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Authors : Riccardo MEREU (POLIMI)

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Project officer: Maria-Laura TRIFILETTI

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Summary

This book presents a holistic framework for planning sustainable and just energy access solutions in developing contexts, with a focus on Africa. It introduces the Comprehensive Energy Solution Planning (CESP) approach, which integrates technical energy system design with social, economic, and institutional considerations. The book highlights decentralized renewable systems, especially minigrids, as key tools for equitable electrification. It emphasizes energy justice, sound policymaking, viable business models, and impact evaluation as essential for long-term sustainability. Overall, it argues that people-centered, integrated planning is crucial to achieving a just energy transition.

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Date	By
2026-01-07 10:20:51	Léonard LéVêQUE (LGI)
2026-01-16 14:51:15	Mathilde VIDELO (LGI)



LEAP-RE

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and Innovation Partnership on Renewable Energy

Research & Innovation Action

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PoliMi

Disclaimer

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Summary

This book presents a holistic framework for planning sustainable and just energy access solutions in developing contexts, with a focus on Africa. It introduces the Comprehensive Energy Solution Planning (CESP) approach, which integrates technical energy system design with social, economic, and institutional considerations. The book highlights decentralized renewable systems, especially minigrids, as key tools for equitable electrification. It emphasizes energy justice, sound policymaking, viable business models, and impact evaluation as essential for long-term sustainability. Overall, it argues that people-centered, integrated planning is crucial to achieving a just energy transition.

Keywords

e-book, Energy planning, Local development, capacity building





1. Comprehensive Energy Planning for Local Development Book

A book named “Comprehensive Energy Planning for Local Development – towards a standard for off-grid sizing and a just energy transition” has been pre-approved by the publisher and submitted for publication in the “Research for Development” Series of the Springer Nature editor.

2. Introduction to the Book – Preface by the Editors

Preface by the Editors

Emanuela Colombo, Riccardo Mereu, Nicolò Stevanato

UNESCO Chair in Energy for Sustainable Development, Department of Energy, Politecnico di Milano, Italy

The rational of the book

Sustainable and reliable energy underpins economic activities, social well-being, and institutional functioning; its absence constrains development and amplifies vulnerability. Yet, despite the acceleration of the global “energy transition,” the fundamental promise of modern energy services remains unfulfilled for a substantial share of humanity. Recent joint tracking efforts by the World Bank, the International Energy Agency, the International Renewable Energy Agency, the United Nations Statistics Division, and the World Health Organization confirm that progress toward universal energy access continues to lag behind the trajectory required to meet the Sustainable Development Goals. In 2023, approximately 666 million people still lived without access to electricity, while 2.1 billion relied on polluting cooking fuels, with severe consequences for health, the environment, and livelihoods.

This gap unfolds within a global energy landscape increasingly shaped by:

- **Interdependence and the need of partnership.** No country can be considered an “energy island”: energy systems, supply chains, and transition pathways are deeply interconnected across regions and markets. The geography of energy resources—whether fossil fuels, critical minerals, or renewable potential distribution—is redefining geopolitical relations and opening new spaces for cooperation and trade. In this context, Africa plays a strategic role, both as a continent facing persistent energy access challenges and as a central actor in the global energy transition. Recent initiatives at national, regional, and multilateral levels—including the AU–EU High-Level Policy Dialogue on Science, Technology and Innovation for Sustainable Energy, and the G7 Energy for Growth initiative—reflect a renewed recognition that achieving energy access and energy transition objectives requires balanced, long-term, and mutually beneficial partnerships.
- Fundamental questions on **equity**. While global investments in renewable energy have increased significantly in recent years, their distribution remains highly uneven. Regions with weaker economies—home to nearly two-thirds of the world’s population—receive only a small share of total clean energy investments. Similarly, despite substantial growth in global solar capacity, only a marginal fraction is installed in Africa, where energy systems are characterized by high losses, limited





reliability, and persistent reliance on traditional fuels for cooking. These disparities underscore the need to distinguish between equality and equity in the pursuit of a **just energy transition**. A global transition must be inclusive, but not necessarily uniform: pathways must be differentiated, context-sensitive, and grounded in a realistic understanding of local constraints, development priorities, and transitional roles for different energy sources.

Addressing the above, calls for a **paradigm shift** in planning, production, and consumption within energy systems. Energy should not be treated as an end in itself, but as a means—an instrumental right enabling access to services, economic opportunities, and social development. **Effective energy solutions must therefore be people-driven: designed for, by, and with the communities they are intended to serve.** Evidence from long-term research on decentralized energy systems, and hybrid minigrids in particular, confirms that inadequate assessment of local needs and contexts is among the most recurrent causes of project failure. Oversized systems lead to unnecessary costs, while undersized ones fail to meet demand—both undermining long-term sustainability. Integrated planning approaches that combine engineering rigor with social sciences’ insights are thus not optional, but essential.

