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The impact of green insurance schemes on financial sustainability of renewable energy projects

Olugbenga F Akomolehin * and Joel B Oluwaremi

Department of Finance, College of Social and Management Sciences, Afe Babalola University, Ado-Ekiti. Ekiti -State, Nigeria.

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Abstract

The Green insurance schemes can help serve to reduce risks and improve access to renewable energy financing, thereby improving the financial sustainability of renewable energy projects. While significant, little research has examined the impact of green insurance and its components of risk mitigation, cost management, and investment attractiveness on financial sustainability. The study adopts a conceptual framework consisting of mediating and moderating constructs to examine the relationship between insurance coverage (operational, natural, and financial risks) and project profitability, cash flow stability, and long-term viability of projects. Green insurance assists investors eliminate ambiguities and reduce the cost of capital and enables renewable energy developers improve their financial planning, finds the study. Nonetheless, the success of these schemes rests on enabling regulatory policies and positive market dynamics. The findings underscore the importance of customized insurance offerings, heightened awareness, and cooperation among insurers, policymakers, and renewable energy stakeholders to optimize financial resilience. Green insurance schemes are not merely a risk management tool; they aim to create a risk-sharing model that fosters innovative approaches to financing and facilitates a faster transition to sustainable energy solutions. The findings have practical implications for actors interested in the perception and insulation of green insurance in both financial and regulatory systems to promote the growth of renewable energy.

Keywords: Green Insurance; Financial Sustainability; Renewable Energy; Risk Mitigation; Policy And Market Dynamics

1. Introduction

These projects have been at the forefront of finding solutions to global climate change and fostering sustainable development. They provide a framework for lowering greenhouse gas emissions, improving energy independence, and supporting economic growth via job creation and technological advancement [1]. Transitioning to renewable energy is key to avoiding international climate targets and should also provide a sustainable energy future. Mind you, renewable energy projects are very good for society, but not necessarily for the economy. Large upfront capital expenditures and uncertainties surrounding regulatory policies, as well as market dynamics, can hinder investment [2]. Furthermore, the variable and intermittent nature of some renewable sources, like solar and wind, requires investments in energy storage and grid integration, which can drive up costs [2]. These challenges are compounded in emerging markets where access to financing is limited and infrastructure is underdeveloped, limiting the scalability of renewable energy solutions [3]. In response to these financial challenges, an innovative financing vehicle, such as green bonds, has emerged to mitigate these financing challenges by providing debt instruments to attract private investment towards a dedicated environmental project [2]. However, the effectiveness of such instruments ultimately depends on supportive policy frameworks and market maturity. Furthermore, the siting of renewable energy developments is frequently contested on environmental and land-use grounds, exacerbating their financial viability [4]. Solutions to these obstacles to financial

* Corresponding author: Akomolehin F Olugbenga.

viability must address them on multiple fronts and should include some combination of policy support, technological innovation, and stakeholder engagement to create an environment that supports renewable energy investment.

Green insurance schemes involve specialised insurance products created to cover the specific risks of renewable energy projects. This coverage can contribute significantly to the financial viability and operational stability of renewables projects by lowering the risks associated with projects during the critical stages of development, construction and operation. The renewable energy industry presents unique risks, such as technology uncertainties, exposure to natural disasters, and changing regulatory environments. Green insurance mitigates these challenges by providing customized coverage that protects investments from potential losses. For example, policies may include weather surprises, equipment failures, or delays in the completion of projects. This coverage not only safeguards investors against losses, but also opens up pathways for further financing by enhancing the bankability of renewable energy projects [5]. Although, recent advancements in the realm of green insurance have brought forth novel solutions to aid in the transition to renewable energy. For illustration, parametric insurance products targeting the risks of natural catastrophes have emerged, where payouts can be triggered based on specific parameters such as weather indices, enabling a faster claims process and alleviating administrative pressures [6]. Furthermore, insurance schemes are adapting to include new technologies and infrastructure, including battery energy storage systems (BESS), which are essential in the integration of renewable energy to the grid [7].

This of course goes beyond risk mitigation; insurers' participation in renewable energy projects supports the growth and credibility of the industry as a whole. Through their underwriting of renewable energy projects, insurers demonstrate their confidence in the sector's overall viability, thus encouraging additional investment and development. Not only that, but the insurance industry is actively involved in initiatives to support the greentransition. For example, Zurich and Aon have introduced an insurance program for the purpose of fostering hydrogen development, which would look to underwrite smaller hydrogen projects and insure from the construction stages to operational [8] Green insurance programs are crucial in the development of renewable energy projects. They represent a vital risk management tool that can increase financial resilience, attract investment and contribute to the overall transition to a low-carbon economy.

2. Conceptual Review

2.1. Green insurance schemes

Green insurance has become a key tool in the promotion of financial sustainability and environmental risk mitigation and sustainable development. Using this novel insurance mechanism, it enables greener solutions to be integrated into existing risk evaluation and claims processes, that's help bolster financial resilience for people, businesses, and governments. However, what are the quantitative benefits of green insurance? Some insurers even offer coverage for renewable energy installations, such as solar panels, protecting homeowners' investments in alternative energy source.[9] Green insurance improves the financial security of stakeholders in renewable energy projects, energy efficiency initiatives and sustainable agriculture by providing customized coverage for risks associated with these ventures [10]. For instance, [11] have found that countries with comprehensive green insurance policies experience less financial losses during climate-induced crises from compensation for damages and rapid recovery. Not only does this stabilize financial systems, but it also alleviates the economic pressure on both government and private entities.

Qualitative analyses also reveal the significant role that green insurance plays in incentivizing sustainable behaviors and conservation efforts among policyholders. Green insurance provides incentives for businesses to adopt environmentally friendly practices, by integrating sustainability criteria into policy frameworks. To also be eligible for policy issuance or premium discounts, insurers frequently insist that companies firstly apply risk-reducing measures, including energy-efficient technologies and the sustainable management of supply chains [12]. This model promotes the proactive minimization of risk which in turn limits the frequency and severity of claims. In addition, green insurance is responsible for creating greater awareness among policyholders when it holds them accountable, leading to behavioral changes that can help sustain both long-term environmental responsibility and financial security. Adoption of green insurance also increases investor confidence on projects with an environmental focus. Green insurance is seen as a valuable de-risking tool for investments in renewable energy, sustainable infrastructure, and climate adaptation projects by investors. Consequently, this serves as a risk mitigation factor, encouraging the inflow of capital which grows sustainable industries and establishing financial sustainability [13]. Moreover, green insurance promotes sustainable development by aligning financial incentives with environmental objectives.

