Modeling the Future of ASEAN Grids:

Innovative Technologies for Enhanced System Efficiency

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Asia Clean Energy Forum 2026 | ADB Headquarters, Metro Manila
8–11 June 2026

Enerdata – A Global Energy Expert

- **Independent energy research & consulting company since 1991**
- Expert in **analysis and forecasting of global energy & climate issues**
- **In-house** and globally recognized **sectoral databases** and **forecasting models**

60+ committed Consultants and Experts

- **Headquartered in the Grenoble (French Alps) research cluster**; a subsidiary in **Singapore**
- **Global reach**: Clients and projects in Europe, Asia, Americas, Middle East, Africa
- **Connected** with **leading public institutions, financial and corporate actors, academia and NGO actors**

Presentation Overview

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01

The Grid Challenge in ASEAN

ASEAN's Power Systems Under Pressure

Reliability gaps & surging demand require urgent grid modernisation

×2.5	1-3 TW	+210 GW
Electricity demand expected to double by 2050	Total REN capacity in 2050 depending on the scenarios	Total additional capacities by 2030 under the current policy targets of IND, MAL, TH, PHI and VN Including **+140 GW** of renewables

Reliability Today

- Singapore, Malaysia & Thailand: <1h outage/year. Philippines, Indonesia, Vietnam: still several hours
- Myanmar, Cambodia: outage duration among the highest in the region

Demand & Capacity Outlook

- Demand growth 4-5%/yr across ASEAN; driven by data centres & industry
- 82% of new demand projected to be met by fossil fuels without structural grid change (ACE)
- 13 of 27 key ASEAN Power Grid interconnections completed as of 2025
- ASEAN targets fully integrated grid operations by 2045

Sources: Enerdata, IEA, ASEAN Centre for Energy, ADB

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02

Smart & Grid Enhancing Technologies

Grid Enhancing Technologies (GETs): Key Levers for ASEAN

➔ Software, hardware and system-level tools to extract more from existing infrastructure (non-exhaustive list)

Advanced Conductors (HTLS)

High-temperature, low-sag conductors with composite cores (e.g. ACCC). Operate at higher temperatures and carry 2–3× more power on existing towers without new rights-of-way.

→ **Capacity gains**: +100% on average.
→ **Deployment Status**: In the early scaling phase. Currently accounts for app. 1–2% of the total power grid infrastructure in Vietnam, Indonesia, and the Philippines.

Storage as Transmission Asset (SATA)

[BESS for grid stability] Battery storage deployed strategically to defer or replace transmission upgrades, manage congestion, and improve grid flexibility for VRE integration.

→ **Capacity gains**: +40% on average.
→ **Deployment Status**: Emerging. Includes notable large-scale deployment in the Philippines (e.g., Limay) alongside pilot initiatives in Vietnam and Indonesia.

Dynamic Line Rating (DLR)

Uses real-time weather data (wind, temperature, solar radiation) to dynamically adjust transmission line capacity. Replaces conservative static ratings.

→ **Capacity gains**: +10–40% on average.
→ **Deployment Status**: Pilot phase. Lacks systemic integration; current activity is limited to isolated projects.

Smart Grid & Digitalisation

Advanced metering, SCADA, ADMS, forecasting, demand response, and AI-driven dispatch. Enable real-time balancing of supply & demand.

→ **Capacity gains**: No standard estimate.
→ **Deployment Status:** Non-uniform across technologies. Singapore currently at the forefront of regional implementation, specifically regarding its Grid Digital Twin initiatives.

Sources: Enerdata, capacity gains derived from CurrENT (Prospects for innovative power grid technologies – 2024)

Deployment Status Across ASEAN – And Insights From Europe

➔ **Progress is real but uneven; European benchmarks offers interesting perspectives for scaling-up**

Country	Main Policies	Key Initiatives / Pilots (non-exhaustive)
Indonesia	Smart grid roadmap (RUPTL 2025–2034)	Java-Bali-Madura control centre upgrade; deployment of smart meters; BESS deployment targets
Vietnam	Revised PDP8; Smart Grid Development Roadmap and Plan	Deployment of SCADA/DMS systems; curtailment reduction targets; ambitious BESS deployment targets (20 GW in 2035); DLR pilots planned
Philippines	National Smart Grid Policy Framework and Roadmap; Smart & Green Grid Plan under development; DOE's Philippine Energy Plan	Large-scale RE integration prep, notably through co-located BESS; advanced metering infrastructure and smart grids for off-grid islands; HVDC undersea cable explored
Thailand	Smart Grid Development Master Plan 2015-2036; Power Development Plan (2024-2037)	Renewable forecasting; smart meters; demand response pilots
Malaysia	National Energy Transition Roadmap (NETR); TNB's Grid of the Future" (GoTF) strategy	Smart meters; predictive maintenance; deployment of APFC
Singapore	Smart Grid 2.0	Advanced Smart Grids (Intelligent Energy System pilot; AMI; management of grid inertia through BESS pilots, etc.)