A central tension in this landscape lies between the rapid transformation of global energy systems and the persistence of widespread—and in some cases worsening—energy access gaps. Electrification efforts, climate imperatives, and energy security concerns are accelerating the deployment of decentralized renewable technologies and mini-grid solutions at scale. Yet, a significant share of energy access interventions continues to underperform in practice. Technologies for granting access to energy constitute already a mature market, but the energy solution planning approaches based on traditional engineering-oriented methodologies, cannot provide long-term sustainability in specific contexts. This reflects a fundamental lack of socio-technical considerations to ground energy solutions into local institutional arrangements, social structures, community involvement and behavioral dynamics

Therefore, deriving from the scientific and grey literature as well as from the field experience, many scholars and practitioners have been advocating for a new standard able to account for the most recent advancements in **affordable and sustainable technological solutions**, with a **neutral approach** which evaluates competition across different solutions **based on their impact on the economic, social and environmental dimensions of the specific community**.

Within this perspective, this book aims to support the design, implementation, and long-term sustainability of energy access interventions through a decision-oriented, evidence-based approach which embeds **traditional engineering-oriented with social sciences-based approaches** in project planning. The analytical perspective adopted is intended to serve a broad range of stakeholders: researchers seeking coherent and publishable frameworks, practitioners operating in complex field settings, policymakers and funders aligning regulatory and financial instruments with development objectives, and educators training professionals capable of working across technical, social, and institutional domains.

How to read the book

The book adopts the Comprehensive Energy Solution Planning (CESP) framework to address a key limitation of many energy access initiatives: the focus on technical and economic optimization without sufficient attention to long-term sustainability in local contexts. CESP is conceived as an iterative planning process in which social-science



analysis and engineering approaches are systematically integrated and assumptions are revised across phases as new information becomes available.

The structure of the book moves from contextual framing to practical application. Initial chapters examine the socio-political and institutional dimensions of energy access and the challenges of a just energy transition in Africa, followed by chapters aligned with the main phases of the CESP framework, from needs identification and resource assessment to demand analysis and system modelling. The focus then shifts to implementation and sustainability, addressing business models, enabling activities, and impact evaluation.

To strengthen the connection between conceptual analysis and practical application, each chapter is complemented by two types of boxed content to reinforce a decision-oriented perspective: (i) Case study boxes situate the discussion within concrete institutional, technological, and operational contexts, drawing on documented experiences from policy frameworks, applied research, and real-world implementations; (ii) Methods and tools boxes introduce analytical approaches, digital platforms, and resources relevant to energy access planning and modelling, outlining their rationale, inputs, outputs, and domains of applicability.

The partnership and ethical perspective: the LEAP-RE collaboration

This book is the result of a collaborative effort developed within the LEAP-RE partnership, reflecting the fundamental premise that no country can address the **energy transition in isolation**. In a global energy landscape characterized by deep interdependence across systems, supply chains, and innovation pathways, effective energy access solutions require **scientific cooperation, technical partnerships, and shared knowledge between regions, grounded in mutual responsibility and fairness**.

LEAP-RE (<https://www.leap-re.eu/>) is the Long-Term Joint European Union–African Union Research and Innovation Partnership on Renewable Energy, established to strengthen Africa–Europe cooperation through coordinated research, innovation, and capacity-building activities. Funded under the European Union’s Horizon 2020 framework programme (Grant Agreement No. 963530), LEAP-RE brings together 96 partners from 34 countries. In line with the principles of a just energy transition, the partnership explicitly seeks to address existing asymmetries by promoting differentiated, context-sensitive research agendas and by fostering equitable collaboration between regions with diverse development trajectories and energy needs.

The collaborative nature of this partnership is reflected throughout the book. Contributions span multiple disciplines and institutional perspectives, integrating engineering, social sciences, policy analysis, and implementation experience. This interdisciplinary and cross-regional approach supports energy access solutions that are not only analytically rigorous and operationally feasible, but also equitable, locally relevant, and aligned with diverse regulatory, institutional, and socio-economic contexts—conditions that are essential for the long-term sustainability of energy access interventions.

Closing note

Energy access planning takes place in contexts characterized by high uncertainty, evolving constraints, and strong interdependencies between technical, social, and institutional factors. This book aims to provide a structured and evidence-based reference to support such decision-making processes. By building on the CESP framework and on the collective expertise developed within the LEAP-RE collaboration, it seeks to contribute to the design, implementation, and long-term sustainability of energy access interventions that effectively support development objectives.