Although green insurance has great merits, it faces issues like absence of standardized policies, lack of awareness, and high upfront cost, to name a few. Moreover, no consistently standard set of definitions and criteria for what comprises "green" practices exists, and so the range of offerings – as well as whether a business is covered – can be inconsistent in

policies Also, the lack of adequate infrastructure, awareness and supportive regulatory frameworks prevents the success of green insurance in developing nations [14]. Collaborative efforts among insurers, policymakers, and stakeholders are needed to address barriers and promote the development of inclusive and accessible green insurance frameworks. Improved data collection and analysis also creates an opportunity to improve risk assessment models, which can result in insurance product design that supports an effective trade-off between the financial and environmental sustainability of buildings and other covered assets. Thus, in summary, green insurance is crucial for enhancing financial viability through risk mitigation, sustainable practice promotion, and resilience enhancement against environmental challenges. Its quantitative impact is visible through decreased monetary losses and increased recovery rates, whereas qualitative benefits include promoting sustainability and nurturing eco-friendly practices. By fostering continued innovation and collaboration among stakeholders, green insurance can further establish itself as a critical factor in moving towards a sustainable and financially stable future.

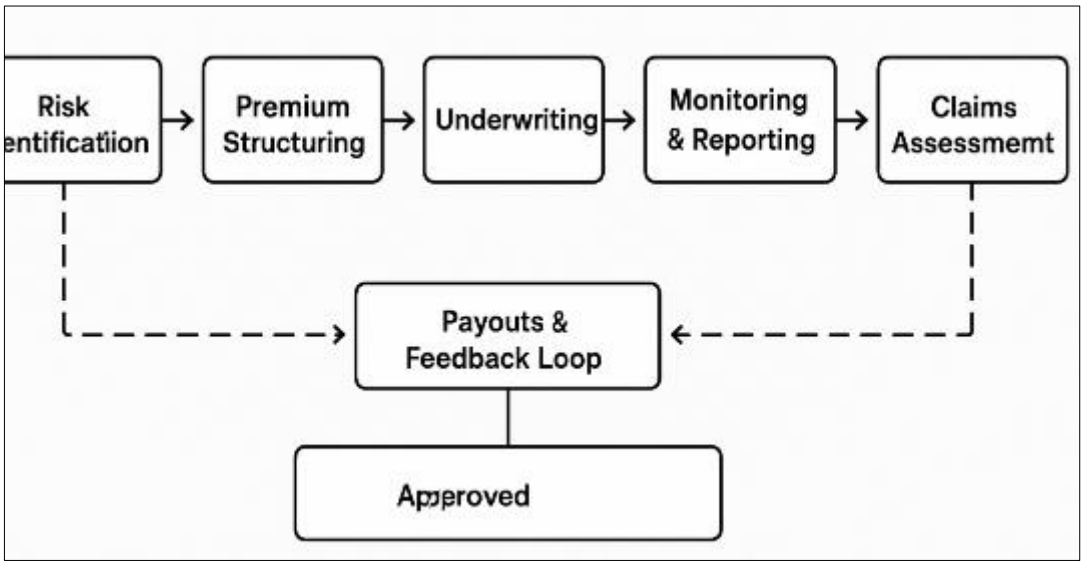

Figure 1 Green Insurance Value Chain Diagram [15; 16].

This diagram outlines the sequential steps involved in implementing green insurance schemes for renewable energy projects. Beginning with risk identification, it moves through premium structuring, underwriting, and monitoring. Claims are assessed when risks materialize, followed by a feedback loop and payout mechanism to improve future risk coverage and project resilience.

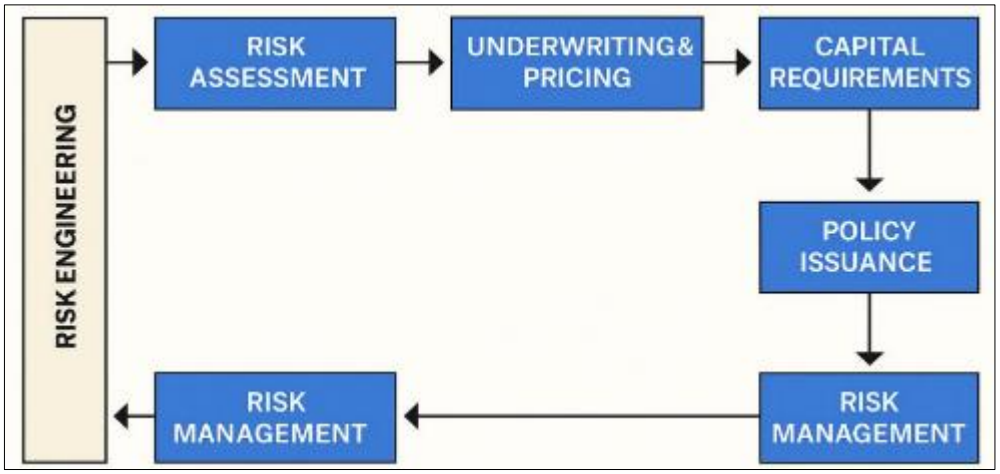

Figure 2 Financial Sustainability Pillars Influenced by Green Insurance [13; 15; 12].

This diagram illustrates how green insurance schemes support four key dimensions of financial sustainability in renewable energy projects: profitability, access to financing, cash flow stability, and long-term viability. By mitigating project-specific risks and stabilizing operational costs, insurance enables developers to secure better financing terms, ensure predictable income streams, and enhance the bankability and durability of renewable energy infrastructure. The

interconnected arrows demonstrate that each pillar reinforces the others, with green insurance serving as the foundational enabler.

2.2. Projects for renewable energy production

Given their role in energy security and GHG emissions reductions, renewable energy projects are key enablers of achievement of global sustainability goals. But their financial sustainability is both a challenge and an opportunity. Of course, high initial capital costs continue to be a challenge. Renewable energy projects, especially in developing economies, need high initial investments which discourage participation from the private sector. As [17] highlighted, without appropriate financing mechanisms suited to address the unique requirements of renewable energy, it had hindered its growth, particularly as seen in regions with limited affordable access to capital. Moreover, regulatory uncertainty and lack of stable and predictable policy frameworks lower investor confidence which adds to financial sustainability challenges [18]. Training materials are current up until October 2023; Mechanisms like green bonds and infrastructure funds are increasingly seen as alternatives for unlocking long-term financing for renewable energy initiatives. In particular, green bonds represent a double benefit attracting green investors and lowering the cost of the capital [19]. Also, with the emergence of an exceptional set of financial technologies like blockchain and peer-to-peer lending platforms, making some types of renewable energy financing much more accessible and efficient. These technologies allow diverse financing models where funding can be raised from individuals towards their local community-based renewable energy systems that may be smaller in scale [20].

