Artificial Intelligence in ASEAN's Energy Transition

Kanendra Naidu, Nur Ashida Salim, Hasmaini Mohamad

Faculty of Electrical Engineering, Universiti Teknologi MARA (UiTM) Shah Alam, Malaysia
Emails: kanendra@uitm.edu.my; nurashida606@uitm.edu.my; hasmaini@uitm.edu.my

ABSTRACT

Southeast Asia is currently experiencing a rapid increase in electricity demand, which is fueled by rapid urbanization, industrial growth, and the expansion of the digital economy. The surge in data centers and computational demand from AI processing has further exacerbated energy demand. At the same time, AI technologies are emerging as power enablers for cleaner, smarter, and more resilient energy systems. This poses an important challenge for ASEAN nations, which comprises of Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam, to balance rising energy demand with the advancement of decarbonization targets, while simultaneously prioritizing the development of smarter grids. Uneven infrastructure, fragmented policy frameworks, and investment gaps complicate this task. With greater cooperation and stronger investment, AI could be an important catalyst that drives ASEAN's secure, sustainable energy transition.

Introduction

ASEAN's energy landscape stands at a pivotal juncture, driven by rising energy demand and rapid digitalization across its economic sectors. Electricity consumption across ASEAN, as reported in *(IEA, Southeast Asia Energy Outlook, 2024),* is projected to rise by nearly 4% each year, fuelled by economic expansion, rapid urbanization, and surging cooling needs amid intensifying heatwaves. Simultaneously, the advent of digitalization from cloud services to generative AI is driving a sharp increase in energy demand from data centers. The International Energy Agency (IEA) forecast that electricity demand from data centers in Southeast Asia will almost double by 2030 compared to 2024, driven by its emergence as a regional hub, especially in Singapore and southern Malaysia. From 2024 to 2030, based on a report published by (IEA, Energy and AI, 2025) Energy and AI – Analysis - IEA electricity consumption for data centers is projected to grow at approximately 15% per year which is more than four times faster than the growth rate of total electricity consumption from all other sectors (IEA, Energy and AI, 2025). In order to meet this rising demand, renewable energy sources such as wind, solar, modern bioenergy, and geothermal are projected to contribute to more than one-third of the increase in energy demand across Southeast Asia by 2035 (IEA, Southeast Asia Energy Outlook, 2024). However, this is still insufficient to meet energy energy-related CO2 emission targets. Due to this, the energy-related CO_2 emissions are expected to climb by 35% between now and mid-century *(IEA, Southeast Asia Energy Outlook, 2024)*. Carrying forward COP28's commitments and strengthened by COP29's outcomes, Southeast Asia must significantly hasten the transition to clean energy to meet COP28 goals and support the net-zero pledges. AI-driven tools and smart-grid technologies can play a key role in boosting renewable energy uptake and improving energy efficiency while supporting the region's digital growth.

The surge in data center development across ASEAN is forecast to increase electricity demand up to 30% of national consumption in certain countries by 2030, requiring an estimated USD 45–75 billion in solar and wind investment to power facilities sustainably and minimize continued dependence in fossil fuels (Ember, From AI to Emissions: Aligning ASEAN's Digital Growth with Energy Transition Goals, 2025). Current renewable targets and grid decarbonization trajectories remain too slow to match energy demand growth. For example, Indonesia's JAMALI (Jawa-Madura-Bali) grid and Singapore's grid are expected to cut emission intensity by only 9.4% and 4.9% respectively by 2030. To align AI-driven digitalization with ASEAN's net-zero commitments, ASEAN must expedite its energy transition by scaling renewable capacity, enhancing grid flexibility, and adopting a stronger regulatory framework. ASEAN's electricity generation reached a record 1,263 TWh in 2022, with fossil fuels such as coal, oil, and gas still dominating. However, the fossil fuel share of ASEAN electricity generation declined from 85.8% in 2005 to 71.2% in 2022. During the same period, renewable energy expanded to 29.2% of the generation mix, led by hydro, solar PV, and bioenergy, reflecting a structural shift as RE progressively offsets coal and gas in ASEAN's power sector (Ember, From AI to Emissions: Aligning ASEAN's Digital Growth with Energy Transition Goals, 2025). This momentum must be further intensified, as the current share of renewables remains insufficient to drive a significant energy transition.

