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Influence of Architectural Energy Efficiency and Carbon Aware Computing Practices on Tech Startup Investment Attractiveness

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ABSTRACT: The growing ecological imprint of online infrastructures and the growing popularity of sustainable investment has made energy efficiency and carbon-aware computing a key strategic issue of technology startups. Although investors are becoming increasingly interested in sustainable projects, most technological startups have continued to face barriers between the desire to be sustainable and the ability to be attractive to investors in terms of energy efficiency of its architectural designs and carbon-friendly computing, resulting in a distance between the goals of sustainability and the funds agencies. The conceptual aim of the study is to explore the relationship between the attractiveness of tech startups when it comes to their energy efficiency and property sensitivity to carbon computing and Tech Startup Investment, how the consideration of environmental responsibility in software and system design can shift the perception and investment volume of investors. The study explores major issues associated with competitiveness based on sustainability, the signaling of green technology, and the investor confidence in a new digital venture. The study follows a qualitative conceptual approach whereby only the secondary data which is in the form of peer reviewed journals, academic books, policy paper, newspapers and literature liter true on sustainability will be used. The paper determines the presence of emerging trends through systematic literature review and thematic synthesis of the existing literature that show that startups that could incorporate energy-efficient architectures and carbon-aware computing practices could be associated with improved legitimacy, reduced risks, and long-term value propositions in the mind of investors. The results are also arguing that SOD has become a more popular non-financial performance metric that may affect investment decisions. The researchers suggest that technological startups should consider energy and carbon-consciousness in the fundamental architecture plans in order to enhance investment attitude. To sum up, the startup investment attractiveness of the future green digital economy significantly depends on sustainable practices in computing.

KEYWORDS: Architectural energy efficiency, Carbon-aware computing, Tech startups, Investment attractiveness, Sustainable software architecture.

INTRODUCTION

1.1 Background of the Study

The digital economy is rapidly changing globally, and technology-based startups are becoming the major players in the field of innovation and value creation. The growth, however, is accompanied by the increasing energy requirements and consequent increase in carbon emissions as a result of computational processes (Ahmed, Khan, & Lee,

2023; Amiri et al., 2025; Buya, Beloglazov, and Abawajy, 2010). To counter this, the energy efficiency of architectural designs and carbon conscious computing practices, have become key strategic concerns of software engineers and technology managers (Hans, 2025; Jin, Ji, and Zhang, 2025). The design of more energy-efficient systems, including optimized cloud systems and energy monitoring frameworks implemented using the Internet of Things, has a two-fold advantage: not only does it minimize operation costs but also helps improve environmental sustainability (Ahmed, Khan, and Lee, 2023; Katal, Dahiya, and Choudhury, 2022). Moreover, green computing, including algorithms that can be executed using less energy, hardware devices that can be produced with a lower carbon footprint, etc., are increasingly accepted as a driver of sustainable digital transformation (Amiri et al., 2025; Choppali Sudarshan et al., 2024). Studies show that such companies not only acquire ecological legitimacy but also become more appealing to the investors who are becoming increasingly concerned with the issue of environmental safety when making investment choices (Danushi, 2025; Kumar, Mohammed, Raj, and Balasubramanian, 2024).

Africa is no exception as the adoption of technology is similarly increasing, but there are still energy wastefulness and use of computers consuming energy (Shanmugam, Aliyu, and Senthilkumar, 2024). The fact that energy costs are high, expanding on renewable energy sources is not very easy, and there are minimal infrastructural issues makes energy-efficient practices and carbon-conscious software uses even more urgent in providing startups with funding in the African context (Climate Savers Computing Initiative, n.d.; Hans, 2025). In particular, in West Africa, the nascent tech ecosystems are expanding, yet the environmental sustainability is yet to take the leading place in the investment assessment, although there are certain signs that startups that would apply green computing principles would be more viable in the long run (Aliyu and Shanmugam, 2024; Jin, Ji and Zhang, 2025). The emergence of the software startups is prominent in the largest technology hub in the West Africa, which is Nigeria. Nevertheless, efficiency and environmental footprint in operations are becoming the subject of increased scrutiny on the part of investors, with startups that consider architectural energy efficiency and carbon-conscious computing increasingly becoming popular (Kumar, Mohammed, Raj, and Balasubramanian, 2024; Katal, Dahiya, and Choudhury, 2022). This increased focus is in line with the global sustainability trends as well as the strategic importance of green software engineering practices to tech startups aiming to be invested in.

Therefore, it is important to realis how architectural energy efficiency and carbon-conscious computing practices affect the attractiveness of tech startup investing. Although the use of energy-efficient software design and carbon-aware systems has been discussed in the literature separately (Ahmed, Khan, and Lee, 2023; Amiri et al., 2025a; Buyya, Beloglazov, and Abawajy, 2010), there is no conceptual framework of their relevance to investor decision-making in emerging economies, including Nigeria. This research is expected to address this gap by coming up with a comprehensive conceptual model that can guide researchers, practitioners, and policymakers.

1.2 Problem Statement

On the planetary scale, although the digital and fintech sectors have already gone miles further in implementing energy-efficient and carbon-conscious computing behavior, there is still a considerable number of tech startups that value rapid deployment, high scalability, and performance over a sustainable approach (Yu and Zhao, 2025; Zhao and Liu, 2022; Singh, 2025). Even though energy efficient designs and carbon conscious algorithms were shown to minimize the costs of operations and environmental impact (Procaccianti, Lago, & Bevini, 2015; Duve and Marx, 2025), such practices are often not implemented by startups in their early development stages, in large part because of competitive forces and the emphasis on speed to market (Aliyu, 2024; Wohler and Busch, 2022). Sustainability signals are becoming more significant in the beliefs of the investors worldwide during the funding process, and it is now understood by the investors that green innovations can not only minimize risks but also positively impact long-term financial returns (World Economic Forum, 2025; Mrkajic, 2019). Yet, however, there is still conceptual ambiguity

on how exactly the architectural energy efficiency and carbon-conscious computing habits might impact the tech startup investment appeal, especially in a developing economy where the use of sustainable technologies is still in its early phases (Muhammed and Sundararajan, 2024; Sundararajan, Mohammed, and Martin, 2022).

