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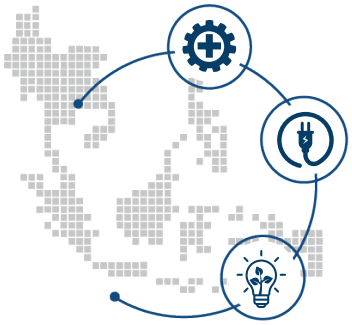
One Community for Sustainable Energy

Securing ASEAN's Renewable Energy Future: Addressing Gaps in Electrical Safety Management System



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Highlights

- Integrating complex systems of variable renewable energy (RE) sources can introduce new electrical accidents, especially in the ambition of RE shares in ASEAN countries. These include risks of fires and system failures due to improper installations, overloading, and climate impacts.
- Electrical accidents are still prevalent in many ASEAN countries, both in general, like in commercial and residential, and specifically related to RE systems.
- Safety agencies in ASEAN countries lack independent agencies focused solely on electrical safety, which limits the effectiveness of enforcement and oversight. Most ASEAN countries still operate within ministerial agency structures, with complex safety and non-safety roles and responsibilities that dilute focus.
- Restructuring agencies into independent agencies in ASEAN could follow models from developed countries like Australia, New Zealand, and the Republic of Korea (ROK) through the Korea Electrical Safety Corporation (KESCO). These models create truly independent agencies that are separate from political and non-safety roles, thus strengthening safety implementation through better regulatory intensity and technological advancements.

1. Introduction

Under the APAEC Phase II: 2021-2025, ASEAN countries aim to increase their renewable energy (RE) capacity to achieve the regional target of 23% share in Total Primary Energy Supply (TPES) and 35% of installed capacity by 2025 [1]. As of 2022, fossil fuels still dominate the energy mix, contributing 81.9% to the TPES, while RE accounts for only 15.6%. Despite this reliance on fossil fuels, ASEAN's commitment to cleaner energy sources is projected to shift the energy landscape to its RE potential significantly. According to the International Renewable Energy Agency (IRENA), the total RE potential across ASEAN countries reaches 17,221.6 GW, with solar PV leading at 15,602.7 GW and offshore wind at 1,152.2 GW, showcasing significant opportunities for solar and wind technologies, while hydropower, biomass, and geothermal also provide notable contributions. This diverse mix positions ASEAN as a key region for RE development [2].

ASEAN's ambition to expand RE integration, particularly variable sources like wind and solar, presents new challenges for grid stability and reliability.

Traditional grids, designed for steady fossil fuel power, must evolve to accommodate intermittent RE by adopting advanced solutions such as Energy Storage Systems (ESS), which store surplus energy during peak production for later use. Smart grids will be essential, enabling real-time monitoring, forecasting, and control to manage RE's variability. Expanded transmission infrastructure is also crucial to connect remote RE sources with demand centres, while distributed generation, such as rooftop solar, requires more adaptable grid operations, demand-side management, load balancing, and enhanced forecasting to ensure resilient, efficient power systems [3].

To integrate RE into their power systems, the increased complexity can also lead to potential electrical hazards. The rise of variable renewable energy (vRE) sources and new technologies makes electrical safety more critical than ever. Improper installations, overloading, and system malfunctions of vRE can significantly raise the risk of electrical fires and accidents [3].

Countries in the region have already experienced numerous incidents linked to electrical faults, including overloaded circuits, faulty wiring, and short circuits, which have caused significant damage and loss of life. As RE systems expand, prioritising electrical safety through an electrical agency that oversees strict standards, proper installations, regular inspection, public awareness, and other safety activities will prevent these hazards in the future [4].

This policy brief explores electrical safety management across ASEAN for RE expansion, addressing the urgency of strong regulatory frameworks and examining their impact on reducing electrical accidents. With the region's growing RE capacity, ensuring robust safety protocols is crucial to mitigating risks tied to grid integration and increased energy output. The brief analyses accident trends and compares ASEAN's practices with best-in-class examples from nations like the Republic of Korea, highlighting the role of comprehensive safety frameworks. By identifying regulatory gaps and lessons from strong enforcement practices, such as those by the Korea Electrical Safety Corporation (KESCO), this brief provides insights and recommendations for bolstering electrical safety—a key element for safe and sustainable RE growth in ASEAN.

2. The Importance and Urgency of Electrical Safety for RE Expansion in ASEAN Countries

2.1. Status of RE Share and Future Development Plan in ASEAN

In 2022, the TPES in ASEAN was approximately 698.1 Mtoe, with the overall share of renewables at 15.6%. Under the APAEC Phase II: 2021-2025, ASEAN aims to achieve renewable energy for a 23% share of RE by 2025.

