JPPIPA 11(6) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Challenges and Opportunities in Implementing Green Data Centers in Indonesia Toward Sustainable Digital Infrastructure

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Received: February 20, 2025
Revised: May 05, 2025
Accepted: June 25, 2025
Published: June 30, 2025

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DOI: 10.29303/jppipa.v11i6.11267

Abstract: This article aims to explore the challenges and opportunities of implementing green data centres in Indonesia, focusing on regulatory influences, technological advancements, financial implications, and competitive advantages. Primary research was conducted through interviews with key stakeholders, including data centre providers, regulatory experts, energy suppliers, members of the data centre association, representatives from training institutions, and climate and energy economists. Secondary research drew from academic papers, published articles, and industry reports to supplement the findings. The study identified significant challenges in transitioning to green data centres in Indonesia. Key issues include the state electricity company PLN's reliance on coal for electricity and the limited availability of renewable energy power plants, despite the country's abundant renewable energy resources. Financial obstacles were noted, such as high initial capital expenditures (Capex) for advanced cooling systems and generators, and high operational expenditures (Opex) for electricity and fuel. However, the adoption of green technologies can reduce long-term Opex by improving energy efficiency. Regulatory gaps and the absence of targeted incentives further complicate the transition to green data centres. Adherence to international standards can provide a framework for sustainable practices, but there remains a significant talent gap in the data centre industry. Strategies to overcome these challenges include adopting renewable energy through Renewable Energy Certificates (RECs), implementing advanced cooling technologies, and utilizing energy-efficient servers and Data Center Infrastructure Management (DCIM) tools. Collaborating with suppliers who meet green criteria is also critical. Transitioning to green data centres offers a competitive edge by attracting clients with green targets and reducing emissions. However, higher initial costs may deter providers, making long-term financial planning essential. This study provides valuable insights for governments and industry stakeholders, emphasizing the importance of sustainable data centre development as part of Indonesia's journey toward a greener economy.

Keywords: Competitive advantage; Green data centres; Sustainable data centres

Introduction

The rapid growth of Indonesia's digital economy has led to a significant increase in the number of data centers across the country. As of 2023, there were 107 data center facilities operated by 39 providers, spread across 23 islands. This places Indonesia as the second-largest data center hub in Southeast Asia, behind Singapore and followed by Malaysia (Aminah et al., 2021). These data centers are essential to the nation's digital infrastructure, acting as central points for storing, managing, and securing large volumes of data, while also hosting applications and providing comprehensive networking and connectivity services. The growing

How to Cite:
Syamsuri, L. M., & Pakartipangi, W. Challenges and Opportunities in Implementing Green Data Centers in Indonesia Toward Sustainable Digital Infrastructure. *Jurnal Penelitian Pendidikan IPA*, *11*(6), 104-118. https://doi.org/10.29303/jppipa.v11i6.11267

reliance on cloud computing, the Internet of Things (IoT), big data analytics, Artificial Intelligence (AI), and the rollout of 5G has further intensified the demand for data centers. One significant driver of this demand is the government's initiative to accelerate digital transformation across various ministries, government bodies, and state-owned enterprises (Shehabi et al., 2018). To support this transformation, the government plans to establish national data centers with a combined capacity of 40 megawatts (MW) across four provinces by 2026. The Minister of State-Owned Enterprises has also expressed ambitions to position Indonesia as a leading data center hub in Southeast Asia. According to the Indonesia Data Center Provider Organization (IDPRO), the energy capacity of Indonesia's data centers is expected to reach 210 MW by 2024, with a compound annual growth rate (CAGR) of 44.83% (Masanet et al., 2020).

The surging demand for data centers presents a significant challenge in terms of energy consumption and environmental impact. Data centers are among the most energy-demanding facilities, with most of the energy used for cooling systems and servers, followed by storage drives and network equipment (Fernandez-Cerero et al., 2020). Large-scale hyperscale data centers, which house tens of thousands of devices, can consume over 100 megawatts (MW) of power—enough to supply around 80,000 households. This heightened energy consumption can lead to increased carbon emissions (Al Kez et al., 2022; Fernandez-Cerero et al., 2020). According to the International Energy Agency (IEA), data centers and transmission networks accounted for 1% of energy-related greenhouse gas emissions, emitting 330 metric tonnes of carbon dioxide equivalent in 2020 (Manganelli et al., 2021; Zhu et al., 2023).

The shift towards green data centers in Indonesia presents both challenges and opportunities, but progress is hindered by regulatory constraints, technological needs, financial considerations, and market competition. The impact of current regulations on the development and operation of green data centers, the demand for energy-efficient technologies and dependable suppliers, and the financial burden of adopting sustainable practices—covering both capital expenditure (Capex) and operational expenditure (Opex)—pose significant obstacles for businesses (Fitriani et al., 2023; Wiryomartono, 2015). Additionally, the potential competitive edge of green data centers over traditional industry players remains uncertain. These challenges underscore the necessity for a thorough examination of strategies to overcome these barriers and fully leverage the opportunities within Indonesia's data center sector (Al Kez et al., 2022; Lestari, 2020).

This study aims to thoroughly investigate the challenges and opportunities associated with the implementation of green data centers in Indonesia, with a particular focus on the impact of regulations, technological requirements, financial considerations, and market competition. The goal is to identify strategies to overcome regulatory and financial obstacles, assess the role of energy-efficient technologies and supplier partnerships, and evaluate the potential competitive benefits of adopting sustainable practices in data center operations.

Method

This study employs a qualitative research approach, utilizing interviews to examine the challenges and opportunities associated with green data centers in Indonesia. Participants were carefully chosen to offer a range of perspectives on the data center industry in Indonesia. Additionally, interviews with data center professionals from other countries were conducted to explore the feasibility of adapting their green practices in the Indonesian context. The research also incorporates a literature review as secondary data, drawing from research papers, white papers, published articles, and reports from data center providers, consultancy firms, and IT journalists.

Thematic analysis was employed to identify recurring themes, topics, ideas, and patterns of meaning across the interviews. NVivo 14 software for Mac was used to conduct the analysis. The interview transcripts were carefully examined to extract relevant themes and codes as presented in Table 1, which were then grouped into the following key categories: Regulations and Standards: This category explores the question, "How do regulations in Indonesia impact the development and operation of green data centers?", Technology and Suppliers: This category examines the question, "What technological solutions and supplier considerations are essential for improving energy efficiency and achieving net-zero goals in Indonesia's data center industry?", Financial Implications: This category investigates the question, "What are the financial implications (Capex and Opex) of transitioning to green data centers for businesses in Indonesia?", Market Competitiveness: This category analyzes the question, "Does transitioning to green data centers offer a competitive advantage in the data center industry compared to other players?", Other Challenges: This category addresses additional challenges that were not directly covered by the primary research questions.