Public-private partnerships (PPPs) are also key in closing the financing gap. These partnerships harness public sector assistance whilst leveraging private sector productivity, making renewable energy projects financially more feasible [21]. Moreover, international development agencies and multilateral financial institutions are still making concessional loans and guarantees available for diminishing the risk of investments — in high-risk markets, in particular. These interventions increase the participation of institutional investors whose portfolios now largely reflect environmental, social, and governance (ESG) criteria [22]. Although there are challenges surrounding financial sustainability, technological advancements in energy storage and management of the grid are addressing intermittency, a critical challenge to renewable energy. Advances in storage have increased the reliability and efficiency of renewable energy systems, which makes them more appealing for investors [23]. [24] At the same time, policies that promote the distribution of energy where it is consumed, like feed-in tariffs and tax credits, are slowly reinforcing the economic sustainability of renewable energy development. you are going to have to develop a full-fledged and innovative approach to financing solar and wind projects complemented with supportive regulatory frameworks and must also capitalise on technological improvements. Addressing these interlinked issues will ensure that renewable energy can reach its full potential as central to sustainable development.

2.3. Coverage for Renewable Energy Projects and Green Insurance Schemes

Green insurance schemes are progressively playing an instrumental role in promoting renewable energy projects by providing specialized insurance solutions that alleviate risks associated with renewable energy generation. In particular, these schemes contribute to the global uptake of sustainability, including United Nations Sustainable Development Goal 7, which aims to ensure access to affordable, reliable, sustainable and modern energy for all. Green insurance protects investors and project developers by alleviating financial and operational risks, creating a cushion that bolsters faith in renewable energy projects.

Green insurance schemes exist to help manage risks related to renewable energy projects, such as weather variability, equipment failures and regulatory uncertainties, which are among the key benefits of green insurance schemes. For example, parametric insurance, which has become popular in the green insurance context, provides policyholders with payments according to predefined parameters such as wind speed or solar irradiance levels; this ensures timely payment without lengthy claims process (International Renewable Energy Agency [25]. Such schemes minimize losses due to unpredictable weather conditions and thus make investments in renewables possible. Additionally, green insurance also increases the bankability of renewable energy projects as it mitigates lenders' concerns over default risks. Many insurers worldwide are now selling products that protect against construction delays, performance shortfalls, and technological defects in renewable energy systems [26] Through this risk transfer mechanism, financial institutions are incentivized to lend to renewable energy developers on commercial terms, spurring project roll out and allowing developers to finance their projects with cheap debt.

The emergence of green insurance has also spurred innovation in policy design. One example are blended finance models, which integrate green insurance as part of their approach, leveraging private sector technical expertise with public sector funding to manage risk while also pursuing more widespread social and environmental objectives[27]. These models have been especially successful in emerging markets with high uncertainty around renewable energy

projects. The benefits of green insurance schemes are countered by disadvantages such as low awareness among stakeholders and the relatively higher premium rates which are often unsuitable to small scale developers. One way to tackle these impediments is to work with insurers, governments and development agencies to develop and implement cost-effective, accessible products and approaches to address specific needs in diverse markets (United Nations Environment Programme [28]. Finally, policymakers can also have great influence in the greater promotion of green insurance solutions by subsidising or providing guarantees to ease the cost burden on developers. In fact, green insurance schemes are essential in de-risking projects within the renewable sector and encouraging sustainable energy transitions. These schemes are developed to attract investments, finance projects, and transition associated activities towards uncertain situations by providing innovative and targeted risk management solutions. With the significant growth of renewable energy across the globe, we need to ensure we are creating the right pathway forward, and the future lies in developing innovative, affordable and inclusive green insurance products.

To ensure the environment and cover the expense of sustainable energy projects, targeted insurance products are designed for the mitigation of the special risks included such projects. These include weather risk insurance, technology risk insurance, and policy risk insurance. Weather risk insurance (usually structured in the form of parametric insurance) protects against losses from adverse weather events affecting the delivery of renewable energy. Some, like solar and wind energy projects, are vulnerable to changes in sunlight and wind speeds, respectively. In contrast, parametric insurance provides an immediate payout based on trigger points, for example a rainfall quantity within a specific time period or wind speed, allowing insurance compensation to flow quickly without extensive claims assessment [29]. This is especially useful for renewable energy projects, since it reduces the risk that they will run out of power due to changing weather conditions.

In addition, Technology risk insurance covers the technology-specific uncertainty related to the deployment of novel or untested renewable energy technologies. Such insurance addresses potential creation stemming from technological failures or underperformance, which can improve investor confidence and accelerate the development of innovative energy solutions. Policies can be designed and structured to help cover start-up commissioning risks, potential operational performance shortfalls and excessive maintenance costs associated with new energy technologies [30]. So hesitance to make these investments can be mitigated by technology risk insurance, which is critical to advancing the energy transition. Policy risk insurance (or political risk insurance) can protect renewable energy investments from losses due to government policy change, regulation, or political instability. Since many renewable energy projects depend on positive government policies — including subsidies or tax incentives — any sudden changes in policies can endanger their financial sustainability. By assuring investors and developers that projects are financially sustainable regardless of changes in public policy, policy risk insurance serves as a safety net. This brings me back to the second axis of the three green insurance schemes—weather risk insurance, technology risk insurance and policy risk insurance—will serve as vital tools in managing the unique risks related to renewable energy projects.

Such schemes provide coverage tailored to the specific needs of their customers, addressing specific challenges associated with renewable energy projects. One of the main advantages of green insurance is its ability to reduce risks across various stages of renewable energy projects. Traditional insurance instruments, particularly when bundled across project phases, offer comprehensive “all-risks” coverage including planning, construction, and operational risks, thereby enhancing project bankability and long-term viability [31]. This risk management framework creates a robust strategy enabling your projects to weather the unforeseen events, thus ensuring resilience and sustainable success. Furthermore, green insurance plans bolster fiscal viability of renewable energy endeavors. Acting as a safety net for potential losses, these schemes allow projects to continue in financially viable ways, providing peace of mind in the face of operational disruption and market volatility. This fiscal solidity is pivotal for the sustained triumph and expandability of renewable energy manifestations, as it empowers persistent income sources and bolsters continual upkeep and evolution operate [32]. Green insurance models play a critical role in mitigating risk, encouraging investment and boosting the financial viability of renewables. Cannabis, as a new market, is difficult to enter beyond land ownership, but that price can detour many developers away from the renewable energy sector where solar or wind generation easier to build.