The 8th edition of the ASEAN Energy Outlook (AEO8) outlines energy prospects from 2023 to 2050 through four scenarios: Baseline (BAS), ASEAN Member States Target (ATS), Regional Aspiration (RAS), and Carbon Neutrality (CNS). By mid-century, the CNS and RAS are projected to reverse the trend of fossil fuel dominance, with the RE share achieving 70.2% and 50.4%, respectively. Total power generation for the year 2050 across three regions—ATS, RAS, and CNS—demonstrates a predominant reliance on renewables, with RAS and CNS achieving over 84% and 90% renewable energy shares, respectively, while ATS stands at 71.9%. Fossil fuel usage is notably lower in the CNS region, at only 8.5% [5]. Figure 1 shows summary data about renewable energy share in TPSE under the scenarios until 2050.

The RE landscape in ASEAN countries presents a diverse mix of technologies at varying stages of development. Based on the data from the Global Energy Monitor, Hydropower currently leads, with 44.57 GW of operational capacity, followed by solar (20.18 GW) and wind (9.39 GW). Bioenergy and geothermal contribute smaller capacities, at 5.27 GW and 4.05 GW, respectively.

Future trends, shown in Figure 2, reveal substantial growth potential for wind and solar. Wind energy leads with 111.64 GW in pre-construction, far exceeding other technologies, while solar follows with 35.55 GW. Hydropower also continues to grow, with 38.35 GW planned.

In projects under construction, hydropower dominates with 11.87 GW, followed by solar at 4.33 GW. Smaller contributions come from geothermal and bioenergy, with 654 MW and 244 MW, respectively.

Overall, while hydropower remains dominant, data suggests a significant future expansion for wind and solar, particularly in the pre-construction phase, positioning them as key players in ASEAN's renewable energy transition [6].

Figure 1 Renewable Energy Share in Total Primary Supply Energy Scenarios 2005-2050

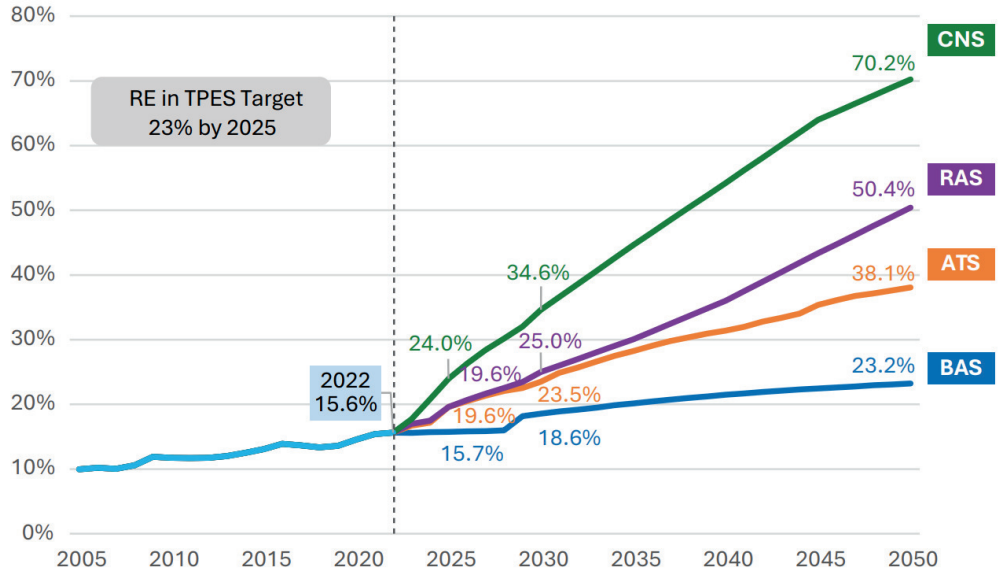
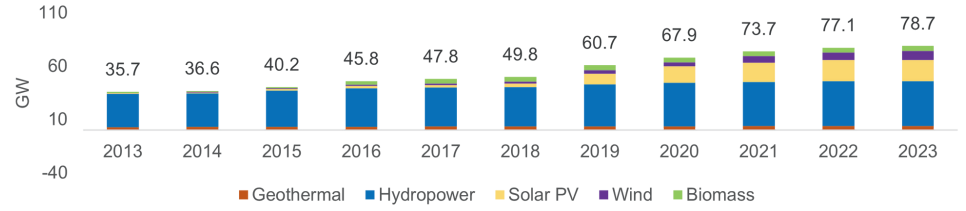
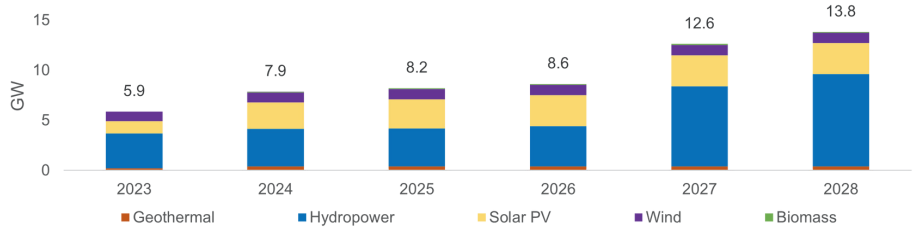