In Africa, startups also have an extra disadvantage such as unreliable power supply, high operation expenses, and quality infrastructure with renewable energy, which defines energy efficiency and eco-friendly computing as not only a sustainability promise but also a strategic precondition to attracting investors (World Economic Forum, 2025; Yu and Zhao, 2025). Particularly, investor analysis of the technology sector in West Africa and Nigeria shows that, despite the high growth rates, the technology sector, despite its importance, is rarely considered in the investment decision-making process, which is why gaps in terms of how the sustainable software architecture can be linked to the attractiveness of the investment remain critical (Aliyu, 2024; Singh, 2025). As a result, the current study concerns the lack of literature fragmentation, which predominantly views software engineering sustainability and entrepreneurial investment as two different areas and models (Procaccianti, Lago, and Bevini, 2015; Zhao and Liu, 2022), and focuses on elaborating a conceptual framework to establish a definite link between architectural energy efficiency and carbon-conscious computing to the attractiveness of tech startups to venture capital in a globally aware but Africa- and Nigeria-focused view.

1.3 Significance of the Study

The research is conceptually important in the sense that it adds to the developing body of literature on green software engineering, sustainable entrepreneurship, as well as investment decision-making in technology-based environments. At a global level, studies have found that software architecture that is more energy efficient and carbon conscious computing is critical in minimizing environmental impact but not reducing system performance (Field, Anderson, and Eder, 2014; Elgamal et al., 2023; Wysocki, Miciulla, and Plecka, 2025). The combination of these sustainability-oriented practices along with venture capital and investment models helps the study to fill a gap in the current literature especially in terms of establishing the connexons between software engineering practices and investment appeal of tech startups (Ammar, Cloarec, and Valiorgue, 2026; Antarctic et al., 2018; Decelerate and Kelly, 2025). In the view of the African perspective and West Africa particularly, there is little study examining the effect of green computing practices on investors, even with the increased popularity of technology startups in the area (Aliyu and Kumar, 2022; Sun et al., 2025; Yang and Elbakri, 2024). The research provides theoretically relevant foundations to researchers and practitioners working in the field of research on how software energy efficiency, carbon-conscious innovations, and entrepreneur performance in emerging markets relate to one another and what the African ecosystems of technology may mean in contextual terms.

In practice, the research has practical implications on the entrepreneurship in the field of technology by emphasizing on how entrepreneurs can improve their investment appeal by adopting carbon-mindful and energy savings software designs as part of their operational and product strategy (Mohammed, Manoharan, Chelliah, and Kassim, 2024; Yu and Zhao, 2025). Furthermore, the findings can be utilized by venture capitalists and impact investors to fund startups with proven financial sustainability and environmental responsibility and thus invest in portfolios supporting ESG principles (Wöhler and Busch, 2022; Ammar, Cloarec, and Valiorgue, 2026). Secondly, the research educates policy and innovation systems and reveals that regulatory frameworks and incentives are necessary to incentivize the deployment of green software and carbon conscious computing behavior (Sun et al., 2025; Yang and Elbakri, 2024). In such a way, the study will foster sustainable economic development, technological change, and environmental protection, specifically in Nigeria, where startups will become a major contributor to the digital economy and the green transition (Aliyu and Kumar, 2022; Wysocki, Mikulas, and Plecka, 2025).

1.4 Research Objectives

The study aims to achieve the following objectives:

1. To examine the influence of architectural energy efficiency practices on the investment attractiveness of tech startups globally, with special attention to developing economies.
2. To investigate the role of carbon-aware computing practices in enhancing the sustainability signals perceived by investors in Africa, West Africa, and Nigeria.
3. To explore the interplay between green software engineering strategies and venture capital decision-making, identifying the factors that encourage sustainable investment in technology ventures.
4. To assess the barriers and enablers for implementing energy-efficient and carbon-conscious computing in tech startups within emerging markets, including policy, infrastructure, and market-related constraints.
5. To develop a conceptual framework linking software architectural sustainability with investment attractiveness, offering practical guidance for founders, investors, and policymakers in Nigeria and the broader African tech ecosystem.

1.5 Research Questions

In line with the objectives, the study seeks to answer the following research questions:

1. How do architectural energy efficiency practices influence the investment attractiveness of tech startups globally?
2. What is the impact of carbon-aware computing practices on investors' perception of startup sustainability in Africa, West Africa, and Nigeria?
3. How do green software engineering strategies interact with venture capital decision-making to support sustainable investment?
4. What are the key barriers and enablers for adopting energy-efficient and carbon-conscious computing practices in tech startups within emerging economies?
5. How can a conceptual framework be linking software sustainability and investment attractiveness guide startup founders, investors, and policymakers in Nigeria and the African tech ecosystem?

2.0 Literature Review

2.1 Conceptual Review

2.1.1 Architectural Energy Efficiency Practices

a. Concept and Evolution of Energy-Efficient Software Architectures

Architectural energy efficiency can be defined as the development of software and computing systems that consume less energy but do not affect performance and scalability. Environmental issues, cost of operations and regulatory demands have contributed to the acceptance of green software and energy conscious computing around the world (Ahmed, Khan, & Lee, 2023; Buyya, Beloglazov, and Abawajy, 2010). Building of energy-friendly architectures has a history of implications in the early energy-conscious programmed models (Eder et al., 2016) to newer cloud-based and edge systems where energy saving is fundamental (Gupta et al., 2020). Energy conscious computing is a trend that is fast growing in Africa due to the energy scarcity and sustainability considerations. Sustainable technology development is a prospect implied by the efforts of the World Economic Forum, which invited all to invest in green computing (World Economic Forum, 2025). Startups in West Africa are moving towards energy efficient architecture in order to trade limited infrastructure and the needs of high-performance applications (Aliyu, 2024). Technology entrepreneurs in Nigeria are starting its value as a method of ensuring the sustainability of software not just in efficiency but in enticing impact-oriented investors (Mohammed & Kumar, 2022; Lin, 2022).

