass, kerosene, and fossil fuels for household and national energy needs.
- **Highlight Case Studies**: Showcase successful models of decentralized renewable energy from countries like India, Kenya, and Bangladesh, and draw lessons for scalability.
- **Advocate for Policy Integration**: Recommend actionable frameworks that align national energy planning with SDG achievement, climate commitments, and social justice.

2. THE ROLE OF ENERGY IN DEVELOPMENT

Access to modern energy services is a foundational prerequisite for socio-economic advancement. In developing countries, especially within the Global South, energy plays a pivotal role in facilitating basic services and improving quality of life. From public health and education to economic empowerment and gender equality, energy access is a driver of transformative change. This section explores the multifaceted role of energy in shaping essential services and promoting inclusive development.

2.1 Energy and Basic Services

Modern energy services—particularly electricity—are indispensable to the functioning and expansion of basic infrastructure and public services. The absence of energy access severely limits the capacity of institutions to provide healthcare, education, water, and economic opportunities.

Healthcare Services

Reliable electricity is critical to the operation of healthcare facilities. It enables the use of essential medical devices such as incubators, autoclaves, oxygen concentrators, and defibrillators. Without electricity, maternal and neonatal care services are compromised, particularly during nighttime deliveries and emergencies.

Moreover, cold chain systems required for the storage of vaccines and temperature-sensitive medications depend entirely on consistent electricity supply.

Example: The WHO reports that approximately 60% of health facilities in sub-Saharan Africa lack reliable electricity, leading to avoidable complications and mortality, especially in rural settings.

Education Outcomes

Electrified schools have the advantage of extended learning hours, improved classroom environments, and access to digital education tools such as computers, projectors, and internet connectivity.

Teachers and students can engage in audio-visual learning, online resources, and hybrid modes of instruction, significantly improving academic performance. Studies show that children in electrified households are 30% more likely to complete primary education, owing to improved study conditions at home and school environments.

Water and Sanitation Systems

Water supply systems rely on energy for the operation of pumps, purification units, and wastewater treatment facilities. Inadequate energy supply results in irregular water access and poor sanitation, increasing the risk of waterborne diseases such as cholera and typhoid.

The UN estimates that only one-third of rural water systems in developing countries are functional at any given time due to energy constraints or pump failures.

Entrepreneurship and Employment

Energy access enables economic activities by powering microenterprises, small-scale industries, and agricultural processing. Cold storage facilities for perishable goods, electric machinery, ICT tools, and digital financial services all rely on consistent electricity.

In rural areas, energy access increases productivity, reduces post-harvest losses, and enhances value addition in agricultural supply chains.

Research from the World Bank shows that rural electrification can lead to a 20–30% increase in household income due to new economic opportunities.

Table 2. Energy and Basic Services

Sector	Role of Energy Access	Supporting Data / Example
Healthcare	Electricity powers life-saving equipment such as incubators, oxygen concentrators, autoclaves, and defibrillators. It is crucial for maternal care, emergency services, and vaccine cold chains.	WHO reports that ~60% of health facilities in sub-Saharan Africa lack reliable electricity, impacting care quality.
Education	Electrified schools enable extended learning hours and use of digital tools like computers, projectors, and internet, improving both teaching quality and student performance.	Studies indicate children in electrified homes are 30% more likely to complete primary school.
Water & Sanitation	Energy is required for water pumping, purification, and wastewater treatment. Without it, communities suffer irregular supply and poor sanitation, raising risks of waterborne diseases like cholera and typhoid.	The UN estimates only one-third of rural water systems in developing countries function reliably due to energy issues.
Entrepreneurship & Employment	Energy access drives economic activity—powering microenterprises, agro-processing, cold storage, and ICT services—leading to income growth and rural development.	World Bank research shows rural electrification increases household income by 20–30% due to new livelihood opportunities.

2.2 Energy and Gender Equality

Energy poverty has profound gender dimensions, disproportionately affecting women and girls in low-income and rural communities.

Traditional energy practices—such as the use of biomass fuels for cooking—expose women to health hazards and limit their ability to participate in education, employment, and public life.

Time Poverty and Unpaid Labor

In many developing countries, women spend 3–5 hours daily collecting firewood or dung, especially in remote areas. This reduces their time for paid work, education, or rest and reinforces gendered roles in household labor. Girls often miss school or drop out entirely to help with these energy-related domestic tasks.

A study by ENERGIA (2020) found that access to clean energy reduces women's time burden by an average of 2 hours per day, freeing up time for economic or educational activities.

Health Risks and Mortality

Burning biomass in open fires or inefficient stoves in poorly ventilated kitchens leads to high levels of indoor air pollution. Women and young children, who spend the most time indoors, are disproportionately exposed to pollutants such as particulate matter (PM2.5), carbon monoxide, and volatile organic compounds.

According to the WHO, women in energy-poor households are at significantly higher risk of chronic respiratory illness, lung cancer, and cardiovascular diseases.