Figure 2 Current and Future Trends of RE Sources in ASEAN



(a)



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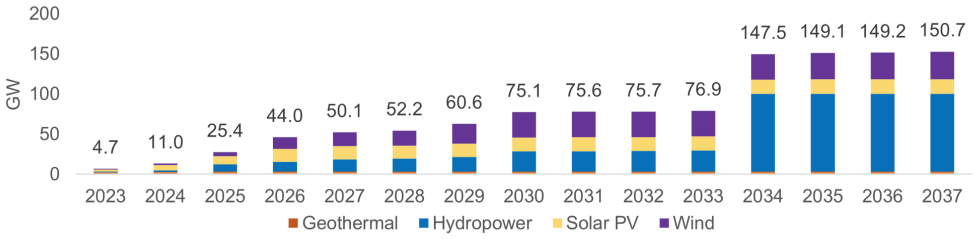


(c)

(a) Operation; (b) Construction; (c) Pre-construction

2.2. Potential Electrical Safety Accidents due to RE Integration in ASEAN Countries

Despite ASEAN's ambitious transition to RE, critical safety challenges remain. Wind and solar energy record some of the highest accident rates in the energy industry [7], [8]. Wind energy is categorised as having a "high" risk of accident, with fire being most common and damaging incident types, closely followed by blade failure [9]. About 40% of fires at wind energy are caused by electrical hazards, while mechanical failures and lightning strikes each account for an additional 20% [10]. Other operational hazards include critical shock from accidental cable contact, posing serious risks to both workers and other people in public areas [11].

In large-scale PV systems, electrical issues count 43% of failures, significantly surpassing other issues, such as mechanical and thermal failures [12]. Common causes of electrical fires in PV installations are due to the installation errors and inverter defects, with most issues arising from poor connections along with the main current path, also known as "serial defects" [13].

ASEAN's climate—marked by high humidity, heavy monsoon rains, and high temperatures—exacerbates these risks. Moisture build-up in PV systems can lead to short circuits, while coastal wind turbines face corrosion and electrical faults due to prolonged saltwater exposure.

Hydropower facilities encounter added risks during heavy rain, which can trigger electrical malfunctions and transformer explosions. Persistently high temperatures in the region also increase overheating risks, particularly for outdoor installations, underscoring the need for robust safety protocols to mitigate these climate-specific challenges [14].

2.3. Occurrence and Severity of Electrical Accidents in ASEAN Countries

To underscore the importance of electrical safety management amidst growing RE generation and facilities, we compiled data on electrical accidents across ASEAN countries by aggregating news reports and data sources from the past decade, as shown in Table 1.

Accidents in residential, industrial, and commercial sectors frequently stem from faulty wiring, overloaded systems, and equipment malfunctions. Incidents like the fire at Vietnam's DK Electric Vehicle factory and market fires in Phnom Penh underscore the serious safety risks and property damage involved.

The financial and human toll is alarming: Brunei recorded USD 68,700 in damages from 31 electrical fires within three months in 2022; Myanmar reported USD 16.6 million in damages, 77 fatalities, and 193 injuries in 2023; and the Philippines saw a 40.4% increase in fire incidents by mid-2024, largely due to electrical malfunctions.

These events demonstrate the pressing need for improved electrical safety to protect lives, reduce economic losses, and ease the burden on public safety resources.