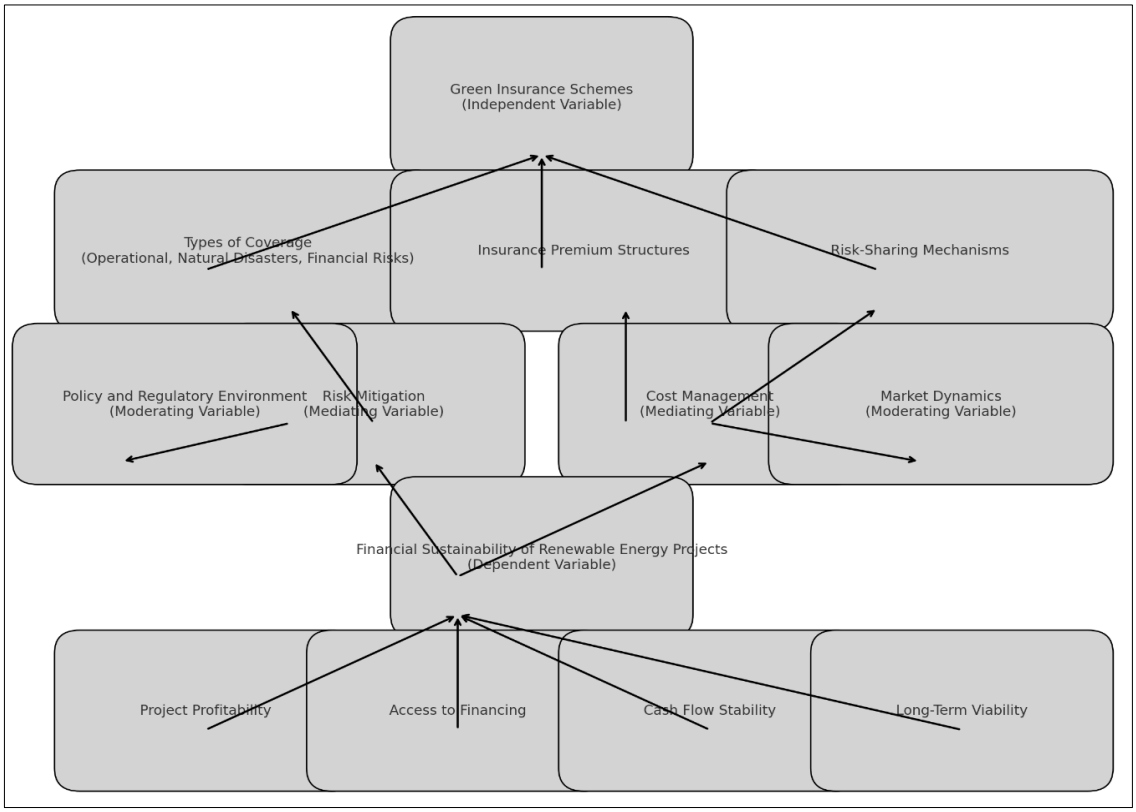

Figure 3 Conceptual framework

(Source: Author's computation)

Through green insurance schemes the conceptual framework displays how these measures affect renewable energy project financial stability by reducing operational risks while minimizing costs. The schemes decrease operational risks while minimizing financial challenges and provide financial stability for access to financing and profits in addition to lengthening project lifetimes. Various policy and regulatory factors together with favorable market conditions boost the effectiveness of green insurance mechanisms. Renewable energy projects realize financial stability alongside extended success through green insurance plans which specifically address project risks and generate cost efficiencies in alignment with sustainability objectives worldwide.

2.4. Effect of Green Insurance Schemes on Financial Sustainability

Green insurance schemes play a critical role in the financing of renewable energy projects, improving access to capital, decreasing the cost of capital and better financing terms. And by helping to mitigate certain risks faced by investors and lenders in renewable energy projects, these insurance products render those projects more bankable. This is essential considering access to capital for renewable energy projects is vital. Policy malfunctions and technical risks can be mitigated through green insurance schemes, which offer assurance to investors about the durability and viability of these projects. Such an assurance can boost investment flows into the renewable energy sector. For example, tackling financing pressures and accelerating project development, insurance solutions have played a key role in unlocking capital for hydrogen projects [33]. The cost of capital, which is the minimum required return needed to satisfy investors by taking on risk, is a critical factor in determining the economic viability of a project. Hence, green insurance schemes lower perceived investment risks and consequently drive down the cost of capital. Research has shown that intermediary mechanisms—such as insurance—help de-risk renewable energy projects, thereby improving financing conditions and lowering capital costs [18]. Mitigating risks translates to better terms when projects seek to raise financing, which further lowers total costs.

The risk profile of a project directly impacts the financing terms, such as interest rates and loan lengths. Green insurance schemes add to this profile by covering exposures to risk of loss, resulting in improved financing terms.Financial engineering tools, such as insurance solutions and ESG-aligned financing, enhance the financial viability of decarbonization projects by improving risk allocation and financing efficiency. These tools help reduce financing barriers and enable the broader deployment of renewable energy technologies [34; 35].The influence of green

insurance schemes on revenue and expenses hence plays a pivotal role in promoting the financial performance of renewable energy projects. From a revenue perspective, these insurance products protect against operational downturns due to events outside of the organization's control and help maintain cash flows. An example would be business interruption insurance which allows to supplement revenue losses during downtime of a project in order to have a stable financial situation . Such green insurance schemes also help ease investor cash flows and are an important tool for assured revenue streams. With increased confidence, companies are more likely to invest, expand, and grow revenue. Green insurance adds to this by providing the incentives and coverage needed to spur investment in both conventional and novel sustainable projects — especially in developing countries [15]. In terms of revenue diversification, renewable energy project-specific insurance products mitigate operational risk so that project developers can pursue different revenue streams without fear of losing money. Such diversification is critical to the sustainable success of such renewable energy projects.

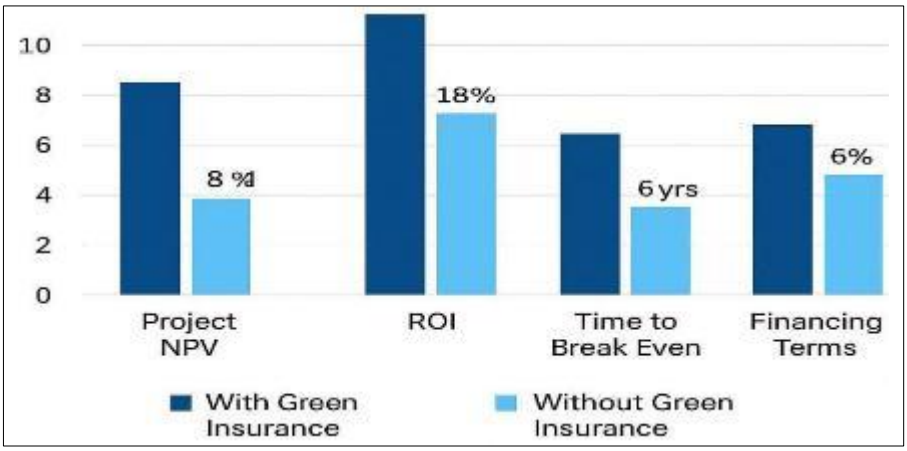

Figure 4 Comparative Financial Metrics [13; 16].