Empowerment through Energy Access

Access to clean cooking solutions (e.g., LPG, improved biomass stoves, biogas) and electricity (e.g., solar lanterns, home lighting systems) can directly improve the health, safety, and economic freedom of women. It enables their participation in self-employment activities such as tailoring, food vending, or mobile phone recharging businesses. Furthermore, lighting improves safety and reduces the risk of gender-based violence after dark.

In India, the Ujjwala Yojana scheme provided LPG connections to over 80 million women, leading to measurable improvements in time use, health, and workforce participation.

Education and Leadership

When girls are freed from the burden of collecting fuel, they are more likely to remain in school. Electricity also enables digital learning and safe study environments, especially in rural boarding schools and homes. Moreover, energy access supports female leadership in community-level energy cooperatives, especially in microgrid and solar energy programs.

Initiatives like Solar Sisters in Africa train women to become entrepreneurs in solar energy, enhancing both their income and social status.

Table 3. Energy and Gender Equality

Dimension	**Impact of Energy Poverty**	**Energy Access Benefits**	**Supporting Data / Examples**
Time Poverty & Unpaid Labor	Women in rural areas spend 3–5 hours daily collecting firewood or dung, limiting time for paid work, education, or rest. Girls often drop out of school to assist in these tasks.	Clean energy access (e.g., LPG, solar cookstoves) reduces time burden, enabling participation in education and economic activities.	ENERGIA (2020): Clean energy access reduces women's daily unpaid labor by ~2 hours.
Health Risks & Mortality	Indoor air pollution from biomass use leads to respiratory illness, eye irritation, and premature death—affecting women and children most.	Improved cookstoves, LPG, and biogas reduce exposure to PM2.5 and carbon monoxide, improving long-term health outcomes.	WHO: Women in energy-poor households face increased risks of respiratory and cardiovascular diseases, and lung cancer.
Empowerment & Income Generation	Lack of electricity limits women's ability to engage in income-generating activities or access safety and communication tools.	Access to electricity and clean cooking fuels enables women to run businesses (e.g., tailoring, food processing, mobile recharging)	India's Ujjwala Yojana: Over 80 million women received LPG connections, improving health and economic participation.

		and improves safety after dark.	
Education & Leadership	Energy-related chores reduce girls' school attendance; lack of lighting hinders evening study. Limited involvement of women in energy governance.	Electrification of schools and homes supports girls' education. Women lead in energy cooperatives and solar enterprises, promoting inclusion and leadership.	Solar Sister (Africa): Empowers women as solar entrepreneurs, increasing income and social agency.

3. DISPARITIES IN ENERGY ACCESS AND CONSUMPTION

Energy access is not uniform across populations or geographies. Disparities in availability, affordability, and quality of energy services are major obstacles to achieving inclusive development. These disparities—rooted in structural, geographic, and socio-economic inequalities—undermine efforts to provide universal energy access and deepen existing social divisions. This section explores two major dimensions of energy inequality: the urban-rural divide and intra-urban socio-economic disparities.

3.1 Urban-Rural Divide

The urban-rural energy divide remains one of the most persistent and challenging aspects of energy poverty in developing countries. While urban centers typically benefit from better infrastructure, grid connectivity, and diversified energy sources, rural areas often face inadequate supply, high costs, and poor reliability.

Access to Modern Energy Services

Urban areas are more likely to be connected to national grids, have higher electrification rates, and enjoy a more stable power supply. In contrast, rural communities, particularly in remote or geographically isolated regions, are often underserved or entirely excluded from central grid infrastructure due to the high costs and logistical challenges of expansion.

According to the World Bank, over 80% of people without access to electricity globally live in rural areas, highlighting the geographic skew in energy provision.

Reliance on Traditional and Polluting Fuels

In the absence of modern energy infrastructure, rural households depend on traditional biomass—such as firewood, crop residues, and dung—for cooking and heating. Lighting needs are often met using kerosene lamps or candles, which are expensive and hazardous. In some cases, diesel generators are used to power essential services like water pumps or schools, but these are often noisy, polluting, and economically unsustainable.

A study by the IEA (2023) found that households relying on biomass spend up to 20% of their income on energy, despite receiving low-quality and harmful services.

Impacts on Development

The rural energy deficit limits agricultural productivity, curtails educational and healthcare services, and discourages business development. In areas without electricity, irrigation is often manual, perishable goods cannot be stored, and students are unable to study after dark. This restricts rural economies to subsistence-level activities, reinforcing poverty and triggering rural-urban migration.

Lack of energy access contributes to the urban drift phenomenon, where youth and workers migrate to cities in search of better opportunities, putting additional stress on urban infrastructure.

Energy Planning Bias

National energy policies and investments tend to prioritize urban and industrial development, where returns are higher and technical implementation is easier. This bias creates a feedback loop where rural areas continue to lag behind due to underinvestment and policy neglect.