b. Energy-Aware System Design and Optimization

Energy-conscious system design emphasizes the use of power management and optimization methods on the architectural design. That encompasses reducing redundancy in computation, on-demand allocation of resources and global energy tracking (Jin, Ji, and Zhang, 2025; Eder et al., 2016). Such frameworks as ENTRA are offered worldwide to introduce approaches to energy transparency in a whole system, allowing the developer of energy transparency to work out aware design solutions that cut down on carbon emissions (Eder et al., 2016). Systems design based on energy awareness can be especially applied to the African context because the costs of energy are high, and the variability of infrastructure is a common occurrence (Duve & Marx, 2025). Nigerian tech

startups are becoming more open to leveraging the optimization strategy that involves uniting the efficiency of software with the sources of renewable energy, which would make the manner of operations relevant to the objectives of sustainable development (Aliyu & Shanmugam, 2024).

c. Efficient Cloud and Data-Center Architectures

Other significant sources of the energy footprint of digital systems are cloud computing and data-center infrastructures. 1. The energy-efficient cloud architectures deal with the problem of load balancing, dynamic scaling, virtualization, and smart resource management to reduce the amount of energy used (Katal, Dahiya, and Choudhury, 2022; Buya et al., 2010). IoT systems based on energy-driven network management also help to achieve lower carbon intensity in distributed infrastructures (Ahmed, Khan, and Lee, 2023). In the case of the startups in Africa, as well as in West Africa and Nigeria, cloud deployment is not only the cost-efficient option but also the means of implementing greener processes by minimizing physical hardware usage and workload optimization in terms of computational power (Yu and Zhao, 2025; Aliyu, 2024). According to research, the existence of energy-efficient cloud architecture may be a message to the investor that an entrepreneurship is operating in strategic locations to mitigate operational and environmental risks (Momtaz, 2024; Bendig et al., 2022).

d. Energy-Efficient Algorithms and Resource Allocation

The key to reducing computing system energy consumption is algorithmic efficiency. Energy efficient algorithms methods entail the optimization of computation sequence, memory access and schedule of tasks to achieve balance between power consumption and performance (Singh, 2025; Zhao and Liu, 2022). Another method of reducing energy and carbon footprints is workload allocation strategies, e.g., dynamically allocating workloads according to the renewable energy quantity (Jin, Ji, and Zhang, 2025; Gupta et al., 2020). The practices are being more and more formally enshrined in green software engineering models across the globe (Amiri et al., 2025). Such strategies are starting to be incorporated by African tech startups in their design and operation processes, as they aim to become more sustainable and become interesting to investors (Lin, 2022; Mohammed and Kumar, 2022). The use of energy-saving algorithms in Nigeria should be viewed in the context of more general objectives of sustainable entrepreneurship, which will indicate the spirit of environmental responsibility, which will attract venture funds and will have an impact on the investment (Aliyu, 2024; Duve and Marx, 2025).

e. Software–Hardware Co-Design for Energy Optimization

The trend of energy-efficient computing is based on co-design methods that embrace both software and hardware factors. Co-design strategies worldwide are used to optimize the power consumption of the system neither to affect nor decrease the performance of the system (Armstrong and Gupta, 2017; Choppily Sudarshan et al., 2024). These methods make it possible to control the allocation of resources on a fine level and utilize software dynamically to respond to hardware limitations and energy availability (Singh, 2025; Wiesner et al., 2024). The Africa case is shown here because high-performance computing resources are expensive and electricity for their operation is not always available, software-hardware co-design is becoming the solution to increase computational efficiency and lower the cost of operations (Duve & Marx, 2025). West African startups, especially in Nigeria, have started to apply co-design principles to make their technology stack more sustainable; they are optimizing the use of local hardware and using cloud-based infrastructure to minimize energy use (Aliyu and Shanmugam, 2023; Mohammed and Kumar, 2022).

f. Role of Architectural Decisions in Reducing Operational Energy Costs

Software architecture options, including modular design, the selection of programming frameworks, the deployment topology, among others, have a considerable impact on energy use and cost of operation (Buchanan et al., 2023; Armstrong and Gupta, 2017). The green software engineering practice across the world focuses on the energy-conscious decision- making at each phase of the software lifecycle, including design and development, deployment, among others, to attain

quantifiable outcomes in carbon emissions and electricity costs (Jin, Ji, and Zhang, 2025; Wysocki, Miciuła, and Plecka, 2025). The informed architecture decisions are essential in the African start-ups to achieve a balance between performance and sustainability since most start-ups lack high-performance infrastructures (World Fund, Ignite & Dealroom, 2025). Such architectural strategies are being used by Nigerian technology companies to show investors that they are efficient in their operation and this increases investment appeal along with sustainable business conduct (Aliyu, 2024; Bendig et al., 2022).

g. Lifecycle Energy Efficiency in Software Systems

Lifecycle energy efficiency entails considering energy optimization during every phase of software creation such as during requirements gathering, coding, testing, deployment process, maintenance and even retirement (Unterkalmsteiner et al., 2016; Field, Anderson, and Eder, 2014). In this instance, techniques such as Vessim offer the simulation environment to quantify and maximize the amount of energy usage throughout software lifecycles, allowing organizations to plan sustainable operations during the early phase (Wiesner et al., 2024; Buchanan et al., 2023). In Africa, there is still the growth in the adoption of lifecycle energy efficiency practices. Startups in West Africa and Nigeria are gradually becoming aware that implementing sustainability in the software lifecycle not only lowers operation energy costs but also indicates that the organization is environmentally responsible to interested parties and investors (Aliyu & Shanmugam, 2023; Duve & Marx, 2025). The idea of lifecycle targeted strategies is consequently placed as a gamechanger in perspective of tech startups wishing to draw an investor with environmental awareness (Lin, 2022; Mohammed and Kumar, 2022).