This bar chart compares financial metrics for renewable energy projects with and without green insurance schemes. Projects with green insurance demonstrate significantly higher net present value (NPV) and return on investment (ROI), highlighting improved financial performance through risk reduction and investor confidence. The visualization reinforces the economic value of green insurance in sustainable project finance.

On the expenditure side, green insurance schemes help reduce expenses by covering potential losses that would otherwise lead to costly money outflows. One example is how parametric insurance can offer pre-defined payouts that are triggered by certain events, thus minimizing the financial burden of the loss [18]. As far as expense control is concerned, these insurance products offer improved management and planning. In transfering specific risks to insurers, project developers can find managing their costs to be more predictable; any adisruptive unexpected cost can it self disrupt a well proved financial model. For expense optimization, green insurance schemes promote best practices and risk mitigation strategies; this can also translate to lower insurance premiums as and when it is implemented consistently over time. Not only does this optimization cut costs, but it also increases the overall efficiency of renewable energy projects as a whole. Green risk transfer models play a crucial role in shaping the financial landscape for renewable energy projects by ensuring more stable and increased revenues while mitigating and lowering costs. Green insurance schemes are increasingly playing an instrumental role in promoting renewable energy projects by providing sustainability-oriented and financing-systemic solutions. They help de-risk investments, enhance project bankability, and support the long-term financial viability of emerging renewable energy initiatives.

2.5. Financing Renewable Energy Projects

There are various financial risks that arise in renewable energy projects, which can hinder their development and sustainability. A major concern is the high upfront costs of these projects, which require large initial capital investments in infrastructure, technology, and site development. This level of financial commitment can be a disincentive to new investors if returns are not generated quickly [36]. Furthermore, the volatility of returns makes it a significant risk to anyone investing in digital currency. These include changing energy prices, developing regulatory environments, and changeable energy generation depending on weather conditions that lead to uncertain revenue streams and difficulties in long-term profitability forecasting [37].

This is where green insurance schemes came into play to cover these financial risks and make renewable energy investments more attractive. These insurance products provide safety nets and coverage against all the questionable

risks in a project from construction delays, equipment failure, and operational disruptions, all of which can help to ease fears of investors. Insurers, for example, are writing new coverage for new technologies and complex projects and developing innovative solutions that support the renewable energy transition [38]. Additionally, project developers can also obtain more trustful economic results, which is key for financial and investment partners, by allocating some of the risks to insurers. And this, in turn, facilitates the shift to alternative sources of energy by reducing the adverse effects of climate change and aiding the establishment of clean technologies [33]. Green insurance schemes are essential for tackling this as renewable energy projects often confront a massive financial challenge just to get started because of their high upfront cost and uncertain returns. These insurance products help facilitate investment and development in the renewable energy sector by reducing risks and improving financial predictability.

2.6. Stakeholder Engagement in Green Insurance

Engaging stakeholders plays a fundamental role to achieve success in implementing green insurance schemes for renewable energy projects. All parties who ensure the operational success of green insurance schemes for renewable energy projects unite their efforts including insurers alongside project developers and financial institutions and regulators as well as policymakers. The different groups add special value toward building financial sustainability and climate resilience of renewable energy investments. Insurers deliver specialized risk reduction instruments which help reduce capital flow risks and strengthen project banking eligibility while developers embed insurance programs into their development frameworks to tackle risks throughout each project phase [16]. Green insurance proves essential to financial institutions because they use insurance presence to provide attractive financing terms that reduce capital costs for clean energy technology investments according to [13]. Through legislative measures along with financial policies and regulatory designs policymakers and regulators create conditions that promote green insurance implementation together with innovative underwriting solutions [16]

High-quality stakeholder engagement works best in situations where stakeholders build mutual trust and incentives match as transparency rules all communication practices. Systemic risk management together with standardization practices result from collaboration which enables the expansion of green insurance solutions across emerging markets. The path toward sustainable energy systems receives support from this integrated approach while meeting climate goals and international development objectives.e are various financial risks that arise in renewable energy projects, which can hinder their development objectives.

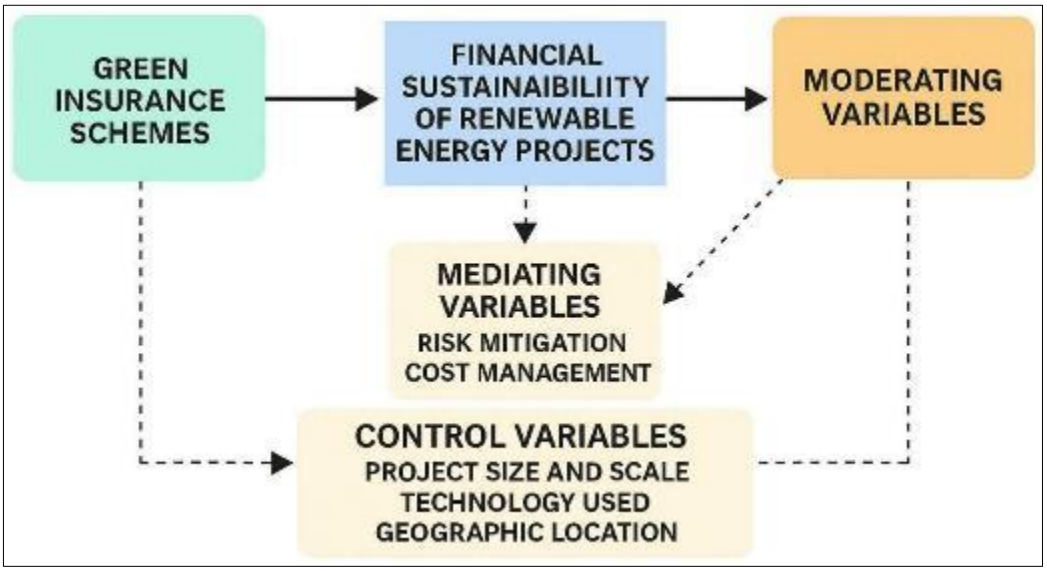

Figure 5 Stakeholder Engagement Flowchart

This comprehensive stakeholder engagement diagram illustrates the interconnected roles of insurers, renewable energy developers, financiers, regulators, and policymakers in implementing green insurance schemes. Their collaboration ensures effective risk-sharing, regulatory support, and financial sustainability of renewable energy projects, advancing climate resilience and clean energy deployment [15; 16].

