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HARNESSING ARTIFICIAL INTELLIGENCE & DIGITAL SOLUTIONS TO ACCELERATE VIET NAM'S ENERGY TRANSITION

Potential Assessment

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Foreword

Viet Nam's energy transition stands at a pivotal moment. With the approval of the revised Power Development Plan VIII (PDP8), the country has laid out ambitious targets to reshape its energy system—significantly increasing the share of renewable energy, enhancing grid flexibility, and ensuring energy security and sustainability. Meeting these targets will require not only bold policy implementation and investment but also the strategic application of innovation and technology.

Artificial Intelligence (AI) and digital solutions offer powerful tools to accelerate this transformation. By enabling more accurate forecasting, real-time grid management, predictive maintenance, and efficient energy use, AI can unlock substantial efficiency gains across the entire energy value chain—from generation and transmission to distribution and consumption. These gains are crucial in a system that is growing rapidly in complexity and scale.

However, the deployment of AI also demands careful consideration. As we embrace these technologies, we must ensure that their use remains transparent, equitable, and responsible. Issues such as data privacy, algorithmic bias, cybersecurity, and workforce adaptation must be proactively addressed. AI should serve as a tool that supports inclusive development and strengthens, rather than undermines, public trust and institutional capacities.

This report - developed by the GIZ Energy Support Programme in close cooperation with Viet Nam's Ministry of Industry and Trade - provides a first step in assessing how AI and digital solutions can support Viet Nam's energy transition. It identifies key areas of opportunity and highlights practical considerations for the way forward.

On behalf of the GIZ Energy Support Programme, I would like to thank all partners and contributors to this report. We hope that its findings will support policymakers, utilities, private sector actors, and development partners in jointly exploring and responsibly leveraging the full potential of digital innovation for a cleaner and more resilient energy future in Viet Nam.

Philipp Munzinger
Programme Director
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Acknowledgement & Disclaimer

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The results presented here may not necessarily represent the opinion of the donor and GIZ.

Abbreviations

Abbreviation	Definition
ACE	ASEAN Centre for Energy
AEDS	ASEAN Energy Database System
ACCEPT	ASEAN Climate Change and Energy Project
APAEC	ASEAN Plan of Action for Energy Cooperation
ASEAN	Association of Southeast Asian Nations
AIF	ASEAN Infrastructure Fund
AI	Artificial Intelligence
AGI	Artificial General Intelligence
AMI	Advanced Metering Infrastructure
BMZ	German Federal Ministry for Economic Cooperation and Development
BOOT	Build-Own-Operate-Transfer
BOT	Build-Operate-Transfer
CVR	Conservation Voltage Reduction
DER	Distributed Energy Resource
DG	Distributed Generation
DLR	Dynamic Line Rating
D-Statcom	Distribution Static Synchronous Compensator
DR	Demand Response
EMS	Energy Management System
ERAV	Electricity Regulatory Authority of Vietnam
ESCO	Energy Service Company
EU	European Union
EV	Electric Vehicle
EVN	Electricity of Vietnam
EVNHANOI	Electricity of Vietnam – Hanoi Power Corporation
EVNHCMC	Electricity of Vietnam – Ho Chi Minh City Power Corporation
EVNSPC	Electricity of Vietnam – Southern Power Corporation
EVNCPC	Electricity of Vietnam – Central Power Corporation
EVNNPC	Electricity of Vietnam – Northern Power Corporation
EVNNLDC	EVN National Load Dispatch Center
FERC	Federal Energy Regulatory Commission (USA)
FLISR	Fault Location, Isolation, and Service Restoration
GCF	Green Climate Fund
GEF	Global Environment Facility
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPU	Graphics Processing Unit
HMI	Human-Machine Interface