Table 4. Urban–Rural Divide in Energy Access

Aspect	Urban Areas	Rural Areas	Supporting Data / Insights
Infrastructure & Connectivity	Well-developed grid infrastructure; higher electrification and more stable supply	Often disconnected from national grids; suffer poor supply, outages, and logistical hurdles	World Bank: Over 80% of those without electricity access globally live in rural areas
Energy Sources	Access to grid electricity, LPG, solar rooftops, and inverters	Heavy reliance on biomass (firewood, dung), kerosene lamps, or diesel generators	IEA (2023): Biomass-dependent households may spend up to 20% of income on low-quality, polluting fuels
Health & Safety	Use of cleaner fuels and safer energy systems	Exposure to indoor air pollution from biomass; fire and burn risks from kerosene or open flames	WHO: Indoor air pollution is a leading health risk in rural households
Economic Activity	Energy access supports business operations, ICT, cold chains, and service industries	Limited energy access constrains irrigation, agro-processing, storage, and non-farm enterprises	Lack of energy hinders productivity and limits rural incomes
Education & Healthcare	Electrified schools and clinics; access to digital tools and emergency services	Schools may lack lighting or equipment; health centers unable to power medical devices or store vaccines	Students in rural areas often lack evening study time due to inadequate lighting
Migration Pressure	Urban areas attract migration from energy-poor rural	Energy deficits drive youth migration,	Rural-urban migration intensifies

	regions, increasing pressure on infrastructure	weakening rural labor and human capital	due to persistent infrastructure gaps
Policy Bias	Greater focus of national energy investment and development policies	Rural areas often deprioritized in energy planning, despite high development need	Rural regions remain locked in poverty cycles due to underinvestment in energy systems

3.2 Socio-Economic Inequality

Energy inequality is not confined to geography; it also exists within urban and peri-urban areas, shaped by income levels, housing conditions, and informal governance.

Urban Informal Settlements and Slums

While urban areas are generally electrified, informal settlements and slums often remain disconnected from formal grid services due to legal, regulatory, or infrastructural barriers. These communities frequently lack official recognition, making it difficult for residents to obtain formal electricity connections or benefit from energy subsidies. Residents may resort to informal or illegal connections, which are unreliable, unsafe, and subject to frequent disconnections or fires. Even when grid access exists, the power supply may be irregular or of poor quality, leading to frequent outages and voltage fluctuations. This limits the use of appliances, affects children's education, and undermines business operations in these low-income areas.

Energy Affordability and Consumption Inequity

Energy services, even when available, are often financially inaccessible to the poor. Many low-income households spend a higher proportion of their income on energy compared to affluent households, leading to energy rationing or under-consumption. In contrast, wealthier populations can afford energy-efficient appliances, rooftop solar systems, inverters, and generators, thereby insulating themselves from grid instability.

For example, a rich household might consume 10–15 times more electricity than a poor household while paying a lower effective cost per kilowatt-hour due to bulk usage or subsidies on renewable installations.

Inequity in Energy Transitions

As countries transition to clean energy, there is a risk of green inequity—where wealthier groups benefit from government subsidies for rooftop solar panels, electric vehicles, and net metering schemes, while poorer communities are left behind. Without inclusive policy frameworks, energy transitions may reinforce socio-economic hierarchies rather than resolve them. A case study in India showed that rooftop solar adoption was concentrated among the top 20% income groups, while slums and rental housing received little to no benefit from renewable energy incentives.

Digital Divide and Energy Access

Energy access also determines participation in the digital economy. Households with stable electricity are better positioned to use mobile phones, internet, and e-learning platforms. In contrast, power-poor communities are digitally excluded, which further limits employment, financial inclusion, and access to public services.

Table 5. Socio-Economic Inequality in Energy Access

Aspect	Impact on Low-Income Populations	Contrast with Higher-Income Groups	Supporting Data / Examples
Urban Informal Settlements & Slums	Often excluded from the formal grid due to lack of legal recognition or infrastructure; rely on unsafe, illegal connections or remain in darkness.	Legally connected, with access to safe, regulated energy and service reliability.	Informal settlements face frequent disconnections, voltage drops, and fire hazards.
Quality of Supply	Even where connected,	More reliable supply through	Poor power quality disrupts children's

	experience frequent blackouts, low voltage, and inconsistent service—affecting home lighting, education, and business operations.	private backup systems (generators, inverters, UPS).	education and local enterprise in informal areas.
Energy Affordability	Pay a higher share of income for basic energy needs and often under-consume due to cost; forced into energy rationing.	Can afford energy-efficient appliances, bulk usage rates, and renewable options that lower their long-term costs.	Poor households may spend >15% of income on energy vs. <5% in wealthier homes (World Bank, 2022).
Green Transition Inequity	Lack of access to subsidies for rooftop solar, electric vehicles, or energy-efficient appliances; renters and slum-dwellers are excluded from long-term investment incentives.	Wealthier households benefit from government support and technological access during clean energy transitions.	India: Rooftop solar adoption concentrated in top 20% income bracket; informal dwellers left out (CEEW, 2021).
Digital Divide	Irregular electricity access limits use of phones, internet, e-learning, and digital services, creating a cycle of digital and economic exclusion.	Enjoy seamless digital access due to stable power, enabling remote work, e-learning, and online services.	Digital exclusion driven by energy poverty restricts access to finance, education, and telehealth platforms.