3. Table of Contents and Summary of the Chapters

The book is structured in the following chapters, where title, authors and a brief summary is reported.

Chapter 1 - The socio-technical challenges of the Just Energy Transition for Africa (Colombo, Mereu, Stevanato)

This chapter frames energy access as a socio-technical challenge central to Africa's development and the global energy transition. It introduces energy justice as a guiding principle, emphasizing distributive, procedural, and recognition dimensions. Africa's low energy consumption contrasts with its growing population and strategic role in critical resources. Decentralized solutions, particularly minigrids, are presented as key enablers of equitable access. The chapter highlights third-generation minigrids and the need for holistic planning tools. It introduces the Comprehensive Energy Solution Planning (CESP) framework, integrating engineering and social sciences. The chapter sets the conceptual and methodological foundation for the entire book.

Chapter 2 - Policymaking for off-grid electrification in emerging economies and developing markets: evidence from country studies (Shendrikova, Falchetta, Hafner)

This chapter analyzes how policy and regulatory frameworks shape off-grid electrification outcomes. Through country case studies (Kenya, Ghana, Senegal, Nepal, Peru), it shows how regulatory clarity and political stability attract investment. The chapter compares centralized and decentralized strategies across contexts. It highlights best practices such as clear licensing rules, tariff regulation, and risk-mitigation mechanisms. Persistent barriers include weak institutions and policy inconsistency. The chapter concludes with policy recommendations to foster inclusive, scalable energy access in developing markets.

Case Study Box - UNDP's Just Energy Transition Approach: Integrated Policy for Leaving No One Behind (Pistolese)

This box presents UNDP's integrated policy approach to just energy transition. It emphasizes inclusivity, social protection, and institutional coordination. The approach aligns energy access with poverty reduction, job creation, and climate goals. It stresses participatory planning and stakeholder engagement. The case illustrates how energy policies can support "leaving no one behind." It provides practical insights for aligning national energy strategies with justice principles.

Chapter 3 - Energy Needs: the Capabilities Approach as a Basis for Priority Identification (Crevani, Milchram, Frigo)

This chapter reframes energy planning by focusing on human capabilities rather than energy quantities alone. Using the Capabilities Approach, it links energy services to well-being, education, health, and livelihoods. It critiques conventional demand metrics that overlook social outcomes. The chapter proposes a structured method to prioritize energy needs based on locally valued capabilities. This approach supports context-sensitive planning and equity. It strengthens the social foundation of the CESP framework.

Methods and Tools Box - Africa Knowledge Platform for Energy Planning (Moner-Girona, Roca-Ristol, Pittalis, Kakoulaki, Szabo, Battistella, Davy, Tonnarelli, Angeluccetti)





This box introduces a digital platform supporting evidence-based energy planning in Africa. It integrates geospatial data, socio-economic indicators, and energy access metrics. The platform enables scenario analysis and policy assessment. It supports planners in identifying gaps and prioritizing interventions. The tool enhances transparency and regional comparability. It exemplifies data-driven support for CESP implementation.

Chapter 4 - Energy resource assessment methodologies for decentralized energy systems modelling (Mereu, Simões, Tsuanyo, Costa, Couto, Cardoso, Onori)

This chapter focuses on assessing renewable energy resources for decentralized systems. It reviews methodologies for solar, wind, and hydropower assessment. The chapter discusses data sources, spatial resolution, and uncertainty. Accurate resource assessment is shown to be critical for reliable system design. It links resource analysis to energy output modeling. The chapter supports robust, site-specific minigrid planning.

Methods and Tools Box - PVGIS (Photovoltaic Geographical Information System) (Martinez, Moner-Girona, Szabo)

This box presents PVGIS, a widely used tool for solar resource assessment. It provides solar irradiation data, PV performance estimates, and climate information. The tool supports both project design and policy analysis. It is accessible, open-source, and widely applied in Africa. PVGIS enhances accuracy in PV system sizing. It exemplifies standardized tools within CESP.

Case Study Box - Geothermal application and case studies in Africa (Zuffi, Fiaschi)

This box reviews geothermal potential and case studies across Africa. It highlights East Africa's leadership in geothermal deployment. Geothermal energy is presented as a stable, low-carbon resource. The box discusses technical, financial, and institutional challenges. It shows how geothermal can support baseload power. The case underlines the importance of resource diversification.