IEA	International Energy Agency
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
IT	Information Technology
JETP	Just Energy Transition Partnership
KPI	Key Performance Indicator
LLM	Large Language Model
LNG	Liquefied Natural Gas
MAS	Multi-Agent Systems
MDB	Multilateral Development Bank
ML	Machine Learning
MOIT	Ministry of Industry and Trade
NQ / TW	Resolution code (e.g., 55-NQ / TW)
NLDC	National Load Dispatch Center
NSMO	National System and Market Operator
OPF	Optimal Power Flow
PDP	Power Development Plan
PDP8	Power Development Plan VIII
PPA	Power Purchase Agreement
PBR	Performance-Based Regulation
PMU	Phasor Measurement Unit
PV	Photovoltaic
RAB	Regulated Asset Base
R&D	Research and Development
RES	Renewable Energy Sources
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCADA	Supervisory Control and Data Acquisition
SDG	Sustainable Development Goal
SGREEE	Smart Grids for Renewable Energy and Energy Efficiency
ToR	Terms of Reference
UK	United Kingdom
USAID	United States Agency for International Development
USTDA	United States Trade and Development Agency
V2G	Vehicle-to-Grid
VDB	Vietnam Development Bank
VPP	Virtual Power Plant

Conceptual Primer: Digitalization, Automation, Smart Grid & AI

Digitalization

- The process of converting analogue signals, records and control mechanisms into digital form (bits) and establishing end-to-end data flows.
- **Enabler** for both automation and AI: without digital sensors, communications and storage, higher-level software cannot operate.

Automation

- Rule-based execution of tasks by machines or software, often replacing manual operations (e.g. relay settings, routine controls).
- **Deterministic logic**: follows predefined rules, does not "learn" or adapt beyond its programmed parameters.

Smart Grid

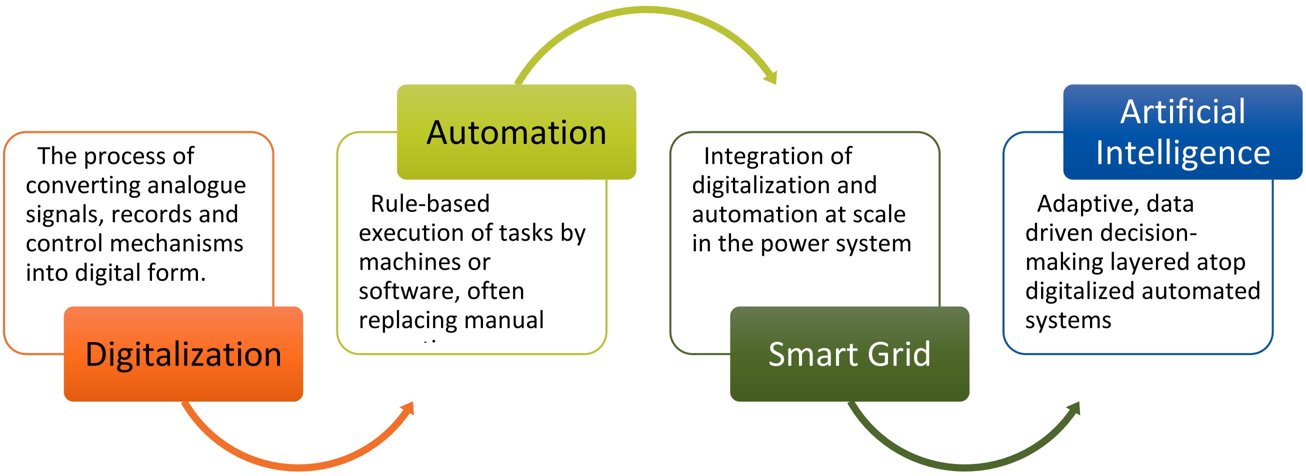
- An electricity network integrating **digitalization**, **automation** and advanced analytics to monitor, protect and optimize power flows in real time.
- **Hardware** (smart meters, phasor measurement units, IoT devices) and **software** (data-management platforms, control algorithms) work in concert to enhance visibility, reliability and resilience.