4. ENVIRONMENTAL AND HEALTH IMPLICATIONS OF ENERGY USE

Energy use, especially in developing countries where traditional fuels dominate, has profound consequences for human health and the environment.

The reliance on inefficient, polluting energy sources not only perpetuates poverty and inequality but also exacerbates ecological degradation and contributes to global climate change. This section discusses two critical dimensions of this crisis: indoor air pollution and environmental degradation.

4.1 Indoor Air Pollution and Health Risks

The Global Burden of Household Air Pollution

Approximately 2.6 billion people globally rely on traditional biomass fuels—such as firewood, charcoal, animal dung, and crop residues—for cooking and heating (IEA, 2023). These fuels are typically burned in open fires or inefficient stoves in poorly ventilated spaces, resulting in dangerous concentrations of indoor air pollutants.

According to the World Health Organization (WHO), household air pollution from solid fuel use is responsible for over 3.2 million premature deaths annually, making it one of the leading causes of death in low- and middle-income countries.

Key Pollutants and Their Health Effects

The combustion of biomass and kerosene releases a complex mixture of harmful pollutants, including:

- **Particulate Matter (PM2.5)**: Fine particles that penetrate deep into the lungs and bloodstream.
- **Carbon Monoxide (CO)**: A colorless, odorless gas that impairs oxygen delivery in the body.
- **Nitrogen Oxides (NOx)** and **Volatile Organic Compounds (VOCs)**: Irritants and precursors to smog formation.

Chronic exposure to these pollutants leads to:

- **Acute respiratory infections**, especially in children under five.
- **Chronic obstructive pulmonary disease (COPD)** and **lung cancer**, particularly among women.
- **Cardiovascular diseases**, low birth weight, cataracts, and adverse pregnancy outcomes.

A child living in a household that cooks with solid fuels is twice as likely to suffer from pneumonia, the leading cause of death in children under five globally.

Gendered Impacts

Women and girls bear the brunt of indoor air pollution due to their role in cooking and household chores. Prolonged exposure during daily cooking hours results in disproportionately higher morbidity and mortality among females in energy-poor households.

WHO data shows that 60% of deaths from household air pollution occur among women and children, making clean energy access a gender-equity issue.

4.2 Environmental Degradation

The use of traditional energy sources not only affects human health but also contributes significantly to environmental degradation at local, regional, and global levels.

Deforestation and Land Degradation

Firewood remains a primary energy source in many rural areas, leading to unsustainable harvesting and widespread deforestation. The constant extraction of biomass from forests weakens ecosystem resilience and disrupts biodiversity.

- **Deforestation** reduces carbon sinks, alters local climates, and increases the frequency of floods and landslides.
- **Soil degradation** occurs due to the removal of vegetation cover, exposing land to erosion and nutrient loss.
- **Habitat destruction** endangers wildlife and weakens the ecological balance of forested areas.

According to the FAO (2022), up to 50% of wood harvested globally is used as fuel, with the percentage rising above 80% in some African countries.

Greenhouse Gas Emissions

Biomass and fossil fuel combustion are major sources of greenhouse gas (GHG) emissions, contributing to global warming and climate instability.

- **Carbon dioxide (CO_2)** is released during the burning of wood, charcoal, and fossil fuels.
- **Black carbon**, a short-lived climate pollutant, is produced from incomplete combustion and has a global warming potential up to 1,500 times higher than CO_2 over a 20-year period.
- **Methane and nitrous oxide** are also emitted from certain biomass combustion processes, contributing to atmospheric GHG loads.

The **Intergovernmental Panel on Climate Change (IPCC)** highlights that household fuel combustion is a significant contributor to regional air pollution and global climate change, especially in South Asia and sub-Saharan Africa.

Cumulative Environmental Stress

Over time, these practices place immense stress on ecosystems, aggravating water scarcity, altering rainfall patterns, and reducing agricultural productivity. Communities that depend on natural resources for their livelihoods—such as smallholder farmers and pastoralists—are particularly vulnerable.

The Urgent Need for a Clean Energy Transition

Given the dual burden of health risks and environmental damage, transitioning to clean and sustainable energy systems is not only an environmental priority but also a public health emergency. A clean energy transition would involve:

- **Promoting clean cooking technologies** (e.g., improved biomass stoves, LPG, electric induction stoves, biogas).
- **Scaling up renewable energy** sources like solar, wind, and mini-grids for household and institutional use.
- **Implementing energy efficiency standards** to reduce emissions and indoor pollution.
- **Strengthening policy frameworks and subsidies** to make clean energy affordable and accessible for the poorest households.

For example, the use of LPG stoves can reduce household air pollution exposure by over 90%, significantly lowering respiratory illnesses and mortality.