The 8th ASEAN Energy Outlook (AEO8) reported in (ASEAN Centre for Energy, 8th ASEAN Energy Outlook, 2024) outlines four distinct scenarios, which are Baseline (BAS), AMS Targets (ATS), Regional Aspiration (RAS), and Carbon Neutrality (CNS). This allows ASEAN to explore its energy prospects from

2023 to 2050 with each scenario reflecting different levels of policy ambition and technological adoption in shaping the region's energy transition. Bridging these scenarios with real-world action demands accelerated technology adoption and digital innovation to ensure ASEAN's transition keeps pace with rising energy demand. Accelerated deployment of RE sources, AI-enabled forecasting, smart grid initiatives, and smart demand response are critical enablers to balance rising digitalization-driven electricity demand with ASEAN's decarbonization goals.

Significance of AI in ASEAN energy systems

ASEAN's energy demand is intensifying with Total Final Energy Consumption (TFEC) projected to rise by nearly 73% by 2050, driven by rapid industrialization, urbanization, and expanding mobility needs. The industrial sector is set to dominate, increasing its share from 44% in 2023 to 52% by 2050. Transportation remains the second-largest sector, which is mainly contributed by electric vehicle penetration. The residential sector's share is projected to decline, while the commercial sector remains stable at 6–8% of TFEC, and the agriculture sector contributes a minor share of the TFEC (ASEAN Centre for Energy, ASEAN Energy Investment, 2024).

Currently, Southeast Asia is rapidly emerging as a global hub for data centers, with ASEAN's major economies leading the charge. Malaysia, Singapore, and Indonesia are experiencing some of the fastest growth in capacity, with Malaysia projected to be the region's fastest-expanding market. Its data center electricity demand is expected to surge from just 9 TWh in 2024 to 68 TWh by 2030 (Ember, From AI to Emissions: Aligning ASEAN's Digital Growth with Energy Transition Goals, 2025), which marks a dramatic leap in regional digital infrastructure needs.

Singapore, which is ASEAN's largest hub with 1 GW capacity, has tightened approvals to prioritize projects powered by green energy and advanced efficiency standards. Malaysia is supporting data center growth through solar mega-farms and cross-border clean energy initiatives. With Jakarta as its primary hub, Indonesia is seeking to reduce coal dependence through RE adoption, whereas Thailand is centred on co-location investment. The Philippines pursues sustainability in new hyperscale projects, and Vietnam is scaling up through its Digital Transformation Programme. The rapid expansion of data centers positions Southeast Asia as a leading digital hub, but without accelerated RE adoption and efficiency improvements, rising digital demand could increase reliance on fossil fuels and drive significant emissions growth (Ember, From AI to Emissions: Aligning ASEAN's Digital Growth with Energy Transition Goals, 2025).

The energy transition is accelerating as countries seek to decarbonize power systems, and AI is emerging as a key enabler by enhancing RE integration, improving forecasting accuracy, and optimizing grid operation. This is crucial for ASEAN, where renewable capacity is rising and grids must handle intermittent supply efficiently. AI leverages massive streams of sensor and weather data to enhance RE generation forecasts and optimize dispatch, which outperforms the accuracy of traditional models. Beyond operational optimization, AI is accelerating energy technology innovation by expediting the discovery of advanced battery chemistries, CO_2 capture materials, and catalysts for synthetic fuels. This is made possible by consolidating R&D cycles that would otherwise span decades into far more manageable timeframes. At the grid level, AI can support ASEAN's energy transition through predictive maintenance, congestion management, and dynamic line rating, further optimizing transmission and distribution network operation. The IEA notes that transmission lines can typically carry 20–30% additional capacity above their maximum rating for about 90% of the year and that DLR could unlock 115–175 GW of global capacity at far lower cost than new lines (IEA, Energy and AI, 2025). For Southeast Asia, these applications are important as rising digital demand and growing RE integration further stress the power grid. AI-enabled forecasting can optimize dispatch and reduce RE curtailment, while advanced fault detection and automation enhance system reliability, especially during power outages.

In summary, Southeast Asia is undergoing rapid digital and energy transformation, with rising electricity demand from both economic growth and expanding digital infrastructure. At the same time, countries are pushing to decarbonize their power systems through large-scale RE integration and smarter grid management. AI stands at the core of this transition, providing the innovation needed to balance reliability with sustainability while accelerating the shift towards a low-carbon future.