Artificial Intelligence (AI)

- **Autonomous agents** range from a mechanical thermostat (sensing temperature → applying a rule → actuating a switch) to modern complex AI systems.
    - **Narrow AI**: software models trained for one task (e.g. load or solar-output forecasting, anomaly detection). The most common application of AI under Smart Grid.
    - **Large Language Models (LLMs)**: neural networks specialized in text generation and reasoning over language currently finding application only in the retail segment of the power market for providing customer support.
    - **(Speculative / Upcoming) AGI/ Superintelligence**: hypothetical future systems with human-level or beyond-human general reasoning.
- **Adaptive decision-making** distinguishes AI from simple automation: AI infers patterns, updates its own parameters and can re-optimize its behavior over time autonomously.

Interdependencies & Future-Proofing

- **Hardware prerequisites** (e.g., meters, sensors, communications networks) provide the data and actuation channels that both automation and AI require or will require in the future.
- The **same hardware** footprint can support progressively more sophisticated AI through software upgrades—future-proofing investments by focusing today on robust, open, interoperable digital infrastructure.



Executive Summary

At the dawn of this crucial decade for climate mitigation, electric power systems are reshaped by two intertwined revolutions: large-scale renewables and data-driven intelligence. Vietnam's PDP VIII envisions 236 GW by 2030, over half from solar, wind, and storage, technologies which intrinsically dependent on granular data streams and advanced controls. A national resolution further paves the way for digital transformation and AI readiness across all ministries, while the JETP offers technology transfer and financing to accelerate a low-carbon, resilient grid. Yet the IEA's 2025 report cautions that AI data centres could consume nearly one trillion kWh by 2030, potentially jeopardizing efficiency gains. Reconciling AI's dual role as optimizer and energy consumer requires in-depth, evidence-based analysis and policy safeguards.

This study, commissioned by GIZ's aims to categorize proven AI solutions, to recommend pilots for scale-up, and to outline technical, institutional, and regulatory preconditions to translate AI's potential into reduced curtailment, improved forecasts, and substantive emissions reductions.AI-enabled digitalisation could transform Vietnam's still very linear power grid into a self-optimising, bidirectional cyber-physical network. The study further explores where AI can deliver the greatest decarbonisation impact, where its own environmental footprint must be managed, and what policy framework is required to scale proven solutions.