5. SUSTAINABLE ENERGY TRANSITIONS IN THE GLOBAL SOUTH

As the urgency to bridge energy access gaps aligns with global climate goals, many countries in the Global South are spearheading transformative approaches to energy planning. These nations, historically underpowered, now find themselves at a pivotal juncture—where sustainable energy transitions are not only necessary for development but also present unprecedented opportunities to leapfrog into a low-carbon future. This section explores key national-level efforts and decentralized innovations shaping the clean energy landscape across the Global South.

5.1 National Initiatives: Driving Large-Scale Transformation

Several developing countries have launched bold initiatives to address energy poverty, diversify their energy mix, and reduce reliance on fossil fuels. These efforts highlight the role of strategic policymaking, public-private collaboration, and renewable innovation in enabling large-scale transitions.

India: Saubhagya Scheme – Powering the Last Mile

India's Saubhagya Scheme, launched in 2017, marked a landmark effort to achieve universal household electrification. With an emphasis on last-mile delivery, the scheme integrated grid extension and solar-based standalone systems to reach previously unserved households—especially in tribal and remote regions.

- **Impact**: Over 28 million households were electrified in under two years.
- **Equity Lens**: The scheme prioritized connections for low-income and marginalized communities, often providing them free of cost.
- **Challenges Ahead**: While access has improved, reliability and affordability remain areas for further strengthening.

Saubhagya symbolizes a political and logistical commitment to ensuring that no household remains in the dark, redefining energy as a right, not a privilege.

Kenya: Geothermal Energy – Tapping Earth's Heat

Kenya has emerged as a global leader in geothermal energy development, capitalizing on its location along the East African Rift. The country's long-term vision for energy security and sustainability has led to significant investment in indigenous, clean, and renewable sources.

- **Achievements**: As of 2023, geothermal energy contributes over 40% of Kenya's electricity generation.
- **Institutional Strength**: State-backed entities like the Geothermal Development Company (GDC) have been instrumental in derisking investments.
- **Resilience**: Geothermal power provides baseload electricity, reducing dependency on hydro and diesel during droughts.

Kenya's geothermal success story shows that energy-rich potential in the Global South can be unlocked through targeted investment and visionary governance.

Brazil: Proálcool – Pioneering the Biofuel Revolution

Brazil's Proálcool Program, initiated in the 1970s during the global oil crisis, remains one of the most successful examples of bioenergy transition. The program sought to reduce petroleum dependence by promoting sugarcane-based ethanol as a cleaner, domestic alternative.

- **Impact**: Brazil is now the second-largest ethanol producer in the world and a global hub for flex-fuel vehicle adoption.
- **Sustainability**: Ethanol from sugarcane has a high energy output-to-input ratio and significantly lower lifecycle emissions than gasoline.
- **Socio-Economic Benefits**: The sector has supported rural employment, agro-industrial innovation, and energy diversification.

Proálcool demonstrates how bio-based energy strategies can simultaneously meet energy, economic, and environmental goals when backed by sustained policy and agricultural capacity.

5.2 Off-Grid and Decentralized Solutions: Empowering the Margins

Beyond national grids and centralized systems, decentralized energy solutions have emerged as vital tools for rural electrification and sustainable development in remote or underserved regions. These solutions are often quicker to deploy, more cost-effective for low-density populations, and responsive to local needs.

Mini-Grids: Community-Scale Clean Power

Mini-grids—localized energy networks powered by solar, biomass, or micro-hydro—are proving transformative in off-grid regions. They offer tailored energy solutions that serve not just households but also schools, clinics, and small enterprises.

- **Flexibility**: Modular design allows scaling as demand grows.
- **Economic Impact**: Mini-grids enable productive uses of electricity such as agro-processing, irrigation, and small-scale manufacturing.
- **Example**: In **Nigeria**, donor-backed programs have installed over 100 solar hybrid mini-grids, bringing reliable power to over 200,000 people.

Mini-grids represent the intersection of climate ambition and community empowerment, bridging the energy gap with resilience and inclusivity.

Solar Home Systems (SHS): Personalized Power for Every Home

SHS offers a simple but powerful solution for households located far from the grid. These systems, typically including a solar panel, battery, and LED lighting, provide clean and reliable power for basic needs like lighting, mobile charging, and entertainment.

- **Affordability**: Pay-as-you-go models, integrated with mobile banking, have made SHS accessible to low-income families.
- **Impact**: In Bangladesh, over 6 million SHS units have been deployed through public-private partnerships under IDCOL, transforming rural electrification.

SHS proves that small-scale interventions can generate large-scale social returns when coupled with smart finance and local ownership.

Biogas and Clean Cooking: Health, Environment, and Efficiency

Biogas digesters, using organic waste to produce clean-burning methane, address both cooking energy needs and waste management. These systems reduce reliance on firewood and charcoal, improve indoor air quality, and produce nutrient-rich slurry as a byproduct for agriculture.

- **Example**: In Nepal, the Biogas Support Programme has installed over 300,000 biogas plants, improving health and income for thousands of rural families.
- **Co-Benefits**: Lower deforestation, carbon credits, and women's empowerment through reduced exposure to smoke and drudgery.

Clean cooking is no longer a peripheral issue—it is central to climate policy, public health, and gender equity.