Result and Discussion

Regulations and Standard
Lack of regulation and incentive

The consensus from the interviews in Table 1 indicates that there is a lack of regulations requiring data center providers to adopt green practices in their operations and development. Furthermore, there are no specific incentives to promote the growth of green data centers (Darko et al., 2017; Xia et al., 2015). This issue is also observed in the UK and the Philippines, where no dedicated regulations for green data centers are in place. In contrast, Singapore has enacted stringent regulations for data center development, particularly after lifting a moratorium on data center construction (Gündes et al., 2015).

Current data centre standard and regulation in Indonesia

Three key regulations govern the development of data centers in Indonesia. Government Regulation No. 82 of 2012 requires electronic system operators, including Over The Top (OTT) service providers, to store data within the country (Rahma et al., 2019; Syahrial et al., 2022). Presidential Regulation No. 95 of 2018 mandates the creation of a national data center for government use, leading to the establishment of the National Data Centre Standard SNI 8799. Additionally, Government Regulation No. 33 of 2023 stipulates that industry players must report on energy conservation efforts (Basri et al., 2006).

Although adopting green practices is currently voluntary, data center providers have the option to obtain certification through either local or international standards. The Indonesia Green Building Council has introduced the Greenship Data Centre rating system, which offers a green building standard specifically for data centers (Gou et al., 2014). Providers can also follow the best practices outlined in the Indonesian Green Data Centre White Paper by IDPRO. A national standard for green data centers is under development and will initially be enforced at the association level for IDPRO members (Cai et al., 2023; Reddy et al., 2018).

International Standards for Green Data Centre

Data center providers can demonstrate their commitment to green practices by adhering to a range of internationally recognized standards. Popular building certifications, such as Singapore's Green Mark and the U.S.-based LEED (Leadership in Energy and Environmental Design) system, are commonly adopted by data centers across the globe (Wagner, 2020). In the Philippines, data centers use both the LEED certification and the local BERDE (Building for Ecologically Responsive Design Excellence) standard, further emphasizing sustainability in the sector (Doan et al., 2023; Fikri et al., 2023). In addition to building certifications, environmental management standards, such as ISO 50001 for energy management, are followed by several Indonesian data center providers. This aligns with practices in the Philippines, where ISO 14001, focused on environmental management, is also implemented. In the UK, data centers are required to obtain environmental permits, ensuring that their operations meet stringent environmental criteria. Additionally, Singapore has developed a specific sustainability standard tailored to the unique requirements of tropical data centers, addressing issues such as energy efficiency and cooling in a hot and humid climate (Cao et al., 2024).

Table 1. List of Interview Questions

Interview Questions	Relation to research questions
Please introduce yourself and provide a brief description of your role in your current profession.	General question
Considering the target to reduce carbon emissions, what are the challenges of implementing green practices in data centres?	
Are there influences from government regulations on the development of green data centres?	How do regulations in Indonesia influence the development and operation of green data centres?
Are there standards that must be met in the development of green data centres?	
How can the effectiveness of a green data centre be measured?	
What strategies can data centre providers implement to achieve net zero emissions?	What technological solutions and supplier considerations are crucial for enhancing energy efficiency and achieving net-zero goals in Indonesia's data centre industry?
What technologies can be adopted for green practices in data centres?	
How important is supplier/vendor consideration in the development of green data centres?	
What is the primary CapEx for a green data centre?	What are the financial implications (Capex and Opex) of transitioning to green data centres for businesses in Indonesia?
Are there impacts on OpEx from implementing green practices in data centres?	
What are the competitive advantages of green data centres in the data centre business compared to other data centre players?	Does the transition to green data centres provide a com- petitive advantage in the data centre business compared to other data centre players?

Interview Questions	Relation to research questions
What is your view on the future of the data centre industry considering ESG requirements and techno- logical advancements?	Closing question

Table 2. List of Interviewees

Codes	Interviewees
Lack of regulation to enforce green data centre development	EH, RK, SO, WP
No incentive from government for green data centre	EH, HS, IY
Lack of regulation to accelerate development of renewable energy power plant	EH, GP
Providing incentive will promote green data centre development	HS, SO
Incentive can reduce green data centre opex	SO
Lack of incentive for renewable energy supplier	GP
No green data centre standard in Indonesia	EH
There are incentives, but not specifically for green data centre	WP
Green practice initiative incentive in renewable energy act draft	HS
(PH) no regulation driving implementation of green data centre	RA
(SG) strict regulation following the lifted moratorium of data centre development	LP
(UK) no standard or regulation specifically for green data centre	PS

Beyond building and environmental management certifications, data centers can also pursue tier certifications like ANSI/TIA-942 or Uptime Institute standards, which provide frameworks for assessing the reliability and sustainability of data center infrastructure (Bjørn et al., 2022). To further reduce their environmental impact, data centers can follow the Science-Based Targets initiative (SBTi), which provides a clear pathway for organizations to set and achieve emission reduction goals. The SBTi categorizes emissions into three distinct scopes: Scope 1 (direct emissions from owned or controlled sources), Scope 2 (indirect emissions from the generation of purchased electricity), and Scope 3 (all other indirect emissions across the value chain) (Hoosain et al., 2023; Murino et al., 2023; Wagner, 2020). By following these standards and initiatives, data centers can not only meet regulatory requirements but also contribute to broader global sustainability goals by significantly reducing their carbon footprint.

Discussion

Driving Force of Green Data Centre Development in Indonesia

Findings from the interviews indicate that the development of green data centres in Indonesia is primarily driven by voluntary actions rather than regulatory mandates as presented in Figure 1. Currently, there is a lack of enforcement and incentives for green practices within the data centre industry. These voluntary initiatives are largely motivated by market access considerations, particularly from multinational companies, especially those based in the United States and Europe, which have set targets to reduce their emissions in line with the Paris Agreement. This requirement also pressures investors to comply with Environmental, Social, and Governance (ESG) standards (Bjørn et al., 2022; Hoosain et al., 2023). Additionally, financial institutions now offer green financing schemes. Green financing refers to loans or investments that support environmentally-friendly activities, such as acquiring eco-friendly products and services or constructing sustainable infrastructure (Doan et al., 2023; Fikri et al., 2023). Since data centres are capital-intensive, green financing presents an opportunity to support the development of green data centres.

Metrics, Technology, and Supplier Consideration of Green Data Centre

There are three commonly used metrics to measure the effectiveness of green practices in data centres: PUE (Power Usage Effectiveness), WUE (Water Usage Effectiveness), and CUE (Carbon Usage Effectiveness) as presented in Figure 2. For carbon reduction programs, data centre providers can set targets based on the Science Based Targets initiative (SBTi), where emissions are categorized into three scopes. Scope 1 includes direct emissions produced by the data centre. Scope 2 covers indirect emissions from the use of energy or electricity supplied by a third party. Scope 3 encompasses indirect emissions from supply chain operations. Based on the SBTi emission categories, data centre providers can determine which equipment or aspects to focus on to reduce emissions within each scope (Avgerinou et al., 2017; Li et al., 2023). Figure 2 depicts the technologies that can be used for each equipment type according to the SBTi emission categories.