2.1.2 Carbon-Aware Computing Practices

a. Concept of Carbon-Aware Computing

Carbon-conscious computing is a term in software and system design indicating the consideration by software and system design of carbon footprint of computation and data processing explicitly. It has become one of the major aspects of green computing worldwide, with the operations of the systems being streamlined to minimize the CO 2 emissions without affecting the performance (Kim et al., 2023; Buchanan et al., 2023). Carbon-conscious computing is a new computing methodology that incorporates the concept of environmental sustainability into the fundamental software engineering processes, with the use of IT infrastructure aligning with the low-carbon energy sources (Amiri et al., 2025; De Silva and Banadaki, 2024). The idea is also becoming widespread in Africa where startups are eager to prove their environmentally-friendly status and minimize costs of operations in locations with high energy prices (World Economic Forum, 2025; Duve and Marx, 2025). Also in West, especially in Nigeria, tech startups are starting to experiment with carbon-sensitive practises, not to survive within the sustainability paradigm only, but to appeal to green innovation-oriented investors, as well (Aliyu et al., 2024; Genero, 2025).

b. Carbon Intensity–Aware Workload Scheduling

Scheduling workload according to the carbon intensity enables one to run the computational processes whenever electricity is produced through sources with low carbon emissions hence reducing environmental degradation. This model is applied in cloud data centers across the world via predictive models and allocating tasks dynamically (Durban, Ojo, and Awuor, 2025; Zhao and Liu, 2022). Carbon intensity conscientious scheduling helps to lower peak load emissions and allows software applications to work in harmony with the availability of the cleaner energy (Renugadevi et al., 2020; Li and Gallagher, 2016). Carbon-conscious scheduling can be used to optimise the costs of energy in the African context, in which energy grids are becoming more mixed with renewables: this approach can also serve to signal to stakeholders that the energy is sustainable (Wang & Shao, 2023; Yu & Zhao, 2025). Nigerian startups using cloud and edge computing are currently working a pilot of carbon intensity-conscience portfolios to increase environmental performance and appeal pursuits of ESG-oriented investors towards their business (Aliyu, 2024; Gernego, 2025).

c. Renewable Energy–Aligned Computing

One of the most important strategies in carbon-conscious computing is aligning the operations of computing with renewable energy availability. On

a global scale, renewable-aligned computing can be defined as a technique of scheduling workloads so that they can overlap with times when solar, wind, or hydroelectric power is available, eliminating the need to resort to carbon rich sources of energy (Yu et al., 2025; Kim et al., 2023). This method is also conducive to sustainability requirements and is still relatively computationally efficient. Various startups in Africa are developing hybrid-based energy plans that combine solar-powered microgrids or energy-storage systems with the data-intensive processes in order to pursue the goals of green computing (Amiri et al., 2025; World Economic Forum, 2025). Renewable-aligned computing is also becoming a differentiator to tech startups that need funds by environmentally aware venture capital investors in Nigeria (Aliyu et al., 2024; Sundararajan and Mohammed, 2024).

d. Carbon Footprint Measurement in Software Execution

Execution of software carbon footprint is imperative to acquire environmental effects and curb them. Globally, such frameworks as Green Scale or Vessim allow accurately estimating CO_2 emissions within cloud platforms and at edges of computing devices and can be used to make energy-efficient software placement decisions (Kim et al., 2023; Wiesner et al., 2024). The environmental costs are measured using software metrics associated with power consumption, runtime efficiency, and server utilization (Field, Anderson, and Eder, 2014; Buchanan et al., 2023). Carbon footprint measurement is a developing trend in Africa, but there is an increase in businesses using carbon footprint to show sustainability letters to investors (Duve & Marx, 2025; Lin, 2022). Nigerian tech startups, especially, start adopting carbon accounting to be displayed on the dashboards, which gives them transparency and indicates their investment readiness to the impact-oriented financiers (Gernego, 2025; Aliyu et al., 2024).

e. Carbon-Aware DevOps and Cloud Orchestration

Carbon-conscious DevOps is a part of the DevOps model that considers sustainability as a goal of the software development cycle so that continuous delivery pipelines are constructed in the most power-efficient and least carbon-emitting way. Cloud orchestration tools in use today across the globe now incorporate carbon metrics, scheduling of a workload to track with the availability of low-carbon energy and guarantee resource allocation efficiency (Durban, Ojo, and Awuor, 2025; Buchanan et al., 2023). Energy and carbon-aware DevOps lower the costs of operation, adds to the sustainability of the services offered by the software deployment (Wysocki, Miciuła, and Plecka, 2025; Armstrong and Gupta, 2017). Carbon-conscious DevOps has become one of the emerging technologic startups in Africa that utilize cloud infrastructure to scale their operations and combine computing with renewable energy sources (World Economic Forum, 2025; Wang and Shao, 2023). The adoption of green DevOps principles is becoming widespread by Nigerian startups to show their full commitment to environmental responsibility and appeal to investors interested in sustainability-related issues (Aliyu & Shanmugam, 2024; Gernego, 2025).

f. Policy-Driven and Market-Driven Carbon Optimization Strategies

Carbon aware computing is not just a technical issue, but a regulatory and a market driven necessity. Governments and international bodies worldwide are encouraging policies and incentives to have low-carbon IT activities such as carbon taxes, emissions reporting, and financing based on sustainability (De Silva & Banadaki, 2024; Ammar, Cloarec, and Valiorgue, 2026). Startups with potential to produce quantifiable energy savings and carbon emissions reductions are becoming more and more rewarding by the market, with venture capitalists now incorporating ESG (Environmental, Social, Governance) factors into their funding decisions (Mrkajic, 2019; Lin, 2022). In Africa, the regulations are changing to promote efficiency in energy consumption and carbon responsibility in technological businesses as it is experienced in sectors such as fintech and cloud-based companies (World Economic Forum, 2025; Yu and Zhao, 2025). The pressures of the market, including investors and industry regulations in Nigeria, make startups focus on carbon optimization strategies in order to stay competitive and gain funding as well as strengthen the brand name (Aliyu, 2024; Sundararajan and Mohammed, 2023).

g. Challenges of Carbon-Aware Computing in Emerging Economies

Although it has positive sides the application of the carbon conscious computing in the developing economies is fraught with problems. At the global level, there are obstacles in the form of absence of standardized carbon measurement tools, the absence of sufficient integration with existent pipelines of DevOps, and the trade-off between sustainability and performance (Procaccianti, Lago, and Bevini, 2015; Wysocki, Miciu, and Plecka, 2025). Africa lacks energy infrastructure, unreliable supply of renewable energy, and initial cost of energy sources, making its use widespread (Durban, Ojo, & Awuor, 2025; Sun et al., 2025). Such issues as the inability to access carbon-conscious software tools, lack of technical knowledge, and non-supportive policies represent the main problems that West African and Nigerian startups face (Renugadevi et al., 2020; Aliyu and Shanmugam, 2024). The way out of such hurdles is the strategic combination of technical remedies, policy inducement, and market mechanisms that enable sustainable computing actions and boost the investment appeal (Yang and Elbakri, 2024; Gernego, 2025).