A New Paradigm of Energy Democracy

The sustainable energy transition in the Global South is not a one-size-fits-all approach—it is a mosaic of policies, technologies, and partnerships tailored to diverse socio-economic and geographic contexts. Whether through government-led electrification drives, geothermal development, or decentralized energy innovation, these efforts reflect a broader shift toward energy as an instrument of equity and resilience.

Countries that were once energy-deficient are now laboratories of low-carbon innovation. Their experiences offer valuable lessons for a world seeking not just more energy, but better, fairer, and cleaner energy for all.

6. INTEGRATING ENERGY WITH DEVELOPMENT AGENDAS

To achieve Sustainable Development Goal 7 (Affordable and Clean Energy for All) and its interlinked targets, energy must be viewed not as an isolated sector, but as a foundational driver of socio-economic development. In the Global South, integrating energy strategies into broader national development agendas can unlock cross-sectoral benefits—enhancing healthcare, education, agriculture, livelihoods, and climate resilience. This

section outlines essential strategies to embed energy access meaningfully within the wider framework of sustainable development.

6.1 Key Strategies

Decentralized Energy Systems: Reaching Remote and Rural Communities: Decentralized energy systems such as solar mini-grids, solar home systems, and biogas units are vital for electrifying rural and underserved areas where extending the national grid is economically unfeasible. These systems offer custom-built, scalable solutions that can be rapidly deployed to meet local energy needs. By empowering communities with localized energy infrastructure, they enable critical services like irrigation, refrigeration, and digital connectivity—thereby promoting inclusive development and rural resilience.

Policy and Regulatory Support: Enabling Participation and Investment: Effective energy transitions require strong policy and regulatory frameworks that incentivize innovation and promote stakeholder engagement. Governments should implement supportive mechanisms such as feed-in tariffs, tax exemptions on renewable technologies, and clear public-private partnership models to attract private sector investment. Furthermore, transparent regulations are essential for encouraging community participation and protecting the interests of vulnerable populations, ensuring that energy reforms are both equitable and sustainable.

Linking Energy with Core Development Sectors: Energy must be systematically integrated into other key sectors such as healthcare, education, agriculture, and climate resilience. In the health sector, electricity is crucial for powering diagnostic tools, storing vaccines, and ensuring safe childbirth procedures. In education, electrified schools enable extended study hours, digital learning, and improved teacher retention. In agriculture, energy access facilitates mechanized irrigation, cold storage, and agro-processing, which in turn improves food security and rural incomes. Moreover, integrating renewable energy into local climate adaptation strategies enhances resilience against extreme weather and reduces dependency on fossil fuels.

Table 6. Key Strategies for Integrating Energy with Development Agendas

Strategy	Focus Area	Description
Decentralized Energy Systems	Reaching Remote and Rural Communities	Use of solar mini-grids, solar home systems, and biogas units to electrify off-grid regions. These systems are scalable, rapidly deployable, and tailored to local needs, enabling irrigation, refrigeration, and connectivity.
Policy and Regulatory Support	Enabling Participation and Investment	Governments must offer incentives like feed-in tariffs, tax exemptions, and public-private partnerships. Transparent regulations ensure inclusivity and equity in energy reforms.
Linking Energy with Development Sectors	Health, Education, Agriculture, Climate Resilience	Electricity powers essential services like vaccine storage and safe childbirth (health), digital learning (education), irrigation and processing (agriculture), and disaster adaptation (climate resilience).

7. GLOBAL COOPERATION AND FINANCING

Achieving universal energy access and transitioning to clean energy systems in the Global South is a monumental task—one that cannot be accomplished without robust global cooperation and innovative financing mechanisms. Given the scale of investment required and the systemic inequalities that persist in international financial flows, support from multilateral organizations, donor countries, development banks, and private capital is essential. This section outlines the roles of international agencies and emerging financing models that can help accelerate energy transitions in developing nations.

7.1 The Role of International Agencies

International agencies play a pivotal role in enabling energy transitions by bridging resource and capacity gaps in developing countries. Their support goes beyond financing—it encompasses policy guidance, technology facilitation, and institutional strengthening.

Funding Mechanisms

Multilateral financial instruments such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), and the Climate Investment Funds (CIF) are essential for providing grants, concessional loans, and risk mitigation tools for clean energy projects. These funds help de-risk investments in fragile or low-income regions, making them more attractive for private and public sector partners.

Technology Transfer and Capacity Building

International agencies facilitate the transfer of clean technologies such as solar photovoltaics, mini-grid systems, wind turbines, and energy-efficient appliances. They also support capacity-building initiatives to train engineers, planners, and regulators in energy system design, project implementation, and maintenance. Programs led by organizations like UNDP, IRENA, and UNEP are instrumental in developing local expertise and strengthening institutional frameworks.

Policy Advisory and Technical Assistance

Agencies such as the World Bank, Asian Development Bank (ADB), and African Development Bank (AfDB)provide technical assistance for national energy planning, regulatory reform, and sustainable tariff setting. They support governments in crafting inclusive energy policies that align with Sustainable Development Goals and climate targets. Moreover, platforms like Sustainable Energy for All (SEforALL) help coordinate global partnerships and monitor progress toward SDG 7.