Table 1 Data on Electrical Accidents Across ASEAN Countries

Country	Massive Electrical Accidents in General
Brunei Darussalam	31 electrical fires were reported from Jan to March 2022, causing USD 68,700 in damages. Cases linked to overloaded electrical systems
Cambodia	761 incidents in 2023, leading to 54 deaths and 97 injuries, many due to electrical faults. Electrical faults caused extensive damage to homes and markets.
Indonesia	2,286 fire incidents in 2023, 53.19% due to electrical short circuits. Electrical shorts caused many fires, especially in Jakarta
Lao PDR	23 fire incidents in 2024 across Vientiane, $4 million in damages. Improper electrical installations frequently cause short circuits
Malaysia	Electrical sources like short circuits caused 60% of 7,447 fires in 2022
Myanmar	1,362 fires in 2023, with faulty electrical wiring a major cause, USD 16.6 million in damages. Faulty wiring and electrical shorts, especially in urban regions
Philippines	40.4% increase in fire incidents by May 2024, with 9,568 fires, many electrical. Overheated electric fans, short circuits, and faulty wiring are common factors
Singapore	276 electrical fires in 2023, a 21.1% rise from the previous year. 52 electrical accidents annually, often linked to uncertified equipment
Thailand	737 fire incidents in 2022, many due to electrical faults. Overloaded circuits and short circuits are frequent issues
Viet Nam	Massive fire at DK Vietnam-Japan Electric Vehicle factory in 2024. Fire at electric vehicle factory highlights infrastructure failures

We also compiled several recent incidents in ASEAN countries that are linked to RE systems, as shown in Figure 3, which highlighted critical safety concerns in the integration of vRE. Overheating panels in Cambodia and Indonesia have led to residential fires, while Malaysia and Myanmar reported incidents involving rooftop PV systems.

In the Philippines, an overheated solar battery caused severe damage in a residential fire, and a rooftop PV accident in Singapore resulted in fatalities due to electrocution. Thailand and Vietnam have faced multiple incidents related to improper installations, electrical overloads, and, in some cases, unauthorized modifications. A recent tragic incident in Vietnam involved a malfunctioning solar system that resulted in fatalities.

Figure 3 Recent Renewable Energy Systems Incidents in ASEAN Countries

The primary causes of these incidents—overloaded systems, faulty wiring, and insufficient protective measures—are consistent across the region. As renewable systems proliferate, technical risks are increasing, especially as solar, wind, and battery storage systems are integrated into grids that were not originally designed to accommodate variable energy sources. Issues like short circuits, transformer failures, and inverter malfunctions are common, while battery storage systems introduce risks of thermal runaway and overcharging, which can lead to fires or explosions if not properly managed.

These incidents showcase that to ensure a safe and reliable renewable energy system across ASEAN, coordinated efforts are essential to upgrade infrastructure, enforce rigorous safety standards, and maintain effective oversight. Addressing these areas will mitigate the risks associated with rapid RE integration, protecting both public safety and the resilience of the region's energy systems.

3. Assessment of the Existing Stakeholders and Regulatory Structure for Electrical Safety in ASEAN Countries

To evaluate the regulatory and stakeholder structures overseeing electrical safety in ASEAN countries, an assessment is conducted by drawing on the research and methodology outlined by Malcome Abbott and Bruce Cohen [4]. Their framework guided the analysis, particularly in breaking down regulatory structures.

Meanwhile, we break down the safety responsibilities using how the KESCO defines the electrical safety components. We also noted the additional regulatory roles beyond safety oversight that each agency may have, as summarised in Table 2.

Three types of electrical safety regulatory agencies exist: commercial, ministerial, and independent agencies. Commercial agencies (together with their government owners) are responsible for administrating safety standards and licensing electrical contractors and electricians, along with a range of other regulatory, planning, and policy functions within the electricity market. Ministerial agencies, on the other hand, are embedded within government ministries rather than operating as autonomous entities. In the case of electrical safety, departments within ministries were established to focus solely on electrical safety, maintaining independence from commercial operations and political influence while still being part of the government's ministerial structure. Independent agencies, as defined globally, operate as autonomous public entities with regulatory authority over specific industry aspects. They are protected from short-term political and commercial interference and may have quasi-judicial powers, such as imposing fines or resolving disputes.

Table 2 Compilation of Agency Responsible for Electrical Safety Management for RE Facilities in ASEAN Countries