European Benchmark:

Although successful pilot programs have been established in several European nations—notably the UK, Germany, and Spain—broad implementation is currently restricted by financial and cultural bottlenecks. **The European Union's regulatory framework is a critical driver**. Despite a policy of technology neutrality that precludes specific deployment targets for GETs (excluding smart meters), TSOs are increasingly incentivized to adopt these technologies. Key drivers include the "70% rule" for cross-border interconnection capacity and the requirement to prioritize non-wire solutions over traditional grid expansion when applying for European funding.

Sources: Enerdata, UN ETP, European Commission, interview with CurrENT

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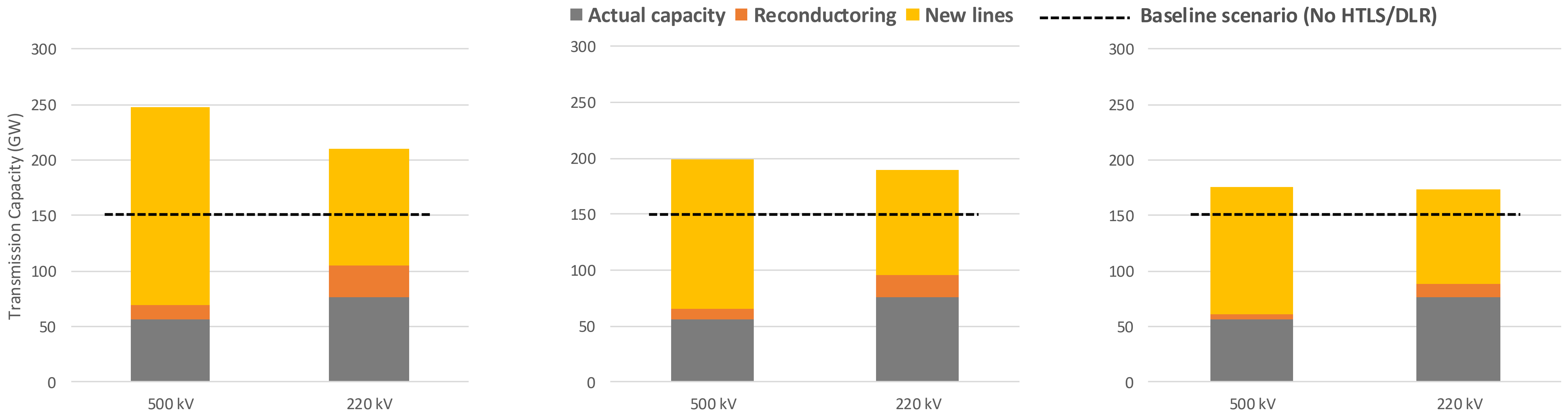
03

Potential Capacity Gains for ASEAN Grids

Estimated Capacity Gains from GETs: A Transfer Methodology for Vietnam

Applying capacity gain benchmarks (HLTS + DLR) to Vietnam's transmission networks — indicative estimates by 2035



SCENARIO 1 – ACCELERATED TRANSITION

- Advanced Conductors: 100% of reconductoring and most new 500kV lines; selective use for new 220kV.
- DLR: Integrated into 20% of the total network.

SCENARIO 2 – POLICY-ALIGNED

- Advanced Conductors: Majority of reconductoring and critical 500kV corridors; limited use for new 220kV.
- DLR: Integrated into 10% of the total network..

SCENARIO 3 – LAGGING DEPLOYMENT

- Advanced Conductors: 50% of reconductoring and few new 500kV corridors; marginal use at 220kV.
- DLR: Integrated into 5% of the total network.