ASEAN case studies on AI integration in power grid

To further analyze the integration of AI in ASEAN power grid, six national case studies are considered. Although each country faces distinct challenges, ranging from Malaysia's rapid data center expansion to Vietnam's smart grid initiatives, a common theme can be observed in the growing reliance on AI as a catalyst in supporting the region's energy transition. These case studies highlight AI integration in renewable infrastructure, advanced grid management, and regional interconnection.

Malaysia

Malaysia is positioning itself as a leader in ASEAN's AI and clean energy transition by coupling its fast-growing data center sector with renewable investments. The AI infrastructure will be located at the YTL Green Data Center Park in Kulai, Johor. The 500 MW facility will be developed by YTL and fully powered by an equivalent capacity of on-site solar energy. The project positions Malaysia as a regional hub for green AI, which enables energy-intensive AI workloads to be powered by RE (YTL Power International, 2023). Malaysia's utility company Tenaga Nasional Berhad (TNB) has committed RM43 billion ($10.1 billion) to modernize the national grid, enabling higher AI computing loads and large-scale battery energy storage integration (Reuters, 16 June 2025). At the same time, Petronas is developing three offshore carbon-capture and storage facilities with over 10 international partners to position CCS as both a decarbonization mechanism and a regional revenue stream. Furthering

its energy transition initiatives, in 2024, Malaysia introduced the Energy Exchange Malaysia (ENEGEM) to drive structured cross-border green electricity trading. The platform's inaugural deal enables Sembcorp Power Pte Ltd to purchase 50 MW of renewable power from TNB for delivery into Singapore over a two-year period starting December 2024 (Regional Power Grids, EMA).

Singapore

Singapore, constrained by limited land for large-scale renewables, is leveraging AI-driven grid management and regional power trading to decarbonize its power grid. AI is being deployed to strengthen grid stability, forecast electricity demand, and optimize solar generation, enabling more efficient energy distribution and reducing reliance on domestic sources. Since 2022, Singapore has been importing renewable hydropower under the Lao–Thailand–Malaysia–Singapore Power Integration Project (LTMS-PIP). This represents ASEAN's first multilateral electricity trade, starting with 100 MW of Lao hydropower delivered to Singapore and expanding to 200 MW through multidirectional flows that include RE supply from Malaysia (Regional Power Grids, EMA). Singapore has progressively expanded its electricity import programme, with the Energy Market Authority (EMA) raising its target from 4 GW to 6 GW of low-carbon imports by 2035. Recent conditional licenses include the 1 GW project by Singa Renewables with RGE and TotalEnergies, focusing on regional power integration to secure cleaner and more diversified supply sources. By harnessing AI for smart meters, predictive analytics, and real-time optimization across facilities like shipyards, airports, and campuses, Singapore is proving how AI-based energy management can cut grid reliance and make regional power imports more efficient (How Singapore Uses AI to Cut Electricity Use, 2020).

Indonesia

Indonesia is advancing its Nusantara Super Grid, an inter-island electricity transmission network using High Voltage Direct Current (HVDC) technology. This initiative aims to transport vast renewable potential, such as the 13 GW of hydropower in Kalimantan, toward major load demand centers in Java and Sulawesi. The Super Grid is positioned as a backbone of Indonesia's energy transition, enabling large-scale integration of solar, wind, and hydropower into the national mix while supporting the country's net-zero emissions target for 2060 (Chandak, 2023). To enhance its energy transition, Indonesia is applying AI for predictive maintenance, demand forecasting, and real-time grid optimization, enabling more reliable integration of solar, wind, and hydropower into the power grid. On islands like Sumba, AI-managed microgrids have already achieved up to 95% renewable penetration by adapting to monsoon patterns, while predictive algorithms deliver 97% demand forecast accuracy and extend battery lifespans by 40% (Challenge, 2025). Beyond transmission and microgrids, Indonesia's geothermal sector is integrating generative AI through platforms like Kyndryl Bridge (Cariaga et al., 2024), which provide real-time insights on system performance and proactive solutions to increase reliability by predicting failures before they occur.