Chapter 5 - Demand assessment methodologies for off-grid energy system modelling (Stevanato, Dominguez)

This chapter examines how electricity demand is estimated in off-grid contexts. It reviews household, productive, and community energy uses. The chapter compares expert-based, archetype, and data-driven methods. Demand evolution over time is highlighted as a key challenge. Accurate demand assessment is essential to avoid system over- or under-sizing. The chapter introduces the Demand–Needs Nexus. It strengthens the demand side of CESP phase 2.

Case Study Box - From Pilot to Portfolio: Renewvia's Practical Conditions for Scalable Minigrids (Martines)

This box presents Renewvia's experience in scaling minigrids. It highlights practical conditions for portfolio-based development. Key factors include demand stimulation, appliance financing, and standardized designs. The case shows how scale improves financial viability. It provides lessons for commercial sustainability. The box links theory to private-sector practice.

Chapter 6 - Energy System Modelling for Optimal Sizing of Off-Grid Technologies (Fioriti, Stevanato, Petrelli, Berizzi)

This chapter reviews modeling approaches for off-grid system sizing. It covers heuristic, optimization, and multi-objective methods. The chapter addresses uncertainty, renewable variability, and demand growth. It compares modeling tools and their applicability.





Advanced optimization supports cost-effective and resilient designs. The chapter forms the core technical pillar of CESP phase 3.

Methods and Tools Box - Geospatial analysis approaches for supporting off-grid energy planning (Falchetta)

This box explores GIS-based approaches for electrification planning. It integrates spatial data on population, infrastructure, and resources. Geospatial tools support least-cost and portfolio planning. They are widely used by governments and developers. The box highlights scalability and transparency. It reinforces spatial intelligence within CESP.

Chapter 7 - Business Model Identification and Formulation in energy access projects (Dibaba, Tomas Fillol, Pinomaa, Honkapuro)

This chapter focuses on financial and organizational sustainability. It reviews business model typologies for off-grid energy. The chapter emphasizes affordability, inclusiveness, and cost recovery. Ownership structures and tariff design are discussed. Enabling policies and stakeholder engagement are highlighted. The chapter aligns technical solutions with long-term viability.

Case Study Box - Fusion Grid system as a feasible way of rural Africa electrification (Demidov, Pinomaa, Honkapuro, Nieminen)

This box presents the Fusion Grid concept for rural electrification. It integrates grid and off-grid solutions dynamically. The system enhances flexibility and resilience. The case demonstrates technical and economic feasibility. It shows innovative pathways for hybrid electrification. The box illustrates future-oriented solutions.

Chapter 8 - Complementary Activities in Energy Access for Ensuring Sustainability (Vinciguerra, Tonini)

This chapter argues that electricity access alone is insufficient for development. It introduces complementary activities such as training, finance, and market access. The chapter uses system dynamics to analyze interactions. A case from Tanzania illustrates integrated planning. The chapter aligns energy with the Water–Energy–Food Nexus. It represents CESP phase 5.

Case Study Box - WEF Nexus and beyond: the case of St. Mary's hospital Lacor (Barbieri)

This box examines energy, water, and food integration in a Ugandan hospital. Reliable energy supports healthcare delivery and resilience. The case shows cross-sector benefits of energy access. It highlights institutional capacity and local impact. The box demonstrates holistic sustainability in practice.

Chapter 9 – Impact Evaluation of Energy for Development Projects (Tomas Fillol, Tonini, Golinucci, Dibaba, Antti Pinomaa, Honkapuro)

This chapter reviews methods for evaluating energy-for-development impacts. It distinguishes ex-ante and ex-post approaches. Tools include LCA, IO models, CGE, and MCDA. Monitoring and evaluation frameworks are emphasized. Stakeholder engagement is critical for meaningful assessment. The chapter completes CESP phase 6.

Case Study Box - Measuring the Impact of Circular Economy Interventions on Livelihoods and Environment in Jordan (Cassiani, Tonini)





This box assesses circular economy interventions in Jordan. It evaluates social, economic, and environmental outcomes. The case demonstrates integrated impact assessment. It highlights livelihood and environmental benefits. The box reinforces evidence-based evaluation.

Conclusion by the Editors (Colombo, Mereu, Stevanato)

The conclusion synthesizes the CESP framework across all phases. It emphasizes energy as an enabler of human development. The chapter highlights participatory, context-sensitive planning. Minigrids are positioned as scalable solutions for equity. Policy coordination and long-term monitoring are stressed. CESP is presented as a living, adaptable framework for just energy transitions.

4. Editorial Process

Each Chapter has been authored by one or more members of the LEAP-RE consortium, when necessary co-authored by external authors, prominent in their fields of research. Each chapter has been peer-reviewed by one or more experts in the field.

The boxes are authored by expert members of international organizations, private companies and civil society bodies to enrich the publication with practical examples from the field.