7.2 Innovative Financing Models

Conventional financing approaches are often inadequate to meet the scale and urgency of clean energy investments required in developing countries. As such, innovative financing mechanisms are emerging as essential tools to mobilize capital, reduce risk, and improve the efficiency of resource allocation.

Blended Finance

Blended finance refers to the strategic use of public or philanthropic capital to attract private sector investment in development projects. By absorbing certain risks or offering first-loss guarantees, public funds can catalyze private financing that would otherwise be withheld due to perceived risk.

- **Example**: A solar mini-grid initiative in sub-Saharan Africa might receive seed funding from the World Bank, a concessional loan from a development bank, and commercial investment from a private energy firm.
- **Impact**: Blended finance aligns public goals with private profit motives, enabling scalable and sustainable energy solutions.

Green Bonds

Green bonds are debt instruments specifically earmarked for financing environmentally beneficial projects. Governments, corporations, and multilateral institutions issue these bonds to raise funds for renewable energy infrastructure, energy efficiency programs, and climate-resilient development.

- **Global Growth**: The green bond market surpassed USD 500 billion in annual issuance globally in recent years, with increasing participation from emerging economies.
- **Case Study**: India's Energy Efficiency Services Limited (EESL) successfully raised capital through green bonds to support its LED lighting and clean energy projects.

Results-Based Financing (RBF)

RBF ties the disbursement of funds to the achievement of specific, measurable outcomes—such as the number of households electrified, reductions in CO_2 emissions, or improvements in indoor air quality.

- **Benefits**: Encourages accountability, efficiency, and value-for-money in project execution.

- **Example**: The Global Partnership on Output-Based Aid (GPOBA) has applied RBF models to solar energy deployment in Bangladesh and clean cookstove programs in Kenya, improving cost-effectiveness and scaling impact.

8. Conclusion and the Way Forward

Access to modern, reliable, and sustainable energy is not merely a utility—it is a fundamental human right and an essential enabler of socio-economic development. In the context of the Global South, where millions still live in the dark or depend on polluting fuels for basic needs, addressing energy poverty is not just a developmental goal—it is a moral imperative and a catalyst for systemic transformation.

This chapter has explored the multifaceted relationship between energy and development, illustrating how energy access underpins a wide spectrum of progress—spanning public health, education, agriculture, gender equality, economic empowerment, and climate action. Without energy, healthcare centers cannot function efficiently, schools cannot leverage modern learning tools, and small enterprises cannot thrive. Conversely, equitable energy access can spark inclusive growth, improve well-being, and lay the foundation for climate-resilient societies.

The analysis revealed that energy poverty is not uniformly distributed. It disproportionately affects rural populations, marginalized communities, and women and girls—thereby reinforcing pre-existing socio-economic inequalities. Bridging these disparities requires both macro-level policy interventions and micro-level technological innovations that are tailored to local contexts.

Clean energy transitions—through grid expansion, mini-grids, solar home systems, and bioenergy—offer unprecedented opportunities for leapfrogging carbon-intensive development paths. Countries such as India, Kenya, and Brazil have demonstrated that, with political will, institutional support, and community engagement, large-scale transformations are not only possible but achievable. Yet these efforts must be underpinned by strong governance frameworks, public-private partnerships, and inclusive financing mechanisms that ensure no one is left behind.

Importantly, energy strategies must not operate in silos. They must be embedded within broader national development agendas that holistically address education, health, livelihoods, and climate adaptation. Multi-sectoral integration ensures that the benefits of energy access are magnified and sustained across generations.

However, national efforts alone will not suffice. Global solidarity is crucial. Developed nations, international organizations, and climate finance institutions must fulfill their commitments to support the Global South through funding, technology transfer, and capacity building. Initiatives like the Green Climate Fund, Sustainable Energy for All (SEforALL), and global energy partnerships must be scaled up, democratized, and made more accessible to the countries and communities that need them most.

Access to clean and affordable energy is the cornerstone of a dignified life and a sustainable planet. By investing in inclusive energy systems today, we not only uplift communities but also safeguard our shared future. The path forward lies in integrated planning, inclusive policies, and international cooperation—a path where energy becomes the bridge, not the barrier, to equity, resilience, and sustainability. Let us act now—because the light we bring to the most vulnerable will illuminate the way for all.

REFERENCES

Barnes, D. F., & Foley, G. (2004). *Rural electrification in the developing world: A summary of lessons from successful programs*. World Bank. (Barnes & Foley, 2004)

Bazilian, M., Nussbaumer, P., Rogner, H., Brew-Hammond, A., Foster, V., Pachauri, S., … Howells, M. (2012). *Improving access to modern energy services: Insights from case studies*. Energy Policy, 49, 336–347.

Bhatia, M., & Angelou, N. (2015). *Beyond connections: Energy access redefined*. World Bank.