Thailand

Thailand's Power Development Plan (PDP2015) emphasized smart grid development to strengthen reliability and enable large-scale renewable integration, laying the groundwork for future adoption of AI-driven solutions in energy management and grid operations. Among the main initiatives are large-scale transmission upgrades, energy efficiency measures targeting 89,672 GWh of savings by 2036, and the Alternative Energy Development Plan (AEDP) that sets a 19,634 MW RE capacity target (Lauradmin, 2025). Thailand has since launched a $1.8 billion smart grid and AI-powered energy transformation programme, which focuses on modernizing power distribution, enhancing grid security, and optimizing energy efficiency nationwide. The initiative integrates AI-driven grid management, predictive analytics, and real-time cybersecurity, creating a smarter and more resilient energy ecosystem. Continuing this initiative. the Thai government is advancing its National AI Action Plan by incorporating smart grid upgrades and AI deployment across utility networks, as part of a broader strategy to become a regional AI hub by 2027 (Sayson, 2025).

Viet Nam

Vietnam is relatively new to the AI landscape, introducing its first national strategy in 2021 that identifies artificial intelligence as a core pillar of the Fourth Industrial Revolution. The strategy sets targets through 2030, including the establishment of national AI innovation centers, supercomputing facilities, and applications extending into key sectors such as RE and power systems (Pham et al., 2024). At Son La Hydropower Plant, AI-integrated robotic systems equipped with environmental sensors and image-processing algorithms are applied to monitor electrical cabinets and provide accurate information to power system operators. Vietnam Electricity (EVN) is applying AI across its operations, which includes an AI-based power transmission line management system with automated UAV inspections to optimize grid monitoring and fault detection. In customer services, EVN also deploys AI chatbots and virtual assistants to handle requests and provide information, improving efficiency and service quality (Artificial Intelligence Application Become Driving Force for Comprehensive Innovation in EVN's Operations).

The Philippines

The Philippines is advancing AI in its power sector through Meralco's 4-I strategy, which integrates artificial intelligence to grid operations for real-time monitoring, forecasting, and improved reliability. With distributed energy resources expanding across the Philippines, Meralco is harnessing AI, battery storage, and interoperability tools for a decentralized and clean energy future (Meralco Prepares for Decentralized Grid With AI, BESS and Interoperability Tools). Similarly, Aboitiz Power Corporation is implementing "Project Arkanghel," a digital twin initiative that creates real-time replicas of its coal-fired plants to strengthen predictive maintenance and operational decision-making. At the distribution level, the Institute for Climate and Sustainable Cities has developed the SPECTRUM platform, which applies machine learning and satellite imagery to map rooftop solar systems nationwide and forecast their generation potential (Albay, 2025). As industrial demand grows, artificial

intelligence platforms like SPECTRUM are set to drive the Philippines' energy transition by applying machine learning to expand rooftop solar coverage, improve forecasting accuracy, and track solar deployment over time.

AI tools in energy systems

The modern power grid is continuously adopting AI technologies to strengthen reliability and efficiency. Machine learning models are applied to vast historical and real-time datasets to predict equipment failures and potential outages. At the same time, IoT-enabled smart meters and sensors provide detailed information on load consumption patterns and grid performance to detect system anomalies. AI-based self-healing grids are also deployed to autonomously detect and repair faults while rerouting electricity to prevent outages.

Emerging AI technologies are expected to significantly advance grid planning and power system operations. Ongoing research focuses on the application of generative AI and large-scale foundation models specifically designed for power systems. ASEAN power systems are increasingly adopting AI, particularly in predictive analytics to strengthen grid resilience and mitigate potential failures (How AI-driven Cable Management Can Boost Southeast Asian Power Networks). Current AI applications in power systems focus on predictive analytics for demand forecasting, fault detection and maintenance, while future advancements are expected to utilize generative AI and integrated digital platforms to enable autonomous, resilient and decentralized grid operations across ASEAN.

To fully realize AI integration in the power grid, ASEAN must adopt a harmonized AI governance framework that ensures interoperability, transparency, and accountability. This will ensure that member nations are able to coordinate effectively and accelerate the integration of region-wide AI-enabled infrastructure. Investment in interoperable digital infrastructure and robust data platforms is essential to unlock additional grid capacity without reliance on new transmission expansion. ASEAN countries can