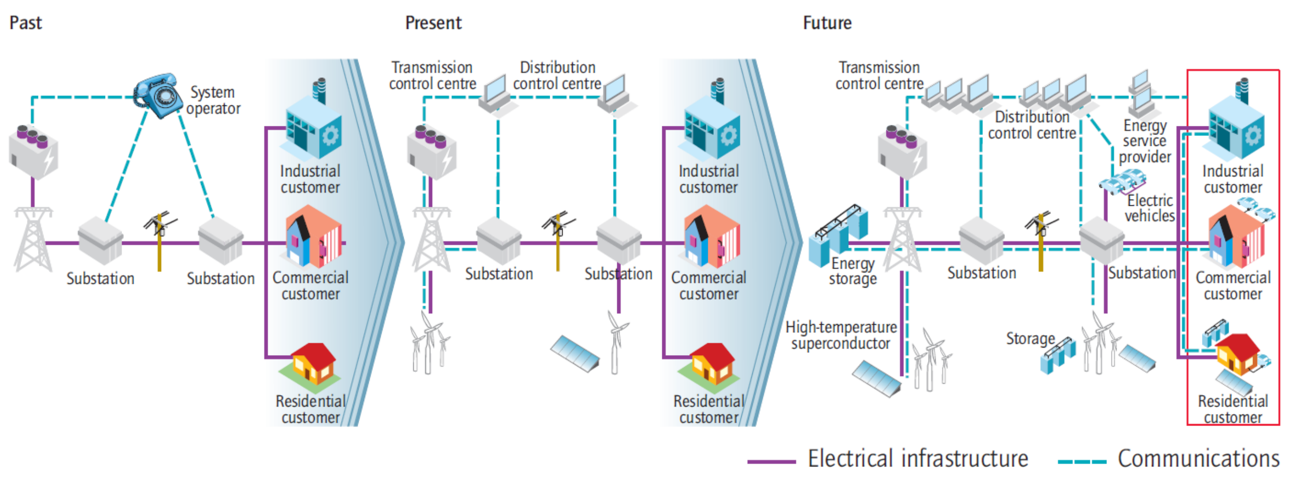


Figure E- 1: Evolution of transmission and distribution systems into smart transmission and distribution grids (Source: IEA, Technology Roadmap – Smart Grids, 2011)

DIGITALIZATION, AI & THEIR CONVERGENCE

It is imperative to define "artificial intelligence" within a policy-oriented framework that addresses both overstated expectations and misplaced anxieties. AI inquiry has long been structured by Russell and Norvig's two-by-two schema of "thinking" versus "acting" and "humanly" versus "rationally," with each quadrant prescribing distinct capabilities and implementation considerations:

	Humanly	**Rationally**
Acting	***Acting Humanly*** Emulate dispatcher decisions (Grid Turing test)	***Acting Rationally*** Goal-oriented strategies under uncertainty
Thinking	***Thinking Humanly*** Bayesian-style reasoning on stability or operator response	***Thinking Rationally*** Symbolic contingency analysis or optimal power-flow verifiers

Contemporary grid applications predominantly employ **narrow AI** which are systems precisely engineered for a single, well-defined function, such as identifying insulator defects in aerial inspections or forecasting solar irradiance fifteen minutes in advance. These solutions frequently surpass human operators in consistency and speed but lack the capacity to generalize beyond their training scope. In contrast, **Artificial General Intelligence (AGI)** denotes a hypothetical agent capable of executing any economically valuable cognitive task at or above expert human performance—seamlessly transitioning from solving optimal power-flow problems to debating regulatory trade-offs. **Superintelligence** refers to a post-AGI phase in which such an agent's cognitive prowess greatly exceeds all human intelligence. While these scenarios captivate both utopian & dystopian narratives, today's grid implementations remain firmly within narrow-AI confines. Nonetheless, the non-linear scaling of transformer and graph-neural architectures with computational power underscores the necessity for regulators to monitor AI's energy consumption and to enforce clear data-and-safety envelopes that prevent unchecked resource growth.

For policymakers seeking a pragmatic toolkit, six paradigms merit particular attention - each corresponding to discrete sides of decarbonized, resilient grids: (i) Machine Learning (ML), (ii) Probabilistic & Bayesian Methods, (iii) Optimization, (iv) Multi-Agent Systems (MAS) & Distributed Intelligence, (v) Knowledge-Based & Expert Systems, (vi) Hybrid Neuro-Symbolic & Graph-Neural Approaches

AI's transformative potential is based on a robust digital infrastructure comprising of high-fidelity sensors, low-latency communications, scalable edge-to-cloud compute & resilient cybersecurity. In return, AI delivers insights that justify further digital investments, creating a worthy cycle. The following table presents a policy matrix aligning boundary conditions with immediate levers.

Table E-2. Policy matrix aligning boundary conditions with immediate levers

	Boundary-condition risk	Priority policy lever	Concrete deliverables
1	**Data quality & coverage** – incomplete metering / patchy connectivity degrade AI accuracy	Infrastructure investment	Universal AMI roll-out; dense high-bandwidth backhaul; near-real-time data feeds
2	**Interoperability** – proprietary protocols create siloes & lock-in	Standards & interoperability	ASEAN-wide harmonised data models, comms protocols, open APIs
3	**Digital equity** – urban bias widens rural-urban gap	Capacity building	Equitable broadband & edge-compute deployment; AI literacy for local utilities
4	**Cyber-resilience** – expanding attack surface across devices & data links	Cyber-resilience mandates	Continuous patching, AI-driven threat detection, mandatory incident reporting
5	**Regulatory agility** – static rules ill-fit self-learning algorithms	Regulatory agility mechanisms	Sandboxes, outcome-based metrics, iterative licensing for AI pilots