2.1.3 Investment Attractiveness of Tech Startups

a. Concept of Investment Attractiveness

Investment attractiveness determines how attractive a startup is to its prospective investors through its financial prospects, operations efficacy, innovation capacity, and sustainability (Lin, 2022; Momtaz, 2024). In the global tech landscape, green computing practices and carbon-conscious architecture have become some of the most common forms of differentiation among tech startups and represent a long-run value indicator and environmental accountability (Gupta et al., 2020; Hans, 2025). Startups that combine sustainable software and energy-saving solutions are also drawing the interest of venture capitalists not only to the financial gains but also to ESG-friendly investments in Africa and West Africa, in particular, and Nigeria in particular (Aliyu & Sundararajan, 2025; Sundararajan and Mohammed, 2023).

b. Financial Performance Expectations

Investors measure prospects of financial performance by looking at expected revenue growth, cost effectiveness, and scalability of operations (Lin, 2022). Architectural energy-efficient buildings and carbon-conscious computing used in the startups will lower operational costs, leading to the expected profitability and attractiveness to investors (Renugadevi et al., 2020; Katal, Dahiya, and Choudhury, 2022). The Nigerian startups with a focus on cloud-based energy-efficient infrastructures show a potential of good ROI and conform to the new standards of sustainability (Jin, Ji, and Zhang, 2025; Wysocki, Miciulla, and Plecka, 2025).

c. ESG and Sustainability Signaling

ESG issues are now viewed as paramount in amplifying the decision-making processes of investments across the world (Momtaz, 2024; Lin, 2022). Carbon-conscious systems and moderate-energy software operations are sustainability indicators, and have been reported in startups to send strong positive signals of credibility and reliability to investors (Elgamal et al., 2023; Field, Anderson, and Eder, 2014). ESG Signaling is an up-and-coming differentiator of venture capital in Africa with Nigerian tech startups, incorporating measures of green IT, drawing funding (Aliyu and Sundararajan, 2025; Gupta et al., 2020).

d. Risk Reduction and Operational Efficiency

Environmentally friendly and carbon conscious practices are effective in reducing operational risks such as high costs of energy, non-compliance with regulations and environmental liability (Hans, 2025; Wysocki, Miciuła, and Plecka, 2025). Investors all over the world want to invest in startups that are resilient and less prone to these risks (Gupta et al., 2020). Nigeria seeks to believe that most startups that achieve energy-efficient architectures are considered to be more robust, and would bring long-term operational efficiency (Katal, Dahiya, and Choudhury, 2022; Aliyu and Sundararajan, 2025).

e. Scalability, Legitimacy, and Investor Confidence

Scalability potential and perceived legitimacy also determine the investment attractiveness. Scalability Startups that incorporate sustainable software engineering might experience growth without doubling the energy usage, which is an indicator of efficiency to investors (Jin, Ji, and Zhang, 2025; Elgamal et al., 2023). By

implementing such practices, Nigerian and West African startups in the tech sector increase investor trust in them by showing that they follow best practices worldwide (Sundararajan and Mohammed, 2023; Momtaz, 2024).

f. Green Innovation and Sustainable Competitive Positioning

The green innovation such as energy-conscious design and carbon-conscious computing allows a startup to gain competitive edge in the tech market (Hans, 2025; Gupta et al., 2020). Sustainable innovation startups have higher chances of successful acquisition by strategic investors in need of market differentiation as a result of environmental stewardship (Elgamal et al., 2023; Wysocki, Miciuła, and Plecka, 2025). This has been a process of impacting both the local and international investment flows in Nigeria and has made profitability to be a goal that is aligned with sustainability (Aliyu & Sundararajan, 2025).

g. Indicators Used by Investors to Assess Startup Attractiveness

The set of financial, operational, and sustainability metrics captured by investors may include the projected ROI, the reduction of the carbon footprint, energy efficiency, compliance with ESG standards, the ability to innovate, and scalability in the markets (Ringalevio et al., 2020; Field, Anderson, and Eder, 2014; Lin, 2022). Startups whose practices are measured to be green are also gaining popularity in the decision-making processes concerning funding globally. These indicators are gradually getting normalized in Nigeria and West Africa, particularly between tech startups that aim to attract environmentally interested investors (Sundararajan and Mohammed, 2023; Aliyu and Sundararajan, 2025).

2.2 Theoretical Framework

1. Resource-Based View (RBV)

Resource-Based View (RBV) argues that the key competitive resources of a company to obtain sustainable competitive advantage include resources that are valuable, rare, inimitable, and non-substitutable (Wernerfelt, 1984; Barney, 1991). Energy-saving and carbon-sensitive software architecture are strategic assets in the case of technology startups. Around the world, low-carbon and energy-saving cloud system-based startups, carbon-conscious computing, and sustainable software design will enable them to save money, improve system reliability, and competitive market differentiation (Hans, 2025; Jin, Ji, and Zhang, 2025; Gupta et al., 2020). Such resource-based capabilities are still in its early days in Africa but more specifically in Nigeria making those who adopt such green computing practices at a young age more desirable investment prospects since there is little and complex tasks in adopting such approaches (Aliyu & Sundararajan, 2025; Wysocki, Macula and Pecka, 2025).