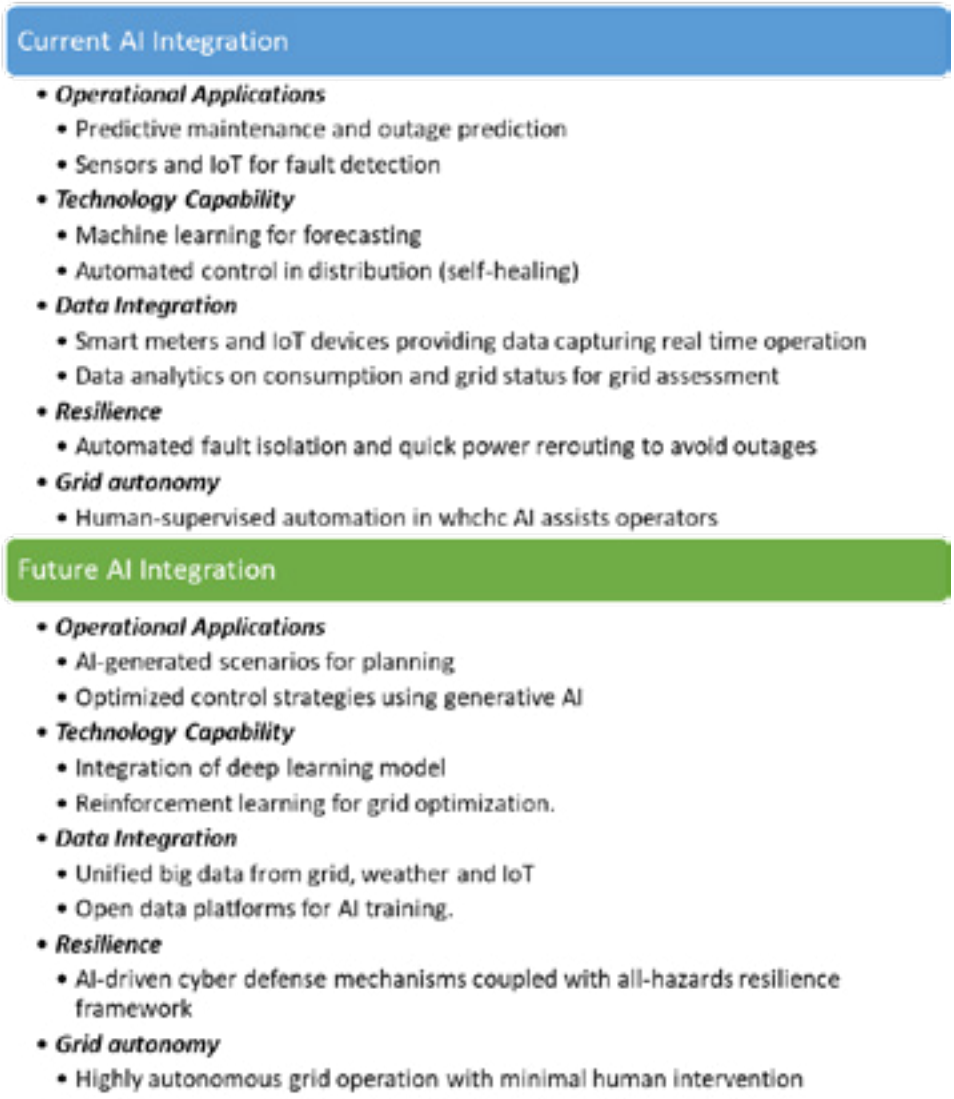

Figure 1: Current and future AI integration in power grid

further advance AI adoption through coordinated pilot programs and regulatory sandboxes that test applications under real-world grid conditions for regional deployment.

Presently, ASEAN's AI adoption in its energy transition is gradual. It mostly emerges through localized initiatives such as predictive analysis for demand forecasting and smart grid projects. Looking ahead, ASEAN's long-term vision is to embed AI comprehensively, enabling decentralized, real-time grid management, predictive maintenance, renewable energy integration, and cross-border power trading through a unified ASEAN Power Grid.

AI integration in power grid can be classified into categories such as operational applications, grid autonomy, predictive maintenance, renewable integration, and cross-border trading. Figure 1 shows how current AI influences these areas at a localized level, while future AI is expected to advance them towards a comprehensive, autonomous, and region-wide deployment.

Challenges and enablers in ASEAN

Integrating an AI solution across ASEAN's energy sectors faces significant challenges. This stems from the region's diversity, which contributes to uneven progress in infrastructure maturity, governance, human capital, and investment capacity. These challenges present an opportunity for ASEAN countries to address to develop a smarter power grid and accelerate the region's energy transition.