Source: Author's compilation

Countries	Main agency responsible for electrical safety	Structure	Responsible on Electrical Safety			Others
			Certification & Inspection	Disaster Management	Research & Development	
Brunei Darussalam	Autoriti Elektrik Negara Brunei Darussalam (AENBD)	Ministerial agency	✓	✓	✗	Administrative, operational, and financial aspects.
Cambodia	Electricity Authority of Cambodia (EAC)	Non-ministerial agency	✓	✗	✗	Economic and operational regulations
Indonesia	Directorate General of Electricity and EBTKE	Ministerial agency	✓	✓	✗	Regulate the business framework, including licensing, pricing, and land use
Lao PDR	Department of Ministry of Energy and Mines (MEM)	Ministerial agency	✓	✓	✗	Pricing, Investment, Service, Consumer Rights
Malaysia	Suruhanjaya Tenaga- Peninsular Electricity Supply Division- Sarawak Energy Commission of Sabah (ECoS)- Sabah	Non-ministerial agency	✓	✓	✓	Economic, environmental, and market dynamics of energy supply
Myanmar	Ministry of Electric Power (MOEP)	Ministerial agency	✓	✓	✗	Administrative, economic, and operational regulations
Philippines	The Energy Regulatory Commission (ERC)	Non-ministerial agency	✓	✗	✗	Fostering a competitive electricity market
Singapore	Energy Market Authority of Singapore (EMA)	Non-ministerial agency	✓	✓	✓	Market Competition and Fairness
Thailand	Energy Regulatory Commission (ERC)	Ministerial agency	✓	✓	✓	Tariff and market regulation
Viet Nam	Electricity Regulatory Authority of Vietnam (ERAV)	Ministerial agency	✓	✗	✗	Power market, power planning, tariff regulation

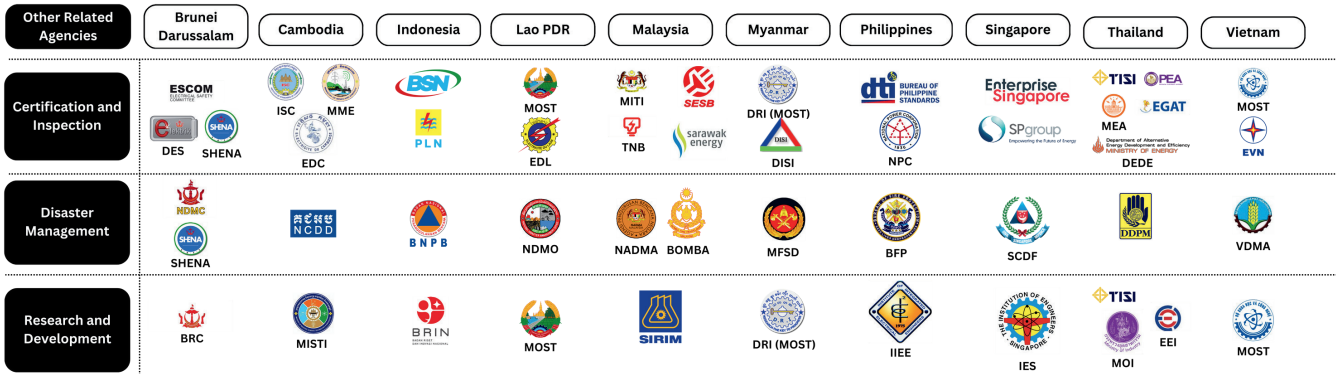
In the case of ASEAN, we can see that currently, no country has a truly independent agency dedicated to electrical safety. Most countries, including Brunei Darussalam, Indonesia, Lao PDR, Myanmar, Thailand, and Vietnam, rely on ministerial structures that also manage broader electricity market policies. Meanwhile, countries like Cambodia, Malaysia, the Philippines, and Singapore have agencies outside ministerial frameworks, but these entities remain involved in commercial matters.

The scope of electrical safety responsibilities across ASEAN is fragmented, with many functions delegated to different bodies. Regulatory agencies often focus on setting safety standards, while other responsibilities, such as certification, inspection, disaster management, and research and development, are managed by separate entities.

For example, in Indonesia, certification and standardisation are overseen by the National Standardization Agency (BSN), while in Thailand, the Provincial Electricity Authority (PEA) and Metropolitan Electricity Authority (MEA) handle the standardisation and certification in distribution and transmission, and the Electricity Generating Authority of Thailand (EGAT) manages the standardisation and certification in generation side.

Disaster management typically falls under dedicated response agencies, such as the Singapore Civil Defence Force (SCDF), while safety-related research and development are often undertaken by national research institutions, such as Indonesia's National Research and Innovation Agency (BRIN). Figure 4 illustrates the involvement of other related agencies in electrical safety functions.

Figure 4 Other Related Agencies Responsible for Electrical Safety



The fragmented structure often leads to insufficient attention to electrical safety, as responsibilities are dispersed among multiple agencies. Furthermore, the overlap of regulatory and commercial functions within these agencies increases the risk of political and commercial influence, which can weaken regulatory enforcement and reduce the intensity of oversight. Global best practices highlight the importance of regulating safety standards through agencies completely independent of commercial interests. Independent regulatory agencies are better positioned to provide unbiased oversight, enforce safety standards rigorously, and advocate for reforms to enhance regulatory intensity. Establishing such agencies in ASEAN could mitigate current challenges, ensuring that safety receives the priority it deserves while reducing the influence of political and commercial interests.

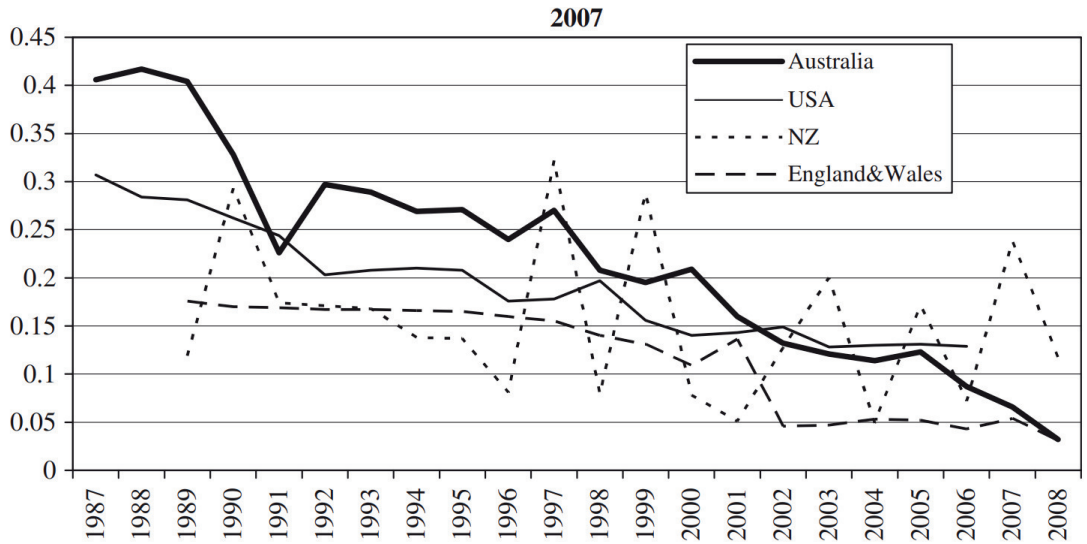
4. Analysis of Electrical Safety Regulatory Structure and Its Impact to Reduce Electrical Accidents: Case Studies from Developed Countries

4.1. Role of Independent Safety Agency for Electrical Safety: Case Study from Australia & New Zealand

In ASEAN countries, electrical safety agencies are predominantly structured as ministerial entities. This arrangement often subjects them to political influence, which can divert focus from safety priorities to broader commercial concerns, such as tariff setting and electricity market regulations, as highlighted in Table 2. This dual responsibility can hinder critical safety activities, including inspections, contributing to frequent electrical accidents.

Establishing independent electrical safety agencies can address these challenges, particularly as electricity systems grow more complex with the integration of vRE. Free from commercial and political pressures, independent agencies can focus exclusively on enhancing safety measures. The restructuring of electrical safety agencies in Australia and New Zealand during the 1990s provides a successful model. As shown in Figure 5, the establishment of independent agencies significantly reduced electrical accidents.

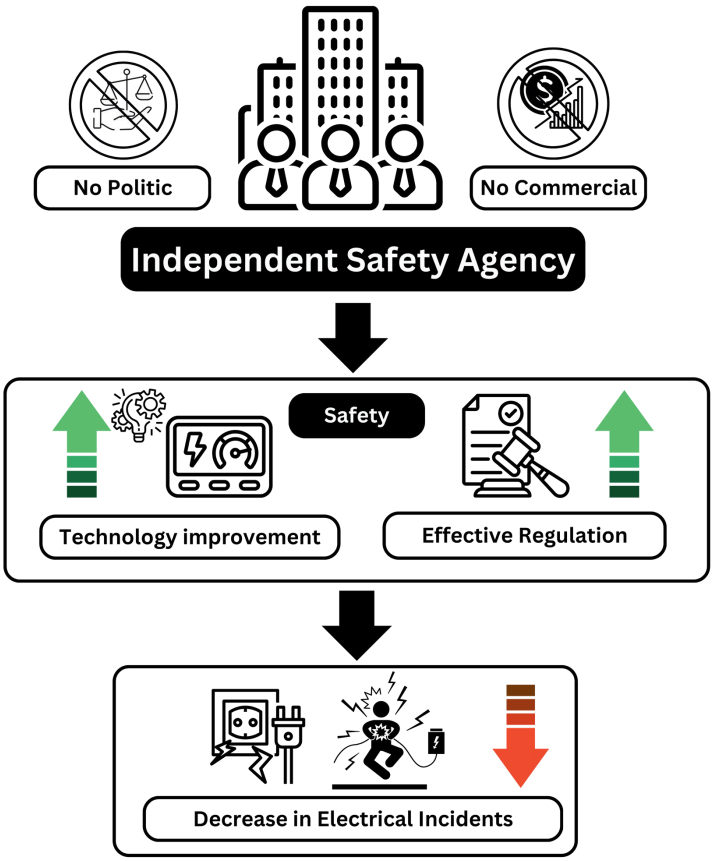
Figure 5 Number of Deaths per 100,000 from electrical incidents in Australia & New Zealand from 1985 to 2007 [4]