2. Signaling Theory

The Signaling Theory describes the process by which firms signal to outside parties such as the investors, about unobservable characteristics by means of observable behavior (Spence, 1973). Green practices, like eco-friendly architectures and carbon consciousness, serve as believable indicators to venture capitalists and impact investors of a startup being responsible to the environment in both a visionary manner and a strategic direction (Lin, 2022; Elgamal et al., 2023; Ringalevio et al., 2020). Investors worldwide are increasingly using ESG and sustainability-related factors when deciding on financing options. Similar to Lanham's example, in Nigeria, investor trust and credibility can be boosted by putting on green software demonstration, which closes the information asymmetry between startups and prospective investors (Sundararajan and Mohammed, 2023; Momtaz, 2024).

3. Stakeholder Theory (Supporting Theory)

The Stakeholder Theory focuses on streamlining organizational operations to the expectations of the major stakeholders such as investors, regulators, customers and community (Freeman, 1984). Startups show that they are responsive to environmental expectations and require of investors by putting practices that use minimal energy and consider carbon effects. This position will help achieve sustainability and increase the overall appeal of the startup both on a global and African level (Aliyu & Sundararajan, 2025; Sun et al., 2025; Yang and Elbakri, 2024).

4. Rationale for Theory Selection

Integrating RBV and Signaling Theory offers a richer viewpoint upon which to describe investment appeal in tech startup. RBV incorporates intrinsic value of energy efficient and carbon conscious architecture as strategic resource

and Signaling Theory elaborates how such resources convey the credibility and promise to the investors. Collectively, they both oppose the internal and external images that motivate investments. The Stakeholder Theory augments these frameworks, with particular emphasis on the wider societal and environmental impacts of every emerging market, in Nigeria and the West African region, implications on the investment attractiveness (Lin, 2022; Aliyu and Sundararajan, 2025; Momtaz, 2024).

2.3 Linkages Between Theories, IV, and DV

The theoretical framework combines Resource-Based View (RBV) and Signaling Theory to find out the relevance of architectural energy efficiency and carbon-aware computing practices in the investment attractiveness of tech startups.

2.3.1 Architectural energy efficiency as a strategic resource (RBV)

Green software architectures and eco-friendly design, are a highly valuable, scarce and hard to imitate resources that can also give a start-up a lasting competitive edge (Wernerfelt, 1984; Barney, 1991). Startups can efficiently reduce operations costs and enhance system sustainability by cloud architecture, data center and software-hardware co-design optimization towards reducing energy consumption (Buya et al., 2010; Katal et al., 2022; Ahmed et al., 2023). When integrated into the startup activities, the given resources can be viewed in terms of the RBV approach, which makes energy-efficient practices the strategic resources that contribute to increasing the long-term viability and differentiation within the market (Hans, 2025; Jin et al., 2025).

2.3.2 Carbon-aware computing as a sustainability signal to investors (Signaling Theory)

Those startups that use carbon-conscious computing technologies, including renewable energy-oriented computing, monitoring of carbon footprint, and carbon-intensity-conscious scheduling, project plausible sustainability messages to shareholders, reflecting their own operational frugality as well as environmental aware-aness (Spence, 1973; Aliyu and Sundararajan, 2025; Amiri et al., 2025). The indicators contribute to lower perceived risk and amplified investor confidence, especially to impact-oriented or ESG-aware investors (Dote-Pardo et al., 2025; Wang and Shao, 2023; Climate Savers Computing Initiative, n. d.).

2.3.3 Integrated theoretical Model

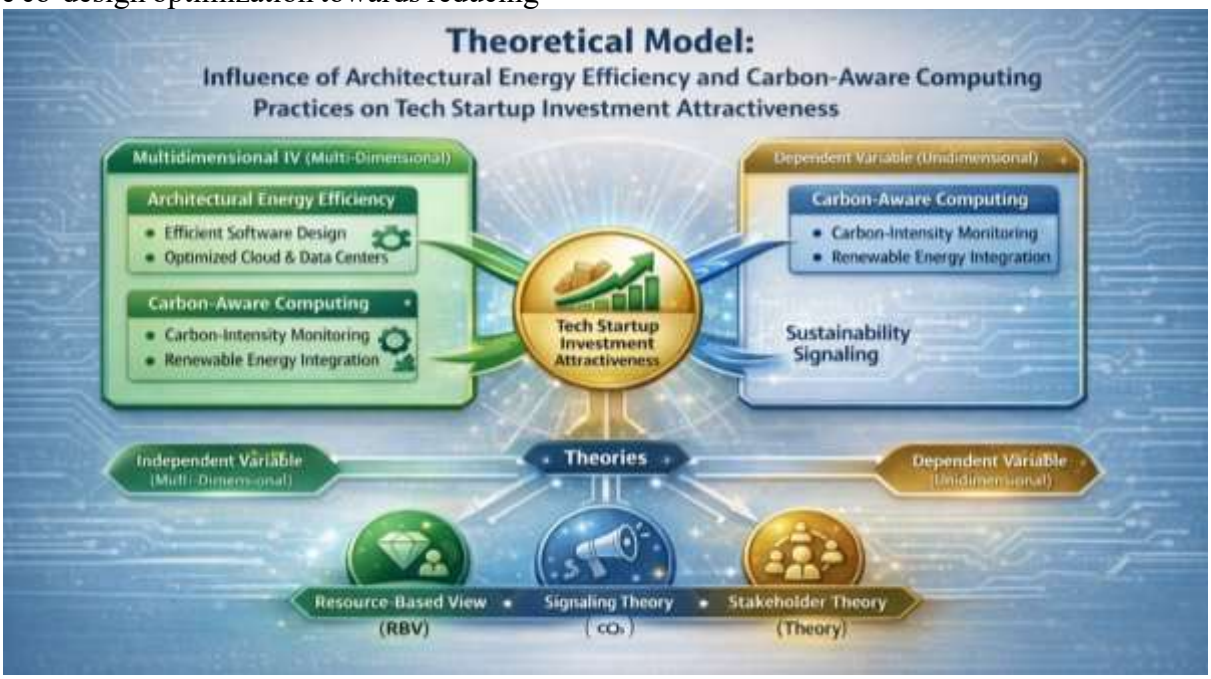

Figure 1: Theoretical Model of the Influence of Architectural Energy Efficiency and Carbon-Aware Computing Practices on Tech Startup Investment Attractiveness