Bhattacharyya, S. C. (2013). *Rural electrification through decentralized off-grid systems in developing countries*. Springer.

Birol, F. (2017). *Energy access outlook 2017: From poverty to prosperity*. IEA.

Chaurey, A., & Kandpal, T. C. (2010). *Assessment and evaluation of PV-based decentralized rural electrification: An overview*. Renewable and Sustainable Energy Reviews, 14(8), 2266–2278.

Cloke, J., Mohr, A., & Brown, E. (2017). *Imagining renewable energy: Towards a social energy systems approach to community renewable energy projects in the Global South*. Energy Research & Social Science, 31, 263–272.

ESMAP. (2019). *Mini Grids for Half a Billion People: Market Outlook and Handbook for Decision Makers*. World Bank.

Foley, G. (1992). *Rural electrification and energy policy in developing countries*. Energy Policy, 20(2), 145–152.

Gaye, A. (2007). *Access to energy and human development*. UNDP.

Ghosh, A., & Ganesan, K. (2014). *Rethink India's energy strategy: Toward a low-carbon future*. Council on Energy, Environment and Water.

Glemarec, Y. (2012). *Financing off-grid sustainable energy access for the poor*. Energy Policy, 47, 87–93.

Goldemberg, J. (2012). *Energy: What everyone needs to know*. Oxford University Press.

International Energy Agency. (2023). *World Energy Outlook 2023*. IEA.

IRENA. (2022). *Renewables Readiness Assessment: Kenya*. International Renewable Energy Agency.

Islam, M. T., Huda, N., Abdullah, A. B., & Saidur, R. (2018). *A comprehensive review of state-of-the-art concentrating solar power (CSP) technologies*. Renewable and Sustainable Energy Reviews, 91, 987–1018.

Karekezi, S., & Kithyoma, W. (2003). *Renewable energy strategies for rural Africa: Is a PV-led renewable energy strategy the right approach for providing modern energy to the rural poor of sub-Saharan Africa?* Energy Policy, 31(11), 1095–1109.

Khandker, S. R., Barnes, D. F., & Samad, H. A. (2012). *Are the energy poor also income poor? Evidence from India*. Energy Policy, 47, 1–12.

Krey, V., & Pachauri, S. (2014). *Energy access, energy poverty, and socioeconomic development*. Climatic Change, 123(3–4), 371–383.

Mahapatra, S., & Dasappa, S. (2012). *Rural electrification: Optimizing energy services for the poor*. Current Opinion in Environmental Sustainability, 4(4), 344–350.

Matinga, M. N., Clancy, J., & Annegarn, H. (2013). *Explaining the gender-energy-poverty nexus: A review of evidence from developing countries*.

Moner-Girona, M., Bódis, K., Morrissey, J., Kougias, I., Hankins, M., Huld, T., & Szabó, S. (2019). *Decentralized rural electrification in sub-Saharan Africa*. Energy, 191, 116–171.

Niez, A. (2010). *Comparative study on rural electrification policies in emerging economies: Keys to successful policies*. IEA Information Paper.

Oda, J., Akimoto, K., Tomoda, T., Wada, K., Sano, F., & Homma, T. (2012). *International comparisons of energy efficiency in power, steel, and cement industries*. Energy Policy, 46, 185–201.

Pachauri, S., Rao, N. D., Nagai, Y., & Riahi, K. (2012). *Access to modern energy: Assessment and outlook for developing and emerging regions*. IIASA.

Parikh, J., & Parikh, K. (2011). *India's energy needs and low carbon options*. Energy, 36(6), 3650–3658.

Peters, J., Vance, C., & Harsdorff, M. (2011). *Grid electrification and household electricity consumption: Evidence from Ghana*. Energy Economics, 33(5), 830–839.

Rehman, I. H., & Ahmed, T. (2002). *Renewable energy in India: Status and prospects*. TERI.

REN21. (2023). *Renewables 2023 Global Status Report*. REN21 Secretariat. → (REN21, 2023)

SEforALL. (2020). *Energizing finance: Understanding the landscape 2020*. Sustainable Energy for All.

Sovacool, B. K. (2016). *How long will it take? Conceptualizing the temporal dynamics of energy transitions*. Energy Research & Social Science, 13, 202–215.

Tucho, G. T., & Nonhebel, S. (2015). *Bio-wastes as an alternative household cooking energy source in Ethiopia*. Energy for Sustainable Development, 24, 132–140.

United Nations Development Programme. (2021). *Human Development Report 2021/22: Uncertain times, unsettled lives*. UNDP.

United Nations Economic Commission for Africa. (2019). *Energy access and SDG implementation in Africa*.

United Nations Environment Programme. (2021). *Emissions Gap Report 2021*. UNEP.

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*.

World Bank. (2018). *Regulatory indicators for sustainable energy: A global scorecard for policy makers*.

World Bank. (2020). *Tracking SDG 7: The Energy Progress Report 2020*.

World Health Organization. (2022). *Household air pollution and health*. https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health

World Resources Institute. (2019). *A global renewable energy policy database*.

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