Chapter

Introductory Chapter: Sustainable Energy Investment and the Transition to Renewable Energy-Powered Futures

Joseph Nyangon and John Byrne

1. Introduction

"Sustainable energy investment" is a widely used phrase and concept in the fields of finance, engineering and economics. Typically, it focuses on evaluating renewable power development and includes assessments of political and regulatory risks, energy risk hedging and portfolio diversification. Often publications on this topic contribute to the climate change response agenda: promote investments in solar- or wind-powered technologies in order to realize a more equitable, sustainable and prosperous future; evaluate financial aspects of carbon budgeting and energy asset risk management; and respond to financial and climate risks associated with mitigation and adaptation policy interventions. Policymakers and energy regulators correctly perceive climate change to pose threats to energy assets, research and development (R&D), technological innovation to accelerate energy transitions and these impacts are projected to grow in the coming decades [1–3]. Concurrently, the energy sector is experiencing a myriad of challenges, from aging infrastructure, retiring workforces, years of stagnant investment to the need to attract new investment in smart grid resilience, business model innovation reforms, changing customer expectations, and more recently COVID-19 forced disruptions [4, 5]. To mitigate the worst possible impacts, attention is now shifting to strategies for de-risking energy investments—for example, long-term climate-risk hedging and adaption strategies in energy infrastructure development around financing, costs, and revenue—to foster local, national and supranational systems of resource autonomy and reduce the risks of climate change [6–9].

Mainstreaming renewable-powered energy investment into business decision-making and risk pricing is an attractive climate-smart solution that societies and economies can adopt immediately to help overcome anachronistic electric power regimes and regional development dynamics. Globally, investments in distributed, renewable energy-powered futures keep accelerating with clear upward trends in worldwide power generation expansion and risk management at the forefront. Nevertheless, finding a low-carbon, risk pricing formula is not easy. Despite compelling arguments for investment in low-carbon technologies and applications, such as small-scale renewables and locally distributed green energy, digitalization, advanced batteries or carbon capture and storage (CCS), these interventions require a pragmatic assessment of their financeability, which in turn hinges on their technical and economic potential with respect to complex factors, including social equity, feasibility, socioeconomic impact, and climate impact. The scale of

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deploying these low-carbon technologies is also an important consideration to investors because project size is a critical determinant of the cost of unit returns. Some institutional investors consider small-scale investments less attractive due to their perceived low rate of returns. On the other hand, large-scale power systems, such as grid-scale battery storage and other scalable carbon-free power technologies require significant investment in risk hedging and portfolio diversification [8, 10]. The two principal risks that are often mentioned in this area involve (i) those arising from the physical effects of climate change on energy infrastructure, institutions, business operations, energy markets and assets, and (ii) risks resulting from investment in zero-carbon transition strategies due to changes in technology, policy, legal, and market factors. **Table 1** summarizes various dimensions of these renewable energy investment risks.

Suitable climate-smart development—combining innovation mix in technology with those in policy development, new business models, systems operations and market design innovation—could do much to keep the global temperature within the 2 °C carbon budget [3, 23]. Mature non-hydro power sources of renewable

Dimension	Risk factor	References
Technological risk	• R&D capacity • Technology maturity, innovation and progressiveness • Alternative technology	[2, 13–15]
Political risk	• Political stability (internal and external conflicts) • Land acquisition risk • Government credit or foreign debts • Bribery and corruption indices • Legislative and administrative actions • Property rights • Transparency and accountability	[9, 16–19]
Economic foundation and market risk	• Gross domestic product per capita • Exchange rate stability • National/regional economic development level • Contract change risk • Market fluctuations • Change in taxes	[2, 16–18, 20]
Resource risk	• Solar PV and solar thermal potential • Hydropower potential • Wind power potential • Biomass power potential • Geothermal power potential	[8, 13, 20–22]
Environmental / social risk	• Cultural difference • Social cohesion, instability and public resistance • Influence on local environment • Energy demand • Force majeure	[3, 7, 17, 18, 20]

Table 1.
Dimensions of renewable energy investment risk management [11, 12].

electricity, such as solar photovoltaics and onshore wind that can be deployed in a wide range of operating conditions, are generally considered low-risk. These technologies attract large-scale investments and deployment globally, but they are sometimes situated in challenging geographical locations and are vulnerable to weather conditions changes. For example, the risk of technical failure due to extreme weather conditions is always present. Risk averse institutional investors prefer investing in energy technologies with higher rate of return, improved reliability, and operational.