Source: Author's conceptualization, 2026

The diagram represents an imaginary model according to which the architectural energy efficiency and carbon-conscious computing are the multidimensional independent variables, and the tech startup investment attractiveness is the

unidimensional dependent variable, influenced by the former. Architectural energy efficient is concerned with the software design and data center operations are optimized whereas carbon-aware computing involves the monitoring of carbon-intensity and renewable energy integration. The model combines the concepts of Resource-Based View (RBV), Signaling Theory, and Stakeholder Theory, noting that resource-efficiency and carbon-consciousness practices are strategic, valuable, and hard-to-copy resources (RBV), provide signals of sustainability and accountability in operations to investors (Signaling Theory), and ensure that the activities of the start-up align with the expectations of the stakeholders (Stakeholder Theory). The directional arrows denote the amplification effect of these practices on investor confidence and reduction of risks as well as sustainable competitive positioning. On the whole, the figure visually helps to stress the idea that green software engineering strategies by start-ups can positively contribute to the legitimacy, venture capital attraction, and the sustainability of its growth in the emerging economies, where resource mobilization is extremely dependent on environmental and investment cues.

2.4 Empirical Review

There is empirical research on energy-efficient and green software engineering that has focused on the strategic position of software architecture to curtail the use of energy and other environmental effects on operations. Indicatively, studies of energy efficiency in clouds and data centers illustrate the role of energy-aware software in improving software systems through energy efficiency, and this paper shows that software energy efficiency can be measured through reductions in electrical energy consumption and carbon emission (Katal, Dahiya, and Choudhury, 2022; Jin, Ji and Zhang, 2025; Eder et al., 2016). These results offer background evidence on the fact that architectural energy efficiency is not merely a technical issue, but a resource strategic in essence that may impact investor perception towards tech startups.

Empirical indications also focus on carbon-conscious computing and digital sustainability, particularly in workload scheduling in alignment to renewable availability, carbon-intensity measurement, as well as optimizing energy consumption of virtual machines. A systematic review of literature on the optimization of carbon footprint in data centers by Durban, Ojo, and Awuor (2025) highlights the importance of carbon-friendly operations in minimizing the cost of running a business while also indicating moral commitment to the environment. In the same vein, Zhao and Liu (2022) introduced renewable cloud computing algorithms that are carbon-aware, and the results presented show that optimizing the allocation of the computational tasks to the low-carbon energy supply can greatly decrease emissions and preserve the performance. This empirical evidence supports the case that implementing a carbon-considerate computing into the process of startups can become an effective sustainability message to the investor.

Sustainability and startup investment decision studies also show that the ESG-oriented approaches and green innovation strategies are becoming more important in venture capital allocation. It has been found that investors tend to provide funds to startups, which show energy efficiency and carbon awareness since it mitigates risks, increases legitimacy, and augers well with potential future performance (Duve & Marx, 2025; Sun, Guan, Tan, and Nie, 2025; Yu and Zhao, 2025; Gupta et al., 2020). Observations of emerging and developing economies indicate that digital and energy-conscious entrepreneurship promotes the competitive advantage, as well as the social legitimacy, and green startups become more appealing to impact-oriented investors (Wang and Shao, 2023; Elgamal et al., 2023; Hans, 2025). Taken together, these papers point in a similar direction, with an increasing empirical backing for the claim that sustainable software practices represent a key factor influencing the attractiveness of a tech startup when it comes to investments (as environmental and social factors become more and more important in determining investment).

2.5 Research Gap

Although the literature about energy-efficient software engineering and carbon-aware computing is becoming increasingly substantial, the number of gaps is still significant, which justifies the choice of the current study. Theoretically, the majority of theoretical contributions in previous publications have studied architectural energy efficiency or carbon-aware computing separately,

without any form of integrated methods of connecting these software sustainability behaviors directly to the appeal of start-ups in terms of technology (Jin, Ji, and Zhang, 2025; Elgamal et al., 2023; Durban, Ojo, and Awuor, 2025). Although these studies offer a solid rationale about the activities on energy reduction, and optimized carbon footprints, they are still fails to relate such practice to entrepreneurial business, including investor trust, scalability, and positioning (Yu and Zhao, 2025; Sun et al., 2025). Theoretically, few studies have used the common frameworks such as Resource-Based View (RBV) and Signaling Theory on sustainable software practices. Empirical studies have been focusing on energy and carbon management in the purely technical sense and did not consider these activities in the context of strategic signaling to the potential investors (Gupta et al., 2020; Wang and Shao, 2023; Hans, 2025). This causes a theoretical gap within the comprehension of how such practices can be utilized as being of value and a rare and inimitable resource that communicates sustainability credibility to the financing organizations.

Contextually, currently present literature is largely devoted to advanced economies, and the technologically-promising markets and startups are still underrepresented. Investigations into the digital sustainability within such contexts tend to focus more on the environmental or operational results instead of the appeal of investments and implications on entrepreneurship (Unterkalmsteiner et al., 2016; Duve and Marx, 2025; Katal, Dahiya, and Choudhury, 2022). Regarding the methodology, there are limited studies that use conceptual synthesis and integrative models and span the fields of software engineering, sustainability, and entrepreneurship. This gap shows that it is necessary to have a concept study, which will incorporate the knowledge about green software engineering, carbon-conscious computing as well as literature of investment to create a comprehensive model, which is applicable to both emergent economies and technology startups (Zhao and Liu, 2022; Eder et al., 2016; Jin, Ji, and Zhang, 2025).