2.7. Green Insurance Schemes Support Sustainable Development Goals (SDGs)

The implementation of green insurance schemes serves as a vital tool for achieving progress toward three United Nations Sustainable Development Goals (SDGs) 7 through 13 and 9. The customized risk management service offered by green insurance enables renewable energy and sustainable infrastructure projects to develop and secure financing at the same time and gain resilience. Green insurance aids the deployment of inexpensive renewable energy systems through its ability to reduce structural uncertainties that surround renewable energy projects. The investments needed for these projects are expensive while they also remain exposed to weather changes thus making financial institutions reluctant to provide backing. The availability of insurance tools like parametric insurance and performance guarantees makes projects more suitable for funding purposes leading to better financial conditions ([39]; [16]). The risk transfer mechanism through which solar wind programs are adopted creates widespread use of renewable technologies that leads to global clean energy availability.

SDG 9 is advanced through green insurance because it offers coverage for novel clean technology development together with grid connection infrastructure. The operational and technical risks emerging from new energy infrastructures—such as battery storage, green hydrogen, and smart grids—are often inadequately addressed by traditional insurance frameworks. Green insurance products fill this gap with innovative underwriting models tailored to new technologies, thereby encouraging investment and fostering innovation in critical sustainable infrastructure [40; 41] . The achievement of SDG 13 depends on green insurance thanks to its effectiveness at increasing climate resilience and adaptation measures. The escalating nature of climate-related disasters requires immediate adoption of financial tools which protect individuals from extreme weather events. Green insurance schemes protect renewable energy assets while giving financial awards for sustainable structural elements and risk minimization techniques [16] Insurance companies act as leading entities that guide government agencies and private entities toward climate-conscious development approaches.

Green insurance operates as a foundational strategic framework which helps meet SDGs by managing investment risks while promoting sustainable construction alongside climate adaptation solutions. The progress of sustainable development depends on green insurance since it serves all three key elements of financial support along with environmental protection as well as technological innovation.

Figure 6 Developing Green Products for Renewable Energy in Emerging Market. [15; 42]

This SDG Alignment Diagram illustrates how green insurance schemes support Sustainable Development Goals (SDGs), particularly SDG 7 (Affordable and Clean Energy), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action). It visually demonstrates that green insurance strengthens risk resilience and investment in sustainable infrastructure, fostering environmental and financial sustainability

2.8. Policy and regulatory environment

The implementation of green insurance schemes depends heavily on supportive policy frameworks that will drive their development while helping to reach global climate goals and Sustainable Development Goal (SDG) 7 related to affordable clean energy solutions. Governments should support the green transition with purpose-built policy measures which combine sustainable insurance framework regulation with economic benefits for both insurance providers and policyholders [43]. Public-private partnerships enabled by governments effectively develop green insurance markets in developing economies through increased investments in renewable energy projects [18]. During global efforts the United Nations Environment Programme (UNEP) and International Energy Agency (IEA) focus on enhancing climate-aligned funding by directing financial resources from banking and micro-credit and insurance as well as institutional investments [28; 44]. The initiatives incorporate environmental and social governance (ESG) criteria into financial systems through mechanisms that align capital allocation with sustainable and climate-resilient outcomes [1].

Green insurance schemes enable SDG 7 success through risk reduction for renewable energy installations and the promotion of sustainable energy investment opportunities. Sustainable building standards result in reduced premiums for insurers who accept programs certified in line with green criteria [22]. Insurance tools enhance the fulfillment of SDG 9 (Industry, Innovation, and Infrastructure) accomplishment and SDG 13 (Climate Action) through their role in risk distribution and strengthened resistance of infrastructure systems alongside communities [45]. Green insurance products gain prominence as climate strategies because they minimize risks thus governments promote them at national and international levels. The inclusion of green insurance within policy frameworks enables both protection and proactive funding of sustainable solutions [46]. Global climate framework alignment with green insurance represents a necessity to build a sustainable and resilient future that promotes fairness.

3. Theoretical Review

Green insurance, insurance and risk management, and financial sustainability are closely related fields that utilize different theoretical approaches to tackle environmental issues while encouraging sustainable behavior. At the heart of these debates is Risk Management Theory, focusing on identifying, evaluating, and minimizing risks to protect assets and maintain organizational resilience. The theory recognizes the growing significance of environmental risks, such as climate change, to economic and social systems, making it a crucial consideration for insurers to include in their risk assessment. Integrating environmental considerations within traditional risk management processes will allow insurers to anticipate and respond more effectively to the growing frequency and severity of climate-related events [47]. Theoretical Perspectives on Practices Stakeholder Theory, for instance, emphasizes that an organization should create value for all stakeholders involved, that is, those whose interests are impacted by the activity of a corporation such as shareholders, employees, consumers, local communities, or the environment [48]. Sector Description — In the field of green insurance, such approach allows for obtaining policies that comply with regulatory mandates but also respond to broader societal demand for responsible behavior towards the environment. Insurers will strengthen their reputation, build stakeholder trust, and contribute to the realization of the broader sustainable development agenda through greater attention to stakeholder-centricity, achieving an equilibrium between financial performance and social responsibility [49].

Moreover, it offers us multiple insights regarding principal-agent relationships. This theory counters the potential conflicts due to varying motives and information asymmetry. Agency Theory can also be applied in the insurance industry whereby incentive structures can be developed that align the interests of management and stakeholders in a way that encourages decisions promoting long-term sustainability over short-term fulfilment. Getting this right is essential to embedding environmental aspects into business strategies, and providing a framework for sustainability initiatives [50]. By incorporating these theories, green insurance and risk management can become even more robust, promoting a holistic view on the role of financial sustainability. Thus a fusion of the systematic risk evaluation of Risk Management Theory, the inclusion of stakeholders of Stakeholder Theory & the alignment of interests through Agency Theory, insurers can forge strategies that are financially viable as well as ecologically sustainable. This whole spectrum approach helps tackle the emerging threats while preparing organizations to succeed in a sustainably crucial future (Deloitte.) All these theories yield significant insights, but as regards the key framework that encompasses green insurance, risk management and financial sustainability, probably the most relevant one is the Risk Management Theory. The principles guide firms toward a practice of systematic risk identification and mitigation, which is directly relevant to challenges arising from environmental changes and sustainable finance. Focusing on holistic risk assessment and management, insurers can navigate the complexities of the modern environmental landscape and be both financially secure and environmental stewards [47].

4. Empirical Review

Green insurance is becoming the tool to manage the risk and increase the bankability of the renewable energy project. These studies highlight some dimensions of their effectiveness, merits, and challenges. For example, [24] examined the impact of green insurance on wind and solar energy projects in China. Their research shows that green insurance mitigates financial uncertainty through coverage against weather variability and disruption to operations, thereby encouraging more investment from both private and institutional investors. In the European studies, the work by [51] makes a case for the adoption of green insurance schemes directly impacting the bankability of some renewables, especially in offshore wind farms with high capitalization and operational risks.