DIGITALIZATION & AI IN POWER SECTOR

Digitalisation is driven by falling sensor and computing costs and the urgency of integrating variable renewables, with AI turning sub-minute data from more than one billion smart meters and vast IoT fleets into real-time optimisation, while policy frameworks on both sides of the Atlantic (and across Asia-Pacific) race to ensure openness, security and fair market access.

Table E-3. International examples

Focus Area	Core Digital / AI Levers	Illustrative Actions & Policies	Quantified Impact/Targets
Capital shift	Grid-digital-capex (2015-22)	> 50 % rise; ~20 % of total network spend	–
Data & visibility	Smart-meter & sensor roll-out	> 1 bn smart meters; ubiquitous IoT	Sub-minute load insight
Renewables integration	Probabilistic forecasting; AI dispatch	ML smooths PV/Wind variability	IEA: -10–15 % power CO_2 by 2030
Demand flexibility	AI-enabled DR & adaptive loads	Buildings / industry shift peaks	Defers network upgrades
EU leadership	2022 Action Plan on Digitalising Energy	Open data space, cyber rules, interoperability	Continent-wide standards
UK initiatives	Ofgem Digitalisation Taskforce, AI Strategy 2021	"Digital spine" real-time data layer	Critical-infrastructure status
US market access	FERC Order 2222 (2020)	DER/VPPs in wholesale markets; PBR pilots	Efficiency rewarded over capex
R&D funding	Horizon Europe, DOE Grid Modernisation, ARPA-E, China	Pilots: AI congestion mgmt, blockchain P2P, autonomous control	Accelerated tech diffusion

Focus Area	Core Digital / AI Levers	Illustrative Actions & Policies	Quantified Impact/Targets
	U-Power IoT, Japan 2030 target		
Global collaboration	IRENA, IEA CETP, ASEAN APAEC	Digital twins, cyber-secure ops, AI planning manuals	Best-practice transfer
Cyber & privacy	EU GDPR, mandatory incident reporting	Secure comms, vendor-neutral open protocols (IEC, IEEE)	Trust + lock-in avoidance

AI-centric digitalisation is no longer experimental; utilities, tech firms, and entire power systems now deploy it at scale to cut outages, raise renewable revenues, and unlock demand flexibility—all with quantifiable, policy-aligned outcomes. Economies have elevated artificial intelligence and digital platforms from niche experiments to indispensable enablers. The following synthesis articulates defining methodologies, exemplar deployments, and distilled lessons for policymakers.

Table E-4. AI applications advancing the power system

Domain	Principal AI-Enabled Functions	Reported Gains & Benchmarks (verbatim)	Governing Best-Practice Levers
1. Renewable Integration & Grid Planning	• Siting optimization • LLM-based permitting • Probabilistic solar/wind forecasts • Curtailment-vs-storage dispatch	• Faster site selection with higher projected yield • Up to 40% reduction in permitting time & cost • 20–30% forecast-accuracy gain, multi-million € balancing savings • Curtailment minimised; negative-price events avoided	• Publish open data sets • Pay for forecast accuracy • Integrate outputs into SCADA / EMS
2. Grid Optimisation & Operations	• Millisecond neural-OPF & wide-area control • Dynamic line rating (DLR) • PMU-driven fault location & self-healing	• Near-optimal dispatch; congestion eased • Up to 30 % extra line capacity; upgrades deferred • Outage duration halved in pilots	• Embed solvers in operator workflow • Keep human-in-the-loop oversight • Calibrate sensors &