To reduce Scope 1 emissions, data centre providers can lower emissions produced by generators by using biodiesel, filters, or catalytic converters. Natural gas can also be used for cleaner emissions compared to diesel. At Telehouse UK, catalytic converters are used to reduce NOx gases. To further reduce Scope 1 emissions, UPS systems with lithium-ion batteries, which offer a longer

lifespan compared to valve-regulated lead-acid (VRLA) batteries, can be implemented. Scope 2 emissions account for the largest share of emissions from data centres, as they predominantly rely on electricity from energy suppliers. To enhance energy efficiency, data centre providers can focus on optimising cooling systems, which are the largest consumers of electricity (Jing et al., 2024). One effective approach is to implement hot or cold aisle containment in data hall design with an air cooling system, which separates hot and cold airflows (Lee et al., 2022). This method has been tested by Schneider, showing that while a cold aisle containment system (CACS) worsened the PUE from 1.84 (uncontained system) to 1.98 at a maximum temperature of 24°C, a hot aisle containment system (HACS) provided a significant improvement, reducing the PUE to 1.69, as shown in Figure 3. For high-intensity servers, such as those used for AI, data centre providers can implement liquid cooling that directly cools the chip (Li et al., 2023).

As mentioned before, direct-to-chip cooling in high-density data centres decreases overall power consumption by 10.2% and improves total usage effectiveness (TUE) by 15% compared to air cooling methods (Cho et al., 2018). Additional practices such as server virtualisation, using Data Center Infrastructure Management (DCIM) tools to monitor operations and emissions, conducting energy audits, optimising application programming algorithms, and managing heat waste can also be implemented to further enhance energy efficiency in data centres (Manganelli et al., 2021). Enhancing energy efficiency in data centres extends beyond hardware optimization to include software and application development. The concept of green coding involves writing software in a way that minimizes its environmental impact. This can be achieved by using efficient code that consumes less energy, optimising data usage, and reducing electronic waste. Key aspects of green coding include minimising resource consumption during software operation—especially as user numbers grow—and keeping data as close to its source as possible (Verdecchia et al., 2021). This approach reduces unnecessary data transfers, excessive cloud usage, and the storage of superfluous data in the cloud. the methodology used in green coding is "lean coding", which emphasises using the least amount of processing power necessary to achieve the desired outcome (Ardito et al., 2015; Katal et al., 2023). For example, web developers can focus on reducing file sizes, such as by replacing high-quality media with smaller files. This not only speeds up website load times but also enhances the user experience while reducing the environmental impact.