These green insurance schemes play a significant role in developing countries as the emerging markets come with inherent risks. [52] examined their effects on renewable energy development in sub-Saharan Africa. Insurance mechanisms targeting not only political and regulatory risks but also natural threats were identified as key factors allowing for a higher level of investor confidence and long-term sustainability of projects. This is consistent with the results by [53], who analyzed green insurance in Latin America. Their research highlights the role of customized insurance products in addressing the financing gap for small-scale solar projects through the provision of warranties against climate variations and equipment malfunctions. Technologically, green insurance schemes increase innovation in renewable energy technologies. Examining the energy sector in South Korea, [54] argue that insurers' assessments of risk actually create incentives for developers to choose technologies with greater reliability and efficacy, leading to improved performance across the board. This finding is supported by [55]; who noted the connection between green insurance presence and offshore wind turbine technology development in the United States. It found that insurance solutions mitigate financial exposure for developers, allowing them to take the risk on innovative technology.

Green insurance schemes will also be important in supporting community-based renewable projects. For example, insurance against project failure is shown to significantly increase public participation and local funding for renewable energy cooperatives in a study by [56] in Germany. Such collective engagement usually produces more beneficial project outcomes for the public and improved social acceptance. Additionally, using a comparative analysis, [57] demonstrated that as countries develop their green insurance market to maturity, it was possible to achieve more rapid penetration and deployment of renewable energy due to decreased project risk and improve financing conditions. But, the implementation of the green insurance schemes faces the challenges. One such study, [58] in Nigeria shows that pollution and high premiums on green insurance products prevent wide acceptance of these schemes . [59] highlight, in some Latin American countries, the absence of a standardized risk assessment framework causes deviations in coverage and prices, making stakeholders shy away from relying on these schemes. The findings are mirrored in a global review of the literature by [60] argue for the regulatory reforms and international cooperation required to harmonise green insurance standards and practices.

Furthermore, studies indicate that the success of green insurance schemes depends upon government support. Research by [61] the key broad trends for the Middle East and North Africa region demonstrate that subsidies and public-private partnerships are critical for lowering premium costs and making green insurance available for smaller developers. For instance, the paper by [62] shows in their study of renewable energy projects in South-East Asia that government-supported reinsurance programs can mitigate risk, thus allowing for a wider scope of coverage. Overall, empirical evidence suggests that green insurance schemes can transform renewable energy projects by limiting risk, increasing financial viability, and spurring innovation. Nonetheless, challenges concerning awareness, affordability, and regulations persist, which require active engagement from stakeholders toward optimizing the design and implementation of these schemes. The inclusion of green insurance in broader renewable energy strategies promises to speed up the global transition to sustainable energy.

5. Case Studies of Green Insurance Schemes

Green insurance schemes maintain an essential role during renewable energy project development by reducing risks which in turn helps improve project monetary outcomes. A pioneering floating solar photovoltaic power plant exists on the Cirata reservoir in West Java with its capacity of 145 megawatts. Two other lenders and Standard Chartered Bank issued a USD 112 million project finance facility for this initiative in 2021 during a 16-year term period. The completed project will become Indonesia's inaugural floating solar installation and Southeast Asia's largest such installation because tailored financial instruments help renewable energy infrastructure (United Nations Environment Programme Finance Initiative [15]. The insurance industry showed emphatic action to solve difficulties that emerge from renewable power generation systems. Specialized insurance coverages developed by insurers defend renewable energy operations against

equipment failures and natural disasters which are specific risks in this energy sector. The proactive insurance strategies play a vital role in loss prevention and enduring renewable energy project sustainability[41].

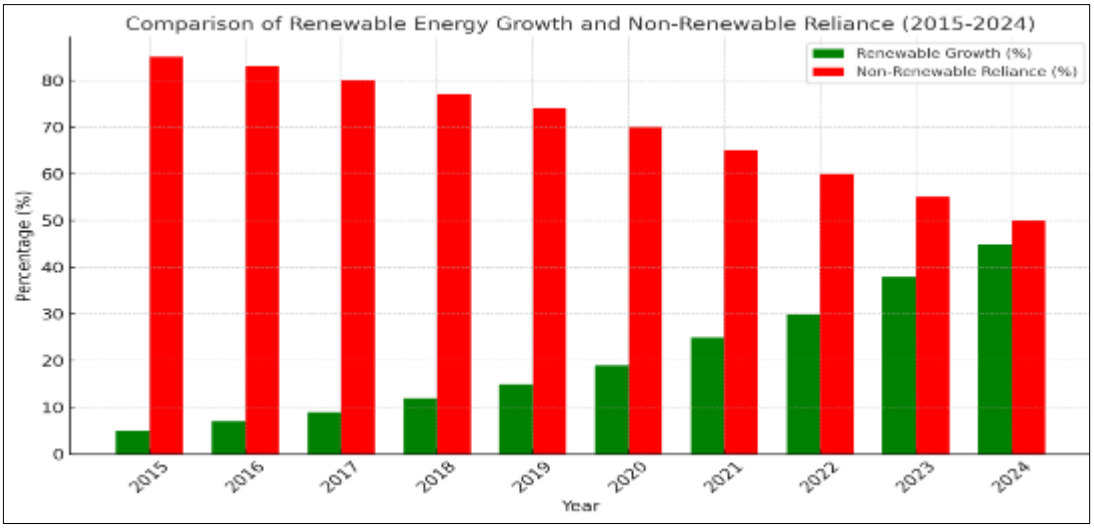

Figure 7 Comparison of Renewable Energy Growth and Non-Renewable Reliance (2015 - 2024) [1]