This arrangement fosters a regulatory environment where expertise and independence enable more rigorous enforcement of safety standards and technological advancements, as illustrated in Figure 6. These agencies operate autonomously from commercial operators and political oversight while maintaining ministerial accountability.[4].

Political independence is essential for effective regulation. Independent regulators can advocate for necessary changes, leveraging public authority and expertise to drive reforms without succumbing to political pressures.

Figure 6 Independent Agency Effect



Conversely, ministerial agencies in ASEAN may face overregulation due to risk-averse political decision-making, which can inflate costs without proportionately enhancing safety. By contrast, Australia and New Zealand have demonstrated that regulatory independence, combined with investment in technological advancements, can sustainably improve safety outcomes [4].

Currently, ASEAN countries have yet to prioritise safety-focused technological innovation. Efforts in research and development are limited, with only Malaysia, Singapore, and Vietnam showing modest progress, as reflected in Table 2. Establishing independent safety agencies in the region could centralise efforts, ensuring that electrical safety technologies evolve to meet the demands of modern energy systems.

4.2. Role of Electrical Safety Management for RE Expansion: Case study in Republic of Korea

In the Republic of Korea (ROK), the rapid industrialisation of the 1970s spurred electricity demand and highlighted regulatory shortcomings. High-profile incidents, such as two fatal nightclub fires linked to electrical faults, prompted the government to establish the KESCO in 1990 [15],[16]. KESCO operates as an independent legal entity under the Electrical Safety Management Act, with comprehensive responsibilities, including inspections, disaster management, research, and public education. This focused framework has bolstered South Korea's electrical safety through systematic oversight and technological advancements. For example, KESCO investigates electrical accidents to identify systemic risks, providing insights that inform regulatory improvements and disaster prevention strategies. Such a model could inspire ASEAN countries to consolidate safety functions under a single, dedicated body, addressing gaps in enforcement and accountability.

ROK's RE share comprised 8.9% of the country's power generation mix in 2022. The government plans to increase this share to 21.6% by 2030 and 30.6% by 2036, with most of the growth coming from solar photovoltaic (PV) systems, as shown in Figure 7 and Figure 8 [17].

To support this expansion, ROK through KESCO has implemented vital programmes to improve RE infrastructure, including inspection of structure systems, remote monitoring and control of PV systems, and development of an integrated Energy Storage System (ESS) management platform.

Figure 7 ROK Electricity Generation Mix 2022, 2030, and 2036

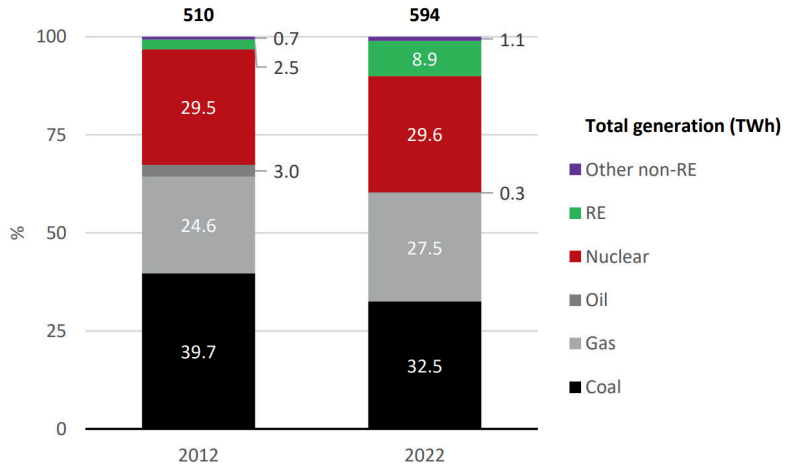
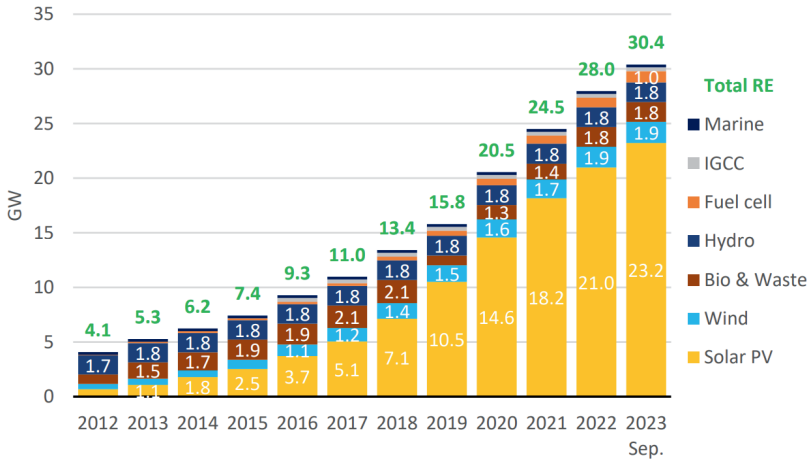