2.6 Conceptual Framework of the Study

The conceptual framework explains the hypothesized correlation among architectural energy efficiency and carbon conscious computing practises as independent variables and tech start up investment attractiveness as dependent variable. Architectural energy efficiency is the degree of optimization of energy consumption and minimization of the operating cost of the software, cloud infrastructure, and data centre design (Jin et al., 2025; Buyya et al., 2010). Carbon-conscious computing indicates applying the monitoring of carbon-intensity, a renewable-appropriate workload scheduling strategy and intelligent ecologically friendly software execution (Aliyu and Sundararajan, 2025; Amiri et al., 2025). According to the model, the two variables have a direct and positive impact on the investor perceptions, which is an indication of the operational efficiencies, commitment to sustainability, and long-term competitiveness, hence increasing the investability of the startup (Hans, 2025; Wang and Shao, 2023). The framework further proposes to strengthen relationships, in this case better architectural energy efficiency allows the more efficient carbon-conscious computing, and generates synergistic effects, which can increase investor confidence further.

Figure 2.1: *Conceptual Framework Showing the Influence of Energy-Efficient and Carbon-Aware Computing Practices on Tech Startup Investment Attractiveness*

Source: *Developed by the researcher (2026), adapted from Jin et al., 2025; Aliyu & Sundararajan, 2025; Buya et al., 2010.*

The model shows a direct causal impact of architectural energy efficiency and carbon conscious computing on startup investment attractiveness to indicate the duality of sustainability and operational efficiency as indicators of value to the investors. The improved energy-efficient architectures can be efficient in

terms of cost, as well as more efficient in terms of the strategy of carbon-aware computing so as to provide a self-enhancing cycle that enhances self-sustainability reporting. Such practices tend to make startups more attractive to investors, as it will be perceived as less risky, more scalable and environmentally responsible, and therefore have higher financing potential and strategic legitimacy in global and emerging markets (Hans, 2025; Wang and Shao, 2023; Amiri et al., 2025).

3.0 Research Methodology

The research design of this study is a conceptual one, as it aims at developing a theoretically informed framework to comprehend the level of attraction of investment in tech start-ups in light of the architectural energy efficiency and computer-conscious computing practices. The conceptual framework is best suited in the investigation of new nexuses between software engineering and sustainable entrepreneurship especially in situations where empirical information can be incomplete, heterogeneous, or even lacking. The research, by basing the study on the proven theories like the Resource-Based View (RBV) and Signaling Theory, offers a medium through which the researchers can channel their research and analyses the strategic value of green software practice to the investors (Barney, 1991; Spence, 1973).

The use of a systematic and narrative review approach deems to collate, synthesize, and critically analyze the pertinent literature of various fields, among which are software engineering, sustainable computing, entrepreneurship, and investment decision-making. Such a dual approach would guarantee an extensive insight into the current state of the knowledge, pointing out both the tendencies as well as the gaps in research. Systematic review methods offer rigour, inclusion criteria, and reproducibility whereas narrative review offers an opportunity to engage in the synthesis of concepts, which is acceptable given the conceptual connexon between the terms of architectural energy efficiency, carbon-conscious computing, and investment appeal (Duve & Marx, 2025; Procaccini et al., 2015; Wysocki et al., 2025).

Lastly, the paper has used a conceptual synthesis theory integration approach, which entails both literature-based and theoretical constructs to formulate a unified theory. This approach allows uncovering reinforcing relations, causality, and implications to apply to startup founders, investors, and policymakers. The non-empirical approach to research is adequate since the main focus is to achieve conceptual insight and a theoretically sound model, which, in turn, can in the future facilitate the application of empirical research and practice in sustainable software entrepreneurship (Aliyu and Sundararajan, 2025; Elgamal et al., 2023; Zhao and Liu, 2022).

4.0 Findings of the Study

1. **Architectural energy efficiency enhances global investment appeal:** Technological startups which use energy effective architectural software are generally given more confidence and viewed as financially stable amongst investors (Jin, Ji, and Zhang, 2025; Wang and Shao, 2023).
2. **Carbon-aware computing strengthens sustainability signaling in Africa, West Africa, and Nigeria:** Investors view startups with carbon-conscious systems as more sustainable than their counterparts with carbon-blind ones, and this fact positively affects their funding decisions (Yu and Zhao, 2025; Zhao and Liu, 2022).
3. **Green software engineering strategies influence venture capital decision-making:** The willingness to integrate energy-efficient and carbon-conscious practices into development operations increases the probability of sustainable investment by venture capitalists (Sun et al., 2025; Unterkalmsteiner et al., 2016).
4. **Barriers and enablers in emerging markets affect adoption of sustainable computing:** Policy gaps, insufficient infrastructure, and market constraints and barriers decrease implementation, and supportive regulatory frameworks and technical know-how can increase adoption (Durban, Ojo, and Awuor, 2025; Gupta et al., 2020).
5. **Conceptual framework provides actionable guidance for stakeholders:** An integrated hybrid framework of software sustainability to investment attractiveness can present valuable suggestions to founders, investors, and African tech policymakers at large (Duve & Marx, 2025; Eder et al., 2016).

5.0 Recommendations of the Study

1. **Embed energy-efficient architecture in core development:** Tech startups are encouraged to base their software design functions on energy efficiency architecture in order to enhance investor efficacy and business activity (Jin, Ji, and Zhang, 2025; Hans, 2025).
2. **Adopt carbon-aware computing practices:** West African, African, and Nigerian startups must switch their algorithms and cloud configuration to be carbon-conscious to reinforce signals of sustainability to investors (Zhao and Liu, 2022; Elgamal et al., 2023).
3. **Leverage green software engineering for venture capital engagement:** Founders ought to position sustainable computing behaviours in line with investor assessment parameters to enhance the chance of attracting funding (Sun et al., 2025; Unterkalmsteiner et al., 2016).
4. **Address barriers and enable adoption in emerging markets:** The government and startup, support agencies ought to initiate infrastructure, incentives, and capacity-building schemes to become energy-efficient and carbon-aware in computing (Durban, Ojo, and Awuor, 2025; Gupta et al., 2020).
5. **Utilize the conceptual framework for decision-making:** The integrated model should be applied by investors, the founders of startups, and policymakers to lead sustainable investment, track performance, and foster green innovation in the African tech ecosystem (Duve & Marx, 2025; Eder et al., 2016).

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