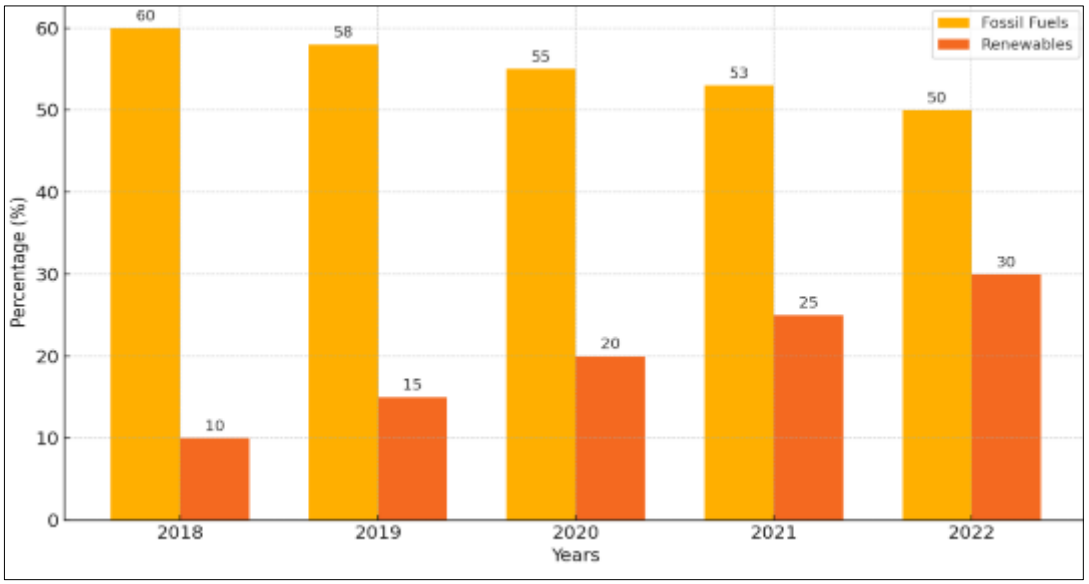

Figure 8 Fossil Fuel Reliance and Renewable Energy Growth [1]

The achievements from these deployments produced multiple key learnings. The successful implementation of specialized insurance products requires dedicated solutions for renewable energy project risks. Traditional insurance policies fail to handle energy facility operation risks and technological challenges that require customised coverage solutions according to [46]. Renewable energy success requires three entities who function as stakeholders to work together: insurers and financial institutions and developers. Business collaborations between insurers and financial institutions together with developers generate thorough project risk knowledge to establish effective risk reduction plans that increase project success rates [45].

The essential nature of ongoing learning and adaptation stands among the key elements for successful operation in this evolving energy sector. The rapid progress of renewable energy warrants insurers to maintain updating their knowledge about new technologies and emerging risks so they can offer suitable and beneficial coverage[41]. The development of efficient green insurance schemes for renewable energy projects depends on specialized products while effective collaboration between stakeholders and adaptable solutions. The elements play a vital role in risk reduction and renewable energy project development advancement.

6. Quantitative and qualitative assessment

Various obstacles prevent the successful deployment and operational excellence of green insurance programs designed for renewable energy systems. The high expense stands as a substantial obstacle for these insurance products. The renewable energy sector has caused insurers to experience profitability problems due to frequent claims and severe damages which has resulted in higher premiums [63]. The pricing models have shown weaknesses in unexpected weather events which leads to increased expenses [64].

Market awareness is another hurdle. The insufficient understanding and education levels regarding green insurance in individuals and businesses creates limited market demand especially in developing nation contexts [65]. The insufficient market knowledge about green insurance products delays the progress of renewable energy project expansion. Only regulatory barriers create major obstacles to progress and development. Lack of policies that support green insurance schemes creates barriers to their implementation. These problems intensify due to lack of proper infrastructure and political instability especially in emerging markets [65].

Green insurance schemes present considerable chances for growth particularly in developing markets regardless of present obstacles. Renewable energy project growth in emerging markets generates increasing insurance requirements that enable insurers to create custom risk-oriented products [40]. New technologies create multiple avenues for green insurance to innovate its products. The implementation of blockchain parameters allows solar energy facilities to obtain insurance protection because blockchain achieves transparent and efficient claims processing [39]. Innovation in insurance products promotes renewable energy projects by providing support for their growth. The insurance partnership between Zurich and Aon creates a program to support hydrogen development by providing coverage for the significant requirements of green energy initiatives [8].

Renewable energy projects face impediments in adopting green insurance schemes because of high costs and limited market understanding and regulatory obstacles but these obstacles exist alongside many promising growth prospects in emerging markets and newer technologies and creative products. The effectiveness of green insurance for promoting renewable energy projects becomes stronger through proper management of challenges combined with effective utilization of available opportunities.

7. Conclusion

The study titled 'The Impact of Green Insurance Schemes on the Financial Sustainability of Renewable Energy Projects' explores how green insurance can serve as a transformative tool in enhancing the financial viability and long-term stability of renewable energy investments in the face of climate change. Findings indicate that green insurance schemes which aim to reduce project-specific risks including variations in weather patterns, technological faults and policy uncertainties dramatically increase investors' confidence and project bankability. Indeed, by lowering their assumed risks, these schemes help open the door to financing and reduce the cost of capital for renewable energy projects, increasing their competitiveness in some contexts with conventional sources of energy generation. In addition, the research highlights that green insurance is in line with the United Nations' Sustainable Development Goals (SDGs), specifically SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action). By safeguarding investments, green insurance not only reinforcers compliance with environmental standards but also rewards continuous integration of new processes and methods in renewable energy development.

However, the review highlights key gaps, particularly, the need for strong regulatory frameworks, standardized insurance policies, adaptable to different renewable energy projects and closer collaboration between insurers, governments and renewable energy developers. Filling these gaps is a requisite for scaling up green insurance adoption to a key driver of financial sustainability for the long term. Green insurance schemes offer a viable mechanism to address the funding gap in renewable energy projects while contributing to resilience and sustainability in the energy transition. Incorporating such schemes into wider policy and financial frameworks can help facilitate the global transition to cleaner, more sustainable energy systems.

7.1. Recommendations

Insurance companies and renewable energy project development teams should establish partnerships for stronger resilience and sustainable performance of renewable energy projects. Insurance specialists must build custom insurance products to cover construction risks together with operational liabilities and climate-driven disruptions which specifically target renewable energy projects. The development of parametric insurance products with predefined triggers like wind speed and solar radiation can improve how project developers are supported.

Complete analyses of risks surrounding renewable energy projects need to be performed separately. The assessment requires incorporation of geographical elements as well as technological and climatic factors to reveal potential threats. Renewable energy developers should collaborate with project partners to establish predictive maintenance programs and comprehensive supply chain protections that boost project durability. Project developers require instruction about insurance possibilities along with procedures for claims submission and effective risk management practices. Insurance providers should deliver accessible educational materials through easy-to-use digital systems along with instant risk advisory notifications.

Renewable energy project developers need to conduct thorough due diligence systems aiming to discover risks that refer to equipment breakdowns and regulatory hurdles and environmental disaster events. The use of independent external consultants for risk assessment helps organizations achieve definitive evaluations of their potential vulnerabilities. A developer needs to assess insurance companies with renewable energy specialization while selecting products that adapt to project developments. Protective measures are possible through frequent assessments and modifications of insurance plans which fit project development periods and newly exposed risks notable in advanced technology or adjustments in regulations.

When insurance expenses are included in project financial models it provides full risk coverage at acceptable project returns. A collaboration with insurers creates the possibility to use premium financing which cuts initial payment amounts while preserving complete coverage levels.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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