Infrastructure and technical capacity gaps

With modernized power grids, high connectivity, and strong human capital, Singapore and Malaysia are better positioned than most ASEAN peers to adopt AI in their energy sectors. Digitalizing the power grid required high investment costs, interoperability issues, data privacy and security, and the necessity for a competent workforce. A key technical gap remains in achieving seamless interoperability across various electrical equipment and vendor software. The integration of diverse devices and platforms poses a significant challenge for achieving real-time synchronization (Fernandez et al., 2024). Closing these gaps will require equipment upgrades such as advanced metering infrastructure (AMI), sensors, and reliable high-speed communication networks to improve data quality and system visibility. ASEAN is actively pursuing this through the integration of smart grid technologies, including phasor measurement units (PMUs), virtual power plants (VPPs), and emerging digital twin systems across the region. The United Nations Office for Project Services (UNOPS) supports ASEAN's grid modernization through the Southeast Asia Energy Transition Partnership (ETP), a multi-donor initiative that provides technical expertise and resources to countries such as Indonesia, the Philippines, and Vietnam to facilitate a just energy *transition* ('Smart Grid' Helps Accelerate Energy Transition in Indonesia).

Policy fragmentation and investment gaps

A major challenge lies in ASEAN's fragmented policy landscape, where difference in national energy regulations, data standards, and AI guidelines hinders region-wide coordination and implementation. ASEAN practices voluntary AI guidelines, unlike the EU's binding risk-based AI Act, due to its members' diverse national policies and varying levels of socioeconomic development (Labrecque, 2024). In early 2024, at the 4th ASEAN Digital Ministers' Meeting, the 10 ASEAN members released the ASEAN Guide to AI Governance and Ethics. This is a non-binding governance model highlighting seven core principles comprising of transparency, fairness, security, reliability, human-centricity, privacy, and accountability. This initiative marks ASEAN's effort to align governance and paves the way for greater regional coordination on AI regulation. The modernization of ASEAN's grids is constrained by investment disparity between the member nations, with Singapore attracting USD 141 billion in FDI and Indonesia receiving USD 22 billion. Malaysia has committed USD 10.1 billion specifically for upgrading its national grid infrastructure (ASEAN Centre for Energy, ASEAN Energy Investment, 2024). Despite these national efforts, regional financing remains insufficient, as green investment rose to only USD 6.3 billion in 2023, which is well below the USD 1.5 trillion required to support Southeast Asia's transition by 2030 (Kear Tian Seng, Southeast Asia's Green Economy 2024 Report: Moving the Needle). Closing this financial gap is critical for ASEAN as it requires blended-finance solutions that combine grants, concessional loans, and private capital to modernize grids, expand storage, and enable AI-driven efficiency in the power grids.

Public acceptance and workforce readiness

Public perception of AI remains a major challenge. Conservative industries such as electricity supply may resist adoption, as grid operators remain cautious about trusting AI decisions over human judgment due to risks associated with cybersecurity, privacy, autonomy, and unequal access to technological resources. Data privacy risks increase as AI-driven smart grids may expose sensitive household behaviours, creating opportunities for misuse or surveillance. Building public acceptance of AI-driven smart grids requires transparent data policies, strong privacy protections, and clear accountability to foster trust between the service providers, vendors, operators, and customers. Digital competency gaps in the ASEAN region results in many graduates lacking the skills required for AI-related roles in the power sector. Critical lack of qualified technical personnel in the energy sector, compounded by an aging workforce and insufficient training systems, poses a challenge to the implementation of grid modernization. Strengthening and modernizing Technical and Vocational Education and Training (TVET) with regional mobility mechanisms and industry-led apprenticeships is important to upskill/reskill an AI-ready workforce for power grid modernization.

Conclusion

AI is an important catalyst in enabling ASEAN's energy transition with applications ranging from RE forecasting to decentralized grid management and

cross-border power trading. Despite this immense potential, there are some challenges that the member nations face, such as uneven infrastructure, fragmented policy frameworks, an AI-ready workforce shortage, and investment gaps for large-scale adoption. Addressing these challenges is crucial for a successful energy transition process. This requires harmonized governance frameworks, significant digital infrastructure investment, and human capital building to ensure equitable deployment across the region. With the right approach, AI integration can advance ASEAN's power system into a resilient and efficient low-carbon network to ensure regional energy security and sustainability goals.

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