Methodology: Average capacity gain estimates from European DLR/HTLS deployment scenarios were applied to Vietnamese transmission network scale projections for 500 kV lines and 220 kV lines through 2035. The analysis is based on the technological priorities and policy targets defined in the revised PDP8 (2025). By 2035, the expansion plan targets:

- New Construction (40,000 km): Split equally between 500 kV and 220 kV lines (20,000 km each).
- Reconductoring (8,000 km): Upgrading 6,000 km of 220 kV and 2,000 km of 500 kV infrastructure..

Data Sources*:* Revised PDP8 (2025), Enerdata, CurrENT. These figures represent an indicative estimate. **They are subject to uncertainties regarding the adoption rate and actual performance of GETs, the actual implementation of PDP8 targets, and the current limitations in available data.**

Estimated Capacity Gains from GETs: A Transfer Methodology for Vietnam

Applying capacity gain benchmarks (HLTS + DLR) to Vietnam's transmission networks — key results

➔ **Timeline Acceleration:** The Policy-aligned scenario unlocks **25–34% gains** compared to baseline through increased regional transfer capacity, increased grid hosting capacity.

➔ **Baseline Improvements:** Even under conservative assumptions, GETs unlock **14–17%** of capacity gains via targeted upgrades compared to baseline.

➔ **Grid Optimization:** System-wide integration of advanced conductors in 500 kV reconductoring projects unlocks **9 GW** of capacity without requiring new rights-of-way.

***+ Additional benefits:** Job creation, investment efficiency, emissions reduction.*

Sources: Enerdata. These figures represent an indicative estimate. They are subject to uncertainties regarding the adoption rate and actual performance of GETs, the actual implementation of PDP8 targets, and the current limitations in available data.

04

Bottlenecks & Recommendations

Barriers to Deployment — and How to Overcome Them

➔ **Structural, financial and regulatory constraints require coordinated action**

Financing Gap

⚠ **Barrier:** Capital requirements for the ASEAN smart grid build-out estimated in the billions of dollars. JETP commitments partially disbursed. Limited bankable pipelines.

✓ **Recommendation:** Enhance the assessment of financial gaps across various transition scenarios; Benchmark and implement blended finance models and incentive frameworks, with a specific focus on non-CAPEX intensive solutions (such as digitalization); Mobilize multilateral financing, leveraging regional platforms such as the Pan-Asia Power Grid Initiative.

Fragmented Standards & Regulations

⚠ **Barrier:** Unharmonised grid codes, data protocols, and permitting processes across ASEAN member states hinder cross-border deployment.

✓ **Recommendation:** Leverage EU-style interoperability standards to facilitate the long-term integration of the ASEAN Power Grid; Reform transmission planning frameworks to mandate the assessment and monitoring of GETs at both national and regional levels, positioning them as essential complements to traditional grid expansion; Foster peer-learning and knowledge exchange – through the ASEAN Smart Grid Forum for example – to accelerate regional best practices

Capacity & Data Gaps

⚠ **Barrier:** Limited high-resolution grid monitoring data. Technical capacity to operate DLR or ADMS systems is scarce in many TSOs. Need to develop local industry.

✓ **Recommendation:** Prioritize capacity building and advanced training for grid operators; Deploy real-time monitoring infrastructure as a foundational step, utilizing advanced analytics or Geographic Information Systems (GIS); Leverage international technical assistance, particularly from EU frameworks, to align with global best practices.

Sources: Enerdata Analysis

Appendix: What are capacity gains (GW) in the context of GETs?

How do GETs such as advanced conductors or DLR enable capacity gains on a power network?

A GW gain enabled by GETs falls into three different categories:

➔ **Increased interregional transfer capacity (flow capacity).** Additional active power (GW) can physically flow across congested transmission corridors or boundaries between regions.

➔ **Increased grid hosting capacity (interconnection queue relief)**. Additional power generation (wind, solar, battery storage) can safely connect to the grid without triggering the need for expensive, slow-to-build physical line upgrades

➔ **Peak demand capacity (grid adequacy).** Squeeze maximum efficiency out of existing wires during peak hours, reducing the need to build "peaker" gas plants or curtail demand.

- ❑ Capacity gains are **dynamic**, not static. Depends on the weather conditions, technologies, etc.
- ❑ Gains are **location-specific** (non-systemic). Only increases capacity across the specific boundary or interface where the technology is deployed
- ❑ Gains are **non-additive.** Cannot simply add up the individual GW gains of multiple technologies applied to the same line.

Sources: Enerdata. These figures represent an indicative estimate. They are subject to uncertainties regarding the adoption rate and actual performance of GETs, the actual implementation of PDP8 targets, and the current limitations in available data.