On the other hand, early-stage crucial technologies that have the potential to provide step-change reductions in both cost and energy requirements, and are not as vulnerable to weather and other external events. For example, CCS, and offshore wind are characterized by several technical and financial uncertainties, and are considered high-risk investments by some investors. Typically, investment in such new technologies is often characterized by a 'wait and see' approach to allow them to undergo deployment cycles before they can attract long-term investment commitments.

2. Reimagining sustainable energy investment

Expectations about the market, policy and technological impact of sustainable energy investment continue to evolve. As evidence of the impact of climate change intensifies, consumers and communities are taking action to support a clean energy future and address institutional capacity gaps in public and private investments that hinder the value of decarbonization and adoption of smart energy frameworks [22]. To this end, governments and organizations are beginning to prioritize key innovations that promote clean energy investment readiness. Some of these actions include:

- Planning for energy infrastructure investment, technology transfer and R and D consistent with net-zero transition goal.
- Repurposing existing fossil fuel infrastructure to reduce the overall cost of transition by applying machine learning and artificial intelligence-supported technologies to tackle the risks of stranded electricity assets.
- Delivering finance for electrification of buildings and building automated performance control to raise energy savings performance guarantee and mitigate energy efficiency risks and a possible rebound effect [14].
- Catalyzing finance and investment flows in technology transfer and development in different configurations within and between institutions and across national, sub-national and local levels.
- Supporting communities, businesses and workers by promoting fair access to long-term innovative financing mechanisms and employment opportunities.
- Applying analytics to improve monitoring, reporting, and verification of clean energy technology transfer and investment in R&D.
- Retooling clean energy investment readiness and loan guarantee programs to improve investment flows, project investability and market efficiency.

Reversing the steady growth of greenhouse gas emissions to reduce the deleterious risk of climate change remains the biggest challenge of modern times [1, 2]. It requires a complete change in basic assumptions on how we produce, deliver and consume energy, for example, by focusing on low- or no-carbon energy technologies and greater energy efficiency deployment instead of heavy reliance on energy system dominated by fossil fuel combustion [14]. This vision conflicts with existing socioeconomic growth paradigm. Typically, there exists strong correlation between energy consumption and economic development—especially among developing nations, where poverty reduction strategies are often modeled against increased economic growth, which results in greater energy demand. This relationship is captured by IPAT (I = PAT) model which emphasizes three main factors affecting the environment, i.e., the environmental impact (I) and its relation to population (P), affluence (A), and technology (T) [24].

The emerging shift toward net-zero carbon dioxide (CO_2) emissions development presents an alternative economic development paradigm that could break this strong linkage between economic growth and environmental pollution or CO_2 emissions. For example, to realize high penetration of renewable electricity generation, a clear long-term pathway exists in reimagining the electric grid. Three pillars of this reimagined grid include (a) decarbonizing the electric power supply through the growth of carbon-free power generation sources to improve reliability, affordability and environmental impact of the electricity, and stimulate local economic development, (b) electrification of transportation and buildings, and (c) sequestering the remaining carbon through carbon capture technologies [8, 12, 14–16, 22]. These are vital socioeconomic goals achieved through investment in inverter-based resources (solar, wind, and energy storage).

This book discusses these core dimensions of renewable energy-powered innovations and investment risk. It is a selective compilation of climate-sensitive working concepts, technological solutions and country-specific case studies positioned within the broader debate of just energy transitions. The volume contributes to the existing body of knowledge needed to accelerate renewable energy deployment to meet rising energy demand and ensure that the transition is global, inclusive, socially equitable, and more sustainable.

Author details

Joseph Nyangon* and John Byrne
University of Delaware, USA

*Address all correspondence to: jnyangon@gmail.com

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