	• Market-anomaly detection	• Cross-border transparency; manipulation deterred	govern data
3. Demand-Side Management & VPPs	• Predictive, price-responsive DR • AI-co-ordinated VPP aggregation	• 50 % household response rate; 3 300 MWh curtailed (UK 2022 programme) • Sub-second frequency response; over 20 MW support during heatwaves	• Intuitive customer UIs • Open standards (OpenADR) • Utility-platform integration; regulatory sandboxes
4. Predictive Maintenance & Asset Care	• IoT data lakes & anomaly detection • Failure prediction for rotating & thermal plant • Drone / robot vision inspection	• 25 % maintenance-cost reduction; life extension • Faster fault flagging; wildfire risk cut	• Unified data architecture • Physics-informed, explainable models • Continuous model-feedback loops
5. Storage & EV Integration	• Price-driven battery dispatch • V2G & smart-charging optimization • AI-accelerated electrolyte/electrode discovery	• Sub-100 ms frequency response; A$ 40 million ancillary-service savings (Hornsdale) • Multibillion-pound UK grid savings projected by 2025 • New Materials discovery compressed from years to months	• High-resolution forecasts tuned to degradation models • Interop standards (ISO 15118-20, OpenADR) • Pilot V2G under sandbox regimes

DIGITALIZATION IN VIET NAM POWER SECTOR

In recent years, the Vietnamese electricity sector has made substantial progress in the adoption of AI and digital technologies across a wide range of operational domains. Key electric utilities have launched numerous initiatives aimed at modernizing infrastructure, improving operational efficiency, and enhancing customer service. The integration of digital technologies and AI has delivered measurable improvements across multiple areas of Vietnam's electricity sector.

Table E-5. Data demonstrating the impact of digital and AI technologies

Impact Area	Key Results
Smart Metering and AMI	● EVNHCMC reduced energy losses from 4.7% in 2019 to 3.53% in 2024, with 2.61% in 2022. ● Remote data collection rate surpassed 97% in 2024, cutting operational costs. ● AI-based consumption analysis led to a 25% increase in electricity theft detection.
Maintenance & Operation Efficiency	● EVNHANOI reduced average annual outage time from over 500 minutes (2017) to around 170 minutes (2023). ● EVNHCMC reached SAIDI of 35 minutes in 2022. ● Overload-related incidents decreased from 15% to 6–8%. ● Manual inspection of transmission lines dropped by 35% due to drone usage. ● Power restoration via FLISR occurs in under 1 minute. ● Achieved 100% unmanned 110kV substations and fully automated medium-voltage networks.
Load & Renewable Forecasting Accuracy	● Short-term load forecasting accuracy improved from 88% to over 95%. ● Renewable energy utilization rates increased from 75–80% to over 90%.
Customer Service Improvements	● Over 90% of customer requests resolved on the same day. ● Customer satisfaction index reached 8.8/10 (EVNHANOI, 2023) and 9/10 (EVNHCMC). ● Over 99% of EVNHCMC's transactions were processed electronically. ● 100% online services available via web/app at EVNHCMC.
Internal Management & IT Governance	● All management KPIs at EVNHCMC are displayed on BI dashboards. ● 100% of responsible personnel use digital signatures securely. ● EVNHCMC was the first enterprise in Vietnam certified at digital transformation level 3/5 by the Ministry of Information and Communications. ● 3.6-point increase in Smart Grid Index from 2021 to 2022 (reaching 71.4/100), ranked 47/94 globally, 2nd in ASEAN.