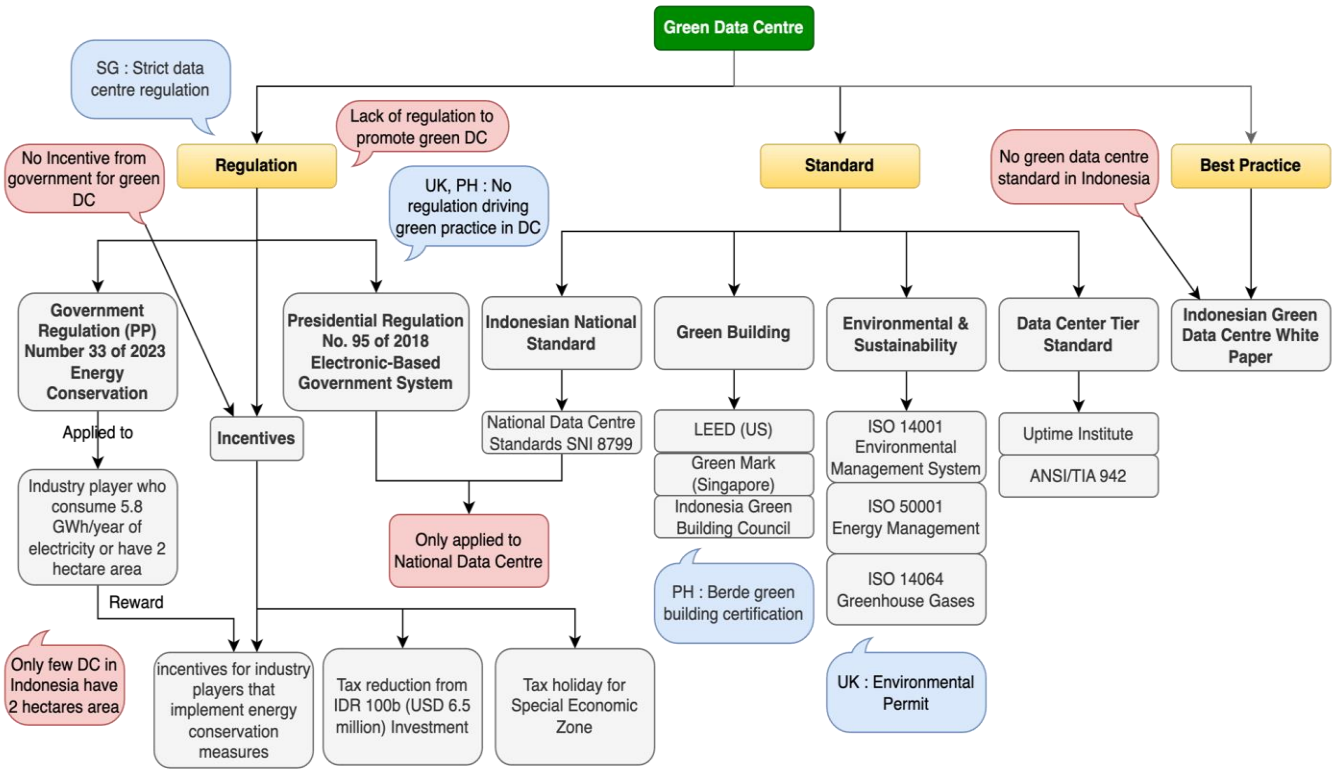

Figure 1. Regulations and standards of data center in Indonesia

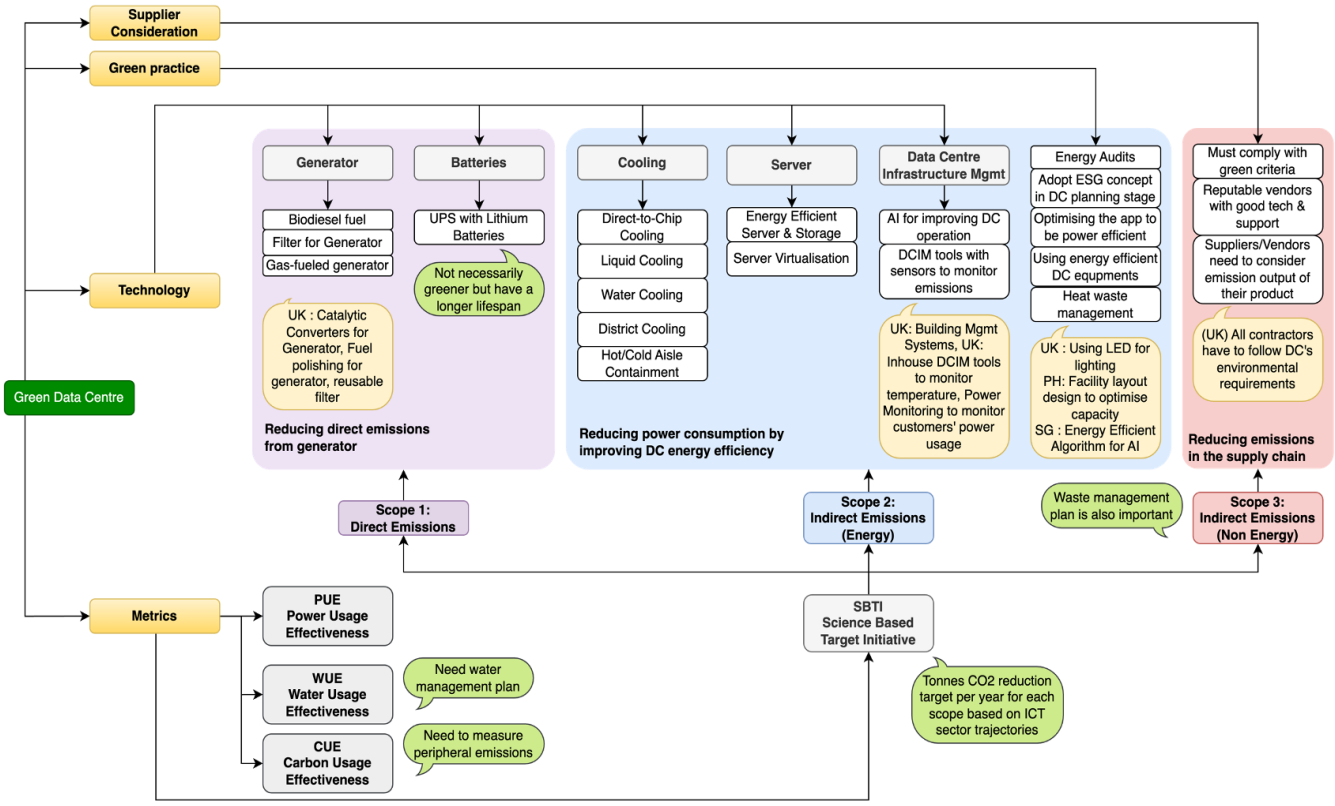

Figure 2. Metrics and technology framework

To effectively reduce Scope 3 emissions, data centre providers can implement several key strategies when working with suppliers and vendors. First, they can require that all supplier and vendors comply with established green criteria, such as holding certifications for environmental standards or demonstrating a commitment to sustainability in their operations (Murino et al., 2023). This ensures that the materials and services provided align with the data centre's sustainability goals. Additionally, selecting reputable vendors with a proven track record and strong support systems is crucial. These vendors are more likely to offer products that meet high environmental standards and can provide the necessary expertise to ensure that the materials and equipment are installed and operated efficiently (Katal et al., 2023; Verdecchia et al., 2021).

In addition, this collaboration helps optimise the performance of the data centre while minimising its environmental impact. Furthermore, data centre providers can prioritise sourcing materials and equipment that have lower associated Scope 3 emissions (Sovacool et al., 2022). This includes choosing products produced with minimal carbon footprints from suppliers who actively reduce emissions throughout their supply chains. By engaging in long-term partnerships with such vendors, data centre providers can influence the broader industry to adopt greener practices, thereby contributing to the overall reduction of Scope 3 emissions. Waste management is a crucial factor in reducing Scope 3 emissions in data centres (Hertwich et al., 2018; Uddin et al., 2015).

Effective waste management practices are essential for reducing the environmental impact of operations by minimizing landfill waste and lowering the demand for new raw materials. Strategies like optimizing resource use, recycling, reusing materials, and implementing circular economy practices—such as refurbishing outdated equipment—are key (Giurea et al., 2024). By prioritizing waste management, data centres can lower emissions associated with their supply chains and contribute to sustainability. Engaging employees in waste reduction and collaborating with certified recyclers further enhances these efforts, ensuring a holistic approach to environmental responsibility (Elroi et al., 2023; Groenewald, 2024).

In Indonesia, the primary source of electricity is provided by PLN, the state electricity company, which faces challenges due to the limited availability of renewable energy power plants and a lack of regulations to promote their development. The proposed power-wheeling scheme in the renewable energy bill could help accelerate the energy transition by allowing private companies and independent power producers (IPPs) to build power plants and sell electricity directly to consumers (Ahsan, 2021). While this could threaten PLN's dominance, it could also open opportunities for

expanding the electricity network, especially with the growth of renewable energy plants. However, to align with energy transition goals, grid sharing should be limited to renewable energy sources (Rahman et al., 2023; Sommeng et al., 2018).

One current solution for demonstrating the use of renewable energy is to purchase Renewable Energy Certificates (RECs). However, this comes with premium tariffs from PLN, which increases the operational expenses (Opex) for data centres. An alternative approach is to negotiate green tariff contracts, which provide the advantage of long-term price stability and access to dedicated power plants, potentially offering a more cost-effective and reliable solution for meeting sustainability goals (Jin et al., 2018; Kwon, 2020). A Power Purchase Agreement (PPA) with an independent power producer (IPP) is not feasible as current regulations do not allow IPPs to sell electricity directly to the customer. An alternative approach to securing renewable energy is on-site generation. On-site generation can be done through solar PV systems or natural gas engines (Goiri et al., 2014). The financial impacts is presented in Figure 5.

Solar photovoltaic (PV) systems require significant space, with 1 hectare producing only 1 MW of power, making them less suitable for data centres located in high-density urban areas of Indonesia. Due to high land costs in these regions, solar PV is limited in its ability to fully support data centre operations and is more appropriate for powering non-critical equipment (Manullang et al., 2022). On-site natural gas generation, supported by Perusahaan Gas Negara (PGN), offers a cleaner alternative to coal-based electricity. By utilizing waste heat for trigeneration, data centres can boost energy efficiency up to 80%. However, hydrogen-based generation, despite its potential for zero emissions, faces challenges such as high costs, space requirements, and the reliance on fossil fuels for hydrogen production, making it unsuitable for large-scale use currently (Silalahi et al., 2021; Temiz et al., 2022).

Indonesia holds vast geothermal energy potential, with an estimated 27.79 GW capacity, but currently, only 5% of the country's total power is generated from geothermal sources, amounting to approximately 2.3 GW (Winters et al., 2015). The slow adoption is due to issues such as the location of potential geothermal sites in protected forests, environmental concerns, and inadequate government incentives. Another promising option is nuclear power, particularly small modular reactors (SMRs), which could provide a viable solution for distributed renewable energy ("Geothermal Energy As An Alternative Source For Indonesia's Energy Security: The Prospect And Challenges," 2020). However, the safety concerns related to nuclear power, especially in a country with frequent earthquakes, remain a significant hurdle. Despite these challenges, both geothermal and nuclear power offer substantial potential for supporting Indonesia's transition to clean energy. However the memory of the Fukushima nuclear disaster, which was triggered by an earthquake, raises concerns about the safety and feasibility of deploying nuclear power plants in a seismically active region like Indonesia (Smith, 2013).

The largest OPEX components are generator fuel and electricity. Since electricity is often purchased with Renewable Energy Certificates (RECs), the premium electricity tariffs further increase OPEX. Despite the high initial CAPEX and OPEX, it is crucial to consider the total cost of ownership over 10 to 20 years (Tripathi et al., 2017). This long-term perspective accounts for potential OPEX reductions from energy-efficient practices, underscoring the overall financial benefits of investing in green data centres (Ren et al., 2012).

Market Analysis of Green Data Centre in Indonesia Political

The political landscape for green data centres in Indonesia is shaped by both supportive and challenging factors. On the positive side, the Digital Indonesia Vision 2045, which aims to position Indonesia as a major digital power in Southeast Asia, and programs by the Ministry of Communications and Informatics to accelerate digital transformation create a favourable environment for the growth of data centres. Additionally, Indonesia's commitment to achieving net zero emissions by 2060 aligns with the global push towards sustainability, potentially encouraging the adoption of green practices in data centres (Handayani et al., 2021). However, the lack of specific regulations to support the implementation of these green practices remains a significant hurdle, hindering the full realization of environmentally sustainable data centre operations in the country (Qalbie et al., 2023). Cost of the data centre is presented in Figure 5.

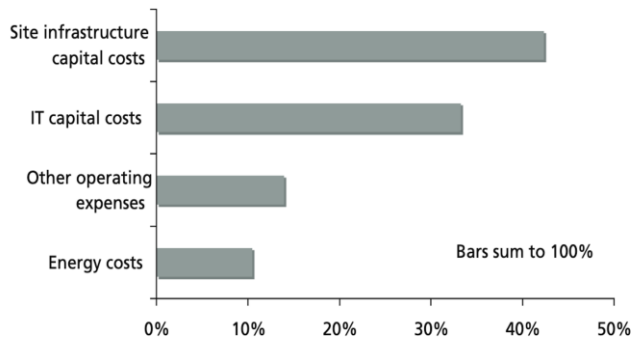

Figure 3. Costs of data center deployments in general

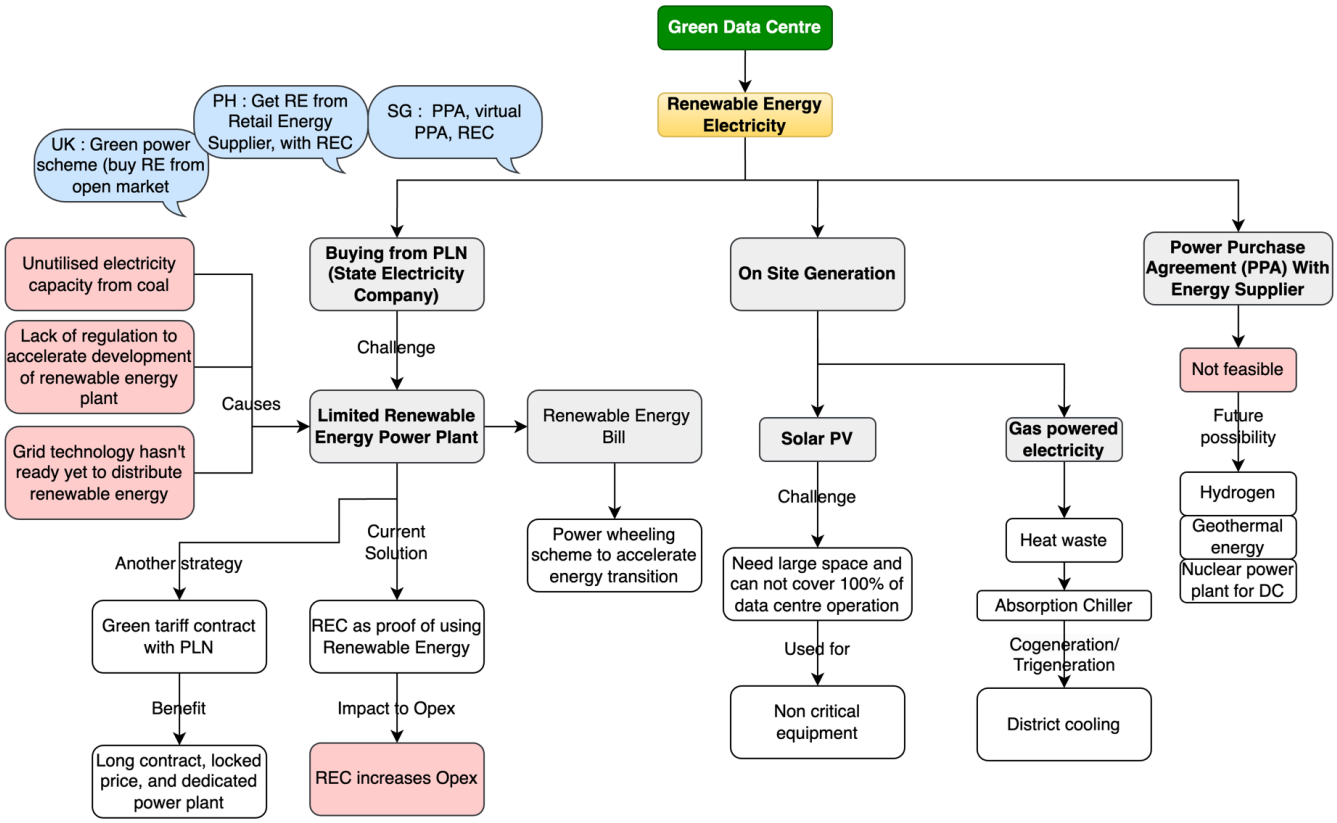

Figure 4. Renewable energy options

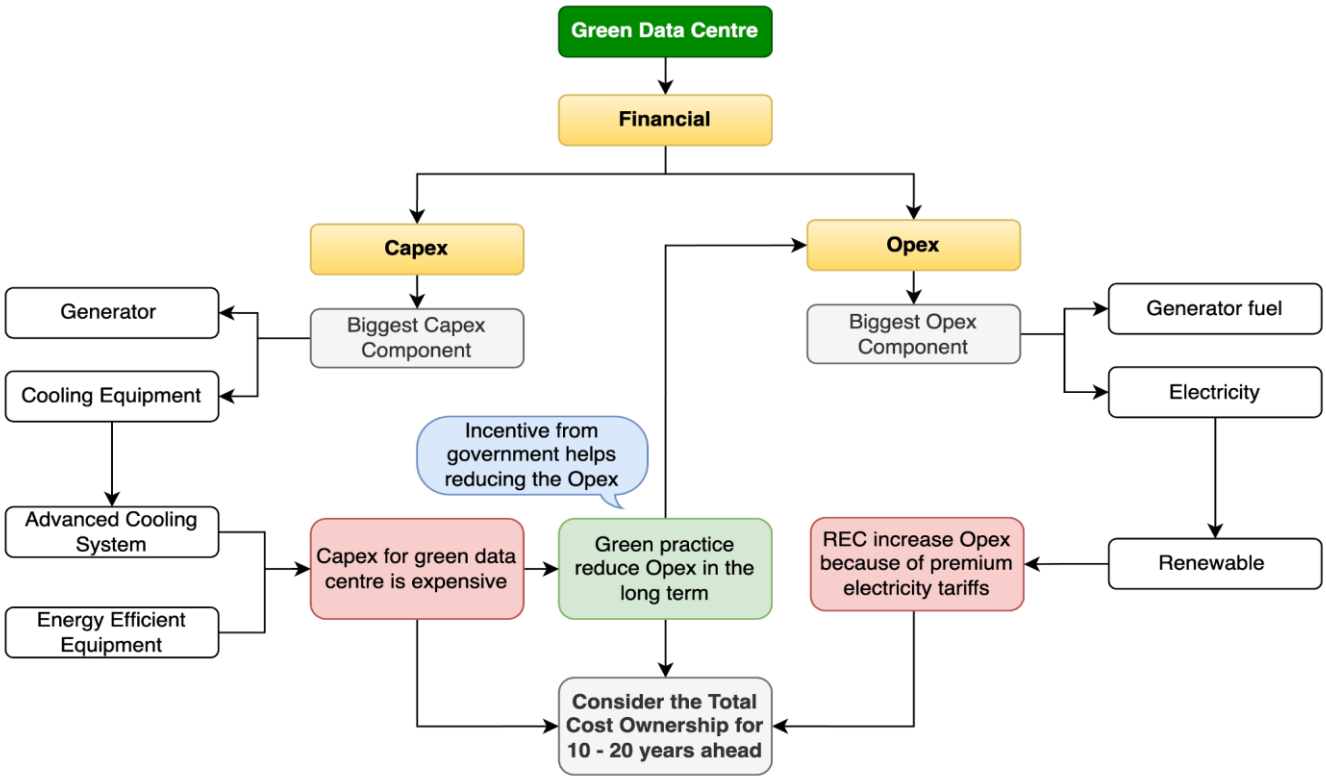

Figure 5. Financial impact

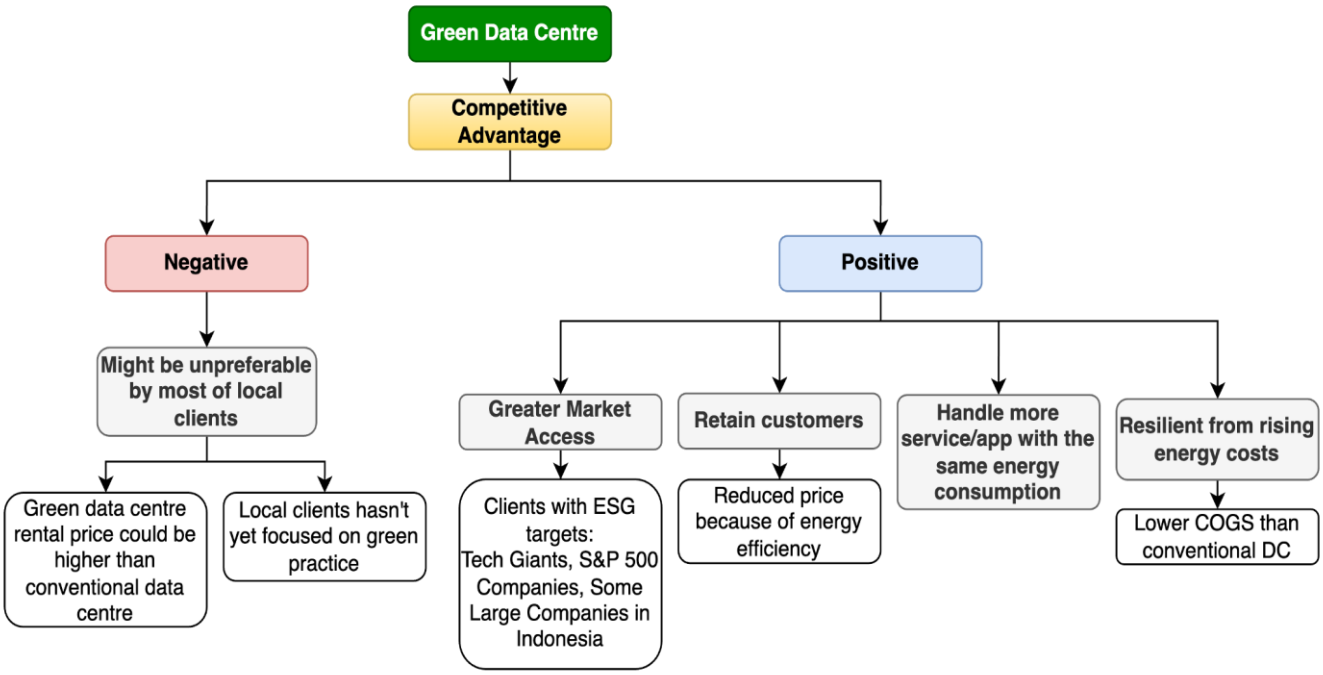

Figure 6. Competitive advantages of green data center

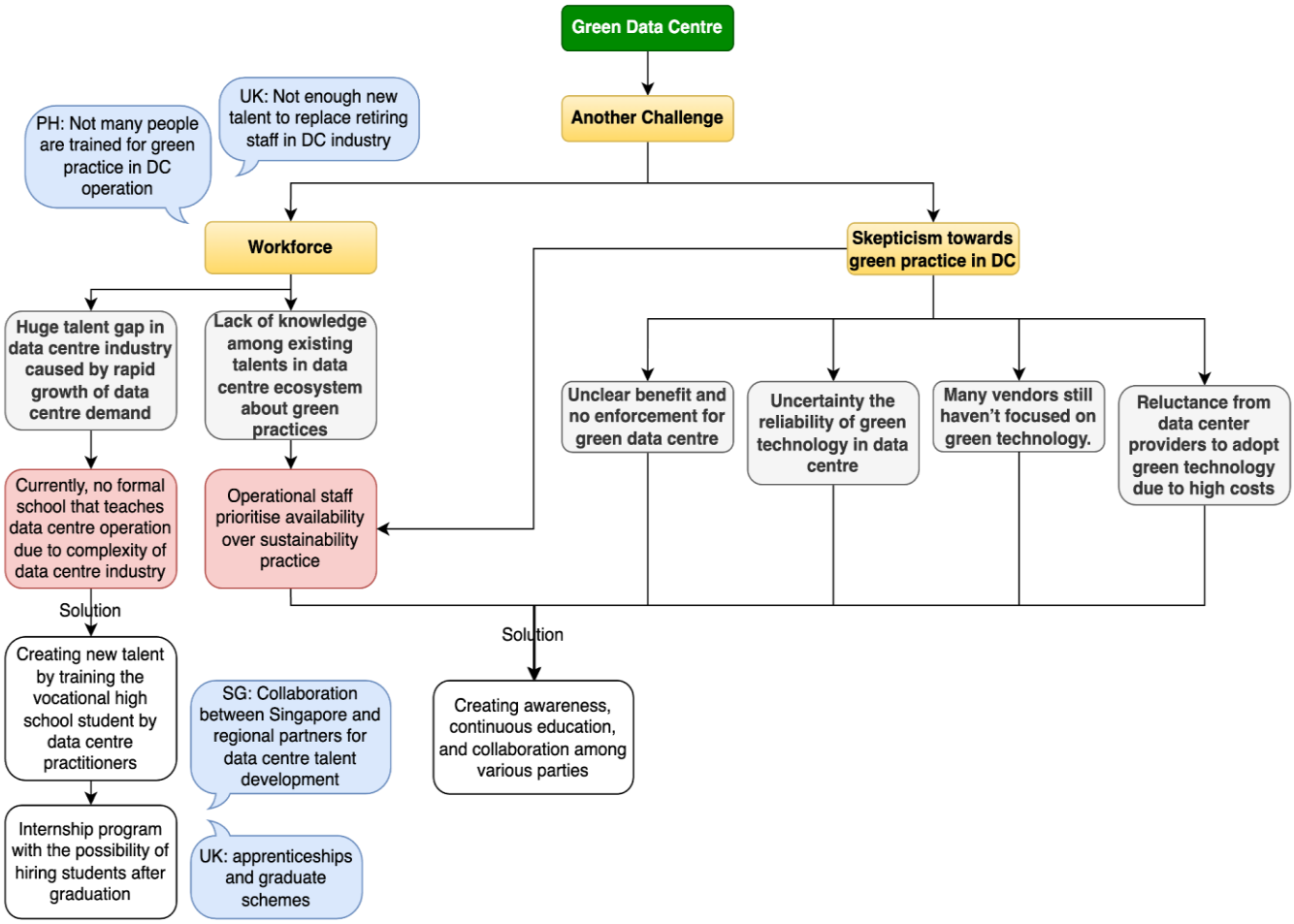

Figure 7. Other challenges in deployment of data center

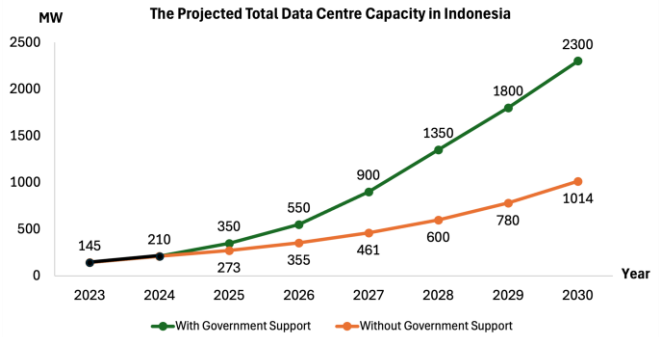

Figure 8. Projected total data center capacity in Indonesia

Economic

The economic outlook for green data centres in Indonesia is promising, supported by a strong forecast for GDP growth, which is expected to increase by 48.73% between 2024 and 2029 (Kurniawan et al., 2018). This robust economic expansion provides a favourable environment for investments in the data centre industry. Additionally, with the average annual inflation rate projected to remain stable at under 3% per year until 2029, economic stability is expected to continue, further encouraging investment and long-term planning. The decline in Indonesia's unemployment rate, from 5.45% in March 2023 to 4.82% in March 2024, also indicates a strengthening labour market, which could provide a skilled workforce for the expanding data centre sector (Anas et al., 2022). These economic factors collectively create a conducive environment for the growth and development of green data centres in Indonesia.

Social and Technical

Indonesia's social and technical landscape offers both opportunities and challenges for the growth of green data centres. By 2030, the country's population is projected to increase by 9% from 2020, creating a larger consumer base and driving demand for digital services (Lestari, 2020). With 68% of the population expected to be in the productive age group by the 2030s, Indonesia is entering a demographic dividend, fostering a skilled, tech-savvy workforce crucial for expanding digital infrastructure (Anas et al., 2022; Kurniawan et al., 2018). This, combined with the forecasted eightfold growth of Indonesia's digital economy by 2030, sets the stage for the adoption of green data centres to support the increasing need for sustainable digital solutions.

On the technical side, the rise of AI and the development of 5G networks are intensifying the demand for advanced, energy-efficient data centres. Indonesia's internet penetration is expected to reach 82.53% by 2026, further driving the need for robust digital infrastructure (Sambodo et al., 2022). However, the expansion of green data centres faces significant challenges, notably the limited availability of renewable energy power plants. As of now, around 61.5% of PLN's electricity is still derived from coal, posing a major obstacle to achieving sustainable operations in data centres (Berawi et al., 2016). While technological advancements are pushing the industry forward, this heavy reliance on non-renewable energy sources undermines efforts to make data centres truly green, highlighting the need for stronger investments in renewable energy infrastructure to support future growth.

SWOT Analysis

Green data centres in Indonesia offer significant strengths, including higher energy efficiency, which makes them more resilient to rising electricity prices, and the ability to align with customers' Environmental, Social, and Governance (ESG) targets, enhancing their appeal to environmentally conscious clients. However, they face challenges such as high capital expenditure (Capex) and increased electricity costs due to the purchase of Renewable Energy Credits (RECs), leading to higher leasing costs for customers without providing distinct service advantages compared to conventional data centres (Zahari et al., 2023). Despite these weaknesses, there is a substantial opportunity driven by growing demand for data centres and Indonesia's commitment to achieving net zero emissions. The increasing preference for green data centres among multinational companies with strict ESG goals positions Indonesia as a strategic location for sustainable digital infrastructure. The main threat to this growth is strong competition from conventional data centres, which offer lower prices and the same availability and reliability, appealing to local clients who do not prioritize ESG targets. Additionally, the underdeveloped sustainability climate, marked by a lack of supportive regulations and limited renewable energy resources, may deter multinational companies from investing in green data centres in Indonesia, further challenging their expansion.

In addition, green data centres have the potential to secure greater market access, particularly among multinational companies, such as those in the S&P 500, that prioritise ESG targets as presented in Figure 6. As ESG considerations gain traction, even some large companies in Indonesia are beginning to follow suit. This is supported by data from Schneider Electric, which shows that 83% of data centre operators use sustainability as a key factor in attracting new business (Qalbie et al., 2023). Green data centres can attract and retain customers by offering long-term cost reductions through enhanced energy efficiency. These facilities can manage more servicesor applications with the same level of energy consumption and are better positioned to withstand rising energy costs, thanks to their lower cost

of goods sold (COGS) compared to conventional data centres (Smith, 2013). However, the higher initial costs associated with green data centres may make them less appealing to local clients who are not focused on ESG goals.

Another challenge facing green data centres in Indonesia is the availability of a skilled workforce as clearly presented in Figure 7. The data centre industry currently faces a notable talent gap due to the absence of formal education programs focused on data centre operations, which are complex in nature. A potential solution is to collaborate with training institutions to bridge this gap (Silalahi et al., 2021). Data centre professionals can also play a key role by mentoring new talent and sharing their hands-on experience. Furthermore, providers can set up internship programs to help identify and recruit promising candidates. Indonesia is well-positioned to take advantage of the growing demand for data centres, given its status as the fourth-largest internet user globally, with 212.9 million users in 2023. The country's strong digital infrastructure, managed by Telkom Indonesia with 26 international undersea cables, including vital systems like SEA-ME-WE 5 and SEA-US, boosts its appeal as a global connectivity hub (Sommeng et al., 2018). Additionally, the surge in AI technologies is driving significant demand for data centres, further solidifying Indonesia as an attractive destination for industry growth.

Table 3. Comparison of Data Center Capacity with/without Government Support

Year	With Government Support		Without Government Support		Opportunity
	Data Centre Capacity (MW)	Investment (million USD)	Data Centre Capacity (MW	Investment (million USD)	(million USD)
2025	350	3675	273	2867	809
2026	550	5775	355	3726	2049
2027	900	9450	461	4844	4606
2028	1350	14175	600	6298	7877
2029	1800	18900	780	8187	10713
2030	2300	24150	1014	10643	13507

Indonesia's vast renewable energy potential, estimated at 590 GW, presents a significant opportunity for developing green data centres. With the spillover demand from Singapore, Indonesia can attract attention by offering sustainable solutions aligned with global ESG goals. The establishment of green data centres can drive Indonesia's economic growth by attracting foreign investment and creating numerous job opportunities in sectors such as engineering, IT, and project management. These facilities will require a skilled workforce, which will help reduce unemployment and build a highly capable workforce to support the country's growing digital economy.

The development of green data centres will also contribute to the digitalization of key sectors like manufacturing, finance, and tourism. Digital technologies can enhance production processes in manufacturing, foster innovation in financial services, and improve infrastructure in tourism, all of which will contribute to increased GDP growth. However, several challenges remain, including the limited availability of renewable energy power plants, which currently account for only 18.6% of total electricity generation. Other obstacles include a lack of incentives for green practices, a complicated permit process, and a shortage of skilled workers. To fully realize its potential in the green data centre industry, Indonesia needs to implement regulatory reforms to overcome these challenges and capitalize on its advantages, ensuring sustainable economic growth.

Figure 8 illustrates the projected total data centre capacity in Indonesia, both with and without government support. According to Colliers, AI advancements are expected to drive the country's data centre capacity to 2.3 GW by 2030. Achieving this target will require sufficient renewable energy electricity and strong government support for the construction of new data centre facilities. Even without government support, Indonesia's data centre capacity is still projected to grow at a robust rate of around 30% per year. Table 3 highlights the opportunity cost if the government does not take action to support the development of green data centres in Indonesia, based on the assumption that the investment required for data centre development is 10.5 million USD per MW.

To capitalise on the opportunity for green data centre development, the following strategies to the government are recommended: Implement Green Data Centre Standards: Establish green data centre standards for commercial data centres to ensure consistent technical specifications, prevent self-claims by providers, and maintain industry credibility, Enhance Ease of Doing Business: Simplify the permit process for data centers. Currently, data center providers must submit detailed engineering designs to obtain building permits, which adds extra cost and time to the build data centers from the green fiend Additionally, relaxing the

local content regulations for data center equipment is crucial, as the current rules require a certain percentage of equipment to be produced or assembled in Indonesia, Legislate the New and Renewable Energy Bill: One key clause in the bill is the power wheeling scheme, which will allow independent power producers to sell electricity directly to customers using the national grid. This will accelerate the development of renewable energy power plants. The bill also includes green initiative incentives for industries that implement sustainable practices.

Foster Collaboration between Industry and Educational Institutions: Promote partnerships between the data center industry and educational institutions. This collaboration should focus on research in green data center technologies and the development of a skilled workforce to support the industry's growth.

Conclusion

In response to the research question regarding technological solutions and supplier considerations crucial for enhancing energy efficiency and achieving net-zero goals in Indonesia's data centre industry, data centre providers can focus their improvement efforts by targeting the reduction of Scope 1, 2, or 3 emissions. To reduce Scope 1 emissions, providers can implement low-emission generators and UPS systems with lithium-ion batteries. For Scope 2 emissions, renewable energy can be utilized through the purchase of Renewable Energy Certificates (RECs), green tariffs, or on-site power generation. In addition, energy efficiency can be enhanced by adopting advanced cooling systems, server virtualization, energy-efficient equipment, and Data Centre Infrastructure Management (DCIM) tools. To tackle Scope 3 emissions, providers should select suppliers and vendors who meet green criteria, offer reliable technology and support, and practice improved waste management. For suppliers and vendors to support the development of green data centres in Indonesia, several key actions are recommended. First, they should focus on providing energy-efficient products and sustainable solutions. They must ensure compliance with green standards to help reduce Scope 3 emissions for data centres. Additionally, they should offer customization and scalability options to accommodate future data centre growth, as well as enhance technical support to ensure the optimal performance of green technologies. Building strong partnerships with data centre providers and other equipment vendors is also critical for fostering a collaborative approach to sustainability. In relation to the financial implications (Capex and Opex) of transitioning to green data centres for businesses in Indonesia, it is important to note that Capex is high due to the significant investment required for energy-efficient IT equipment and advanced cooling systems. Operating expenses (Opex) are also elevated, primarily because of the increased electricity costs associated with the purchase of Renewable Energy Certificates (RECs). However, the adoption of energy-efficient equipment can lead to substantial reductions in Opex over time. Therefore, it is essential to take into account the long-term Total Cost of Ownership (TCO) over a 10 to 20-year period to fully assess the financial benefits of transitioning to green data centres.

Acknowledgments
All authors express their sincere gratitude to the Business Administration Program, Faculty of Economics and Business, Telkom University, Indonesia, for providing the academic environment and resources that facilitated the completion of this research.

Author Contributions
Conceptualization, L.M.S.; methodology L.M.S; software, L.M.S; validation, W.P; formal analysis, L.M.S.; investigation, L.M.S; resources, L.M.S; data curation, L.M.S; writing—original draft preparation, L.M.S; writing—review and editing, W.P; visualization, W.P; supervision, W.P; project administration, W.P; funding acquisition, L.M.S and W.P. All authors have read and agreed to the published version of the manuscript.

Funding
This research received no external funding.

Conflicts of Interest
The authors declare no conflict of interest.

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