Figure 8 ROK Cumulative RE Installed Capacity 2012-2023



With ESS adoption growing globally by 28% annually [18], safety concerns, such as fire risks, have become increasingly prominent. KESCO's advanced ESS management system incorporates real-time monitoring, on-site inspections, and early fault detection, enabling swift interventions to prevent damage. These efforts have already averted an estimated USD 61 million in potential losses.

KESCO's dedication to safety R&D in ESS management is also highlighted by its collaboration with Sandia National Labs in the U.S., which aims to establish global ESS safety standards and enhance battery protection. These innovations in ESS management and safety position ROK at the forefront of renewable energy, supporting the growth of a secure and reliable energy infrastructure while advancing both national and global energy goals.

KESCO's collaboration with international partners, such as Sandia National Laboratories in the United States, underscores its commitment to advancing global safety standards.

By prioritising R&D in areas like ESS safety, KESCO has positioned ROK as a leader in secure and reliable RE infrastructure. This approach aligns with national energy goals while mitigating risks associated with the rapid deployment of solar PV systems and other vRE technologies.

The ROK model highlights the transformative potential of a dedicated safety agency like KESCO. Its focus on inspections, enforcement, and technological development demonstrates the importance of a centralised approach to electrical safety. ASEAN countries, facing similar challenges with the integration of vRE, could benefit from establishing agencies that prioritise safety over commercial concerns. By adopting similar electrical safety management framework as KESCO and the ROK, ASEAN nations could develop comprehensive safety standards and innovative technologies to mitigate risks, ensuring that the expansion of renewable energy is both sustainable and secure.

5. Summary and Findings

This policy brief highlights the urgent need to improve electrical safety management in ASEAN as the region accelerates its RE transition. The ambitious national and regional targets have driven the rapid integration of vRE sources, such as wind and solar, into traditional grid systems. However, these grids, originally designed for stable fossil fuel energy, face significant challenges in accommodating the variability and technical complexities of vRE. These issues heighten the risk of electrical hazards, including fires and system malfunctions, particularly in commercial and residential settings where improper installations, system overloading, and insufficient safety measures are prevalent.

Currently, electrical safety agencies in ASEAN are often embedded within ministerial frameworks, limiting their effectiveness. These agencies frequently have overlapping responsibilities, such as tariff regulation and electricity supply management, which dilute their focus on safety. Without true independence, they cannot prioritise the development of robust safety protocols, or the adoption of advanced safety technologies needed to address the growing complexities of RE systems.

Case studies from developed countries, including Australia, New Zealand, and the Republic of Korea (ROK), provide valuable insights into overcoming these challenges. In Australia and New Zealand, the establishment of independent electrical safety agencies has significantly reduced accidents by enabling focused regulation and fostering technological innovation. Similarly, South Korea's KESCO demonstrates the importance of a dedicated safety body. KESCO combines regulatory enforcement with R&D, addressing critical safety risks such as those associated with ESS and distributed energy resources.

This policy brief highlights the advantages of establishing independent electrical safety agencies in ASEAN countries to address the safety challenges of RE integration. Such agencies, operating autonomously and free from commercial and political influences, could focus on enhancing safety regulations, advancing compliance, and fostering innovation in safety technologies, such as those needed for complex systems like ESS. Public education initiatives could also complement these efforts, raising awareness of electrical safety in both residential and commercial contexts. By considering these insights, ASEAN nations can explore pathways to mitigate safety risks, safeguard lives and property, and build a secure energy infrastructure that supports the region's RE ambitions.

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