RECOMMENDATIONS FOR VIETNAM

- **Inter-system fit:** *Voltage limits, Remote Terminal Unit (RTU) specs, cyber rules, and data formats are all prescribed; any AI module must plug into these without hacks.*
- **Cybersecurity provisions:** *New digitalization applications widen the attack surface, so the Law on Electricity now flags cybersecurity as a must-check item in every project.*
- **Fair access:** *Plans call for AMI and smart-grid links in both cities and rural zones, keeping digital benefits spread wide.*

Some key recommendations for safe & smooth AI applications roll-out based on this analysis include:

Vietnam's pursuit of an AI-enabled smart grid demands a carefully developed financing strategy. Annual investment requirements —estimated at VND ~95 trillion (USD ~4 billion)— surpass state and utility budget envelopes. Leveraging the USD 15 billion commitment under the Just Energy Transition Partnership (JETP) will therefore hinge on assembling a diversified capital stack, deploying innovative de-risking instruments, and aligning regulatory incentives with investor expectations. To utilize the full USD 15 billion JETP commitment and catalyze private co-investment, the following can be proposed:

1. **Blended Portfolio Architecture:** *Sequence grant-financed pilots into concessional MDB scaling, followed by targeted private equity—thereby optimizing risk-reward profiles.*

2. **Accelerated PPP (model in India) Pilots:** *Launch an "Accelerated Smart Grid Initiative" modeled on India's BOOT framework to expedite smart-meter and EV-charging network roll-out.*

3. **RAB Adaptation:** *Incorporate AI/AMI assets into a Regulated Asset Base mechanism, furnishing EVN and private operators with regulatory certainty and stable returns.*

4. **Smart Energy Finance Unit:** *Establish a dedicated agency to develop bankable pipelines, coordinate MDB and donor engagements, and package propositions for ESG investors.*

5. **Regulatory Harmonization:** *Align tariff structures, tax incentives (e.g., accelerated depreciation), and priority-sector lending to sustain rapid digital-grid adoption without fiscal strain.*

6. **Inclusive Deployment Mandates:** *Ensure rural AMI coverage, robust consumer safeguards in MAP-like schemes, and fintech-enabled payment modalities to prevent digital exclusion.*

To prioritize Vietnam's array of AI- and digital-grid innovations, a simple, transparent multi-criteria ranking approach has been employed based on strategic criteria—such as technical feasibility, cost-benefit, and impact. The outcomes of the ranking process will serve as the foundation for developing a preliminary roadmap of AI and digitalization interventions, structured to enable a phased and coordinated implementation aligned with the strategic milestones outlined in PDP8 (revised).

This roadmap will provide stakeholders with a clear, actionable framework for aligning technical initiatives and policy measures to effectively drive Vietnam's power system modernization and digital transformation.

- **2025–2030 (Short-term priorities):** Establish the digital and AI foundation by implementing pilot projects focused on AI-based forecasting, digital grid infrastructure deployment, and predictive maintenance pilots. Concurrently, regulatory groundwork will be laid to enable these innovations, setting the stage for larger-scale efforts.

- **2030–2035 (Medium-term priorities):** Scale up intelligent systems and smart grid control capabilities, including real-time wide-area energy management, AI-powered grid resilience, and enhanced interconnection coordination. Regulatory frameworks will be strengthened to support expanded data infrastructure, advanced demand response programs, and cross-border energy market integration.

- **2035–2050 (Long-term priorities):** Achieve full AI integration across the power system with fully automated grid operations, advanced energy storage management, and distributed energy resource orchestration. The focus will also be on enabling sophisticated market intelligence, decarbonization efforts, and robust AI-driven cybersecurity frameworks to support a renewable-centric, resilient grid.

The detailed roadmap is presented in the table below.

Table E-6. Time Range and AI/Digitalization Roadmap until 2050

Time range	Key Power Development Targets	AI & Digital Tech Application Strategy
2025–2030 Laying the Digital & AI Foundation.	• Total capacity: 183–236 GW • Massive increase in solar, wind (onshore/offshore) & storage systems • Introduction of nuclear energy • Key focus on LNG, domestic gas & energy imports/exports	***Technical Activities:*** • AI-Enhanced Load and Renewable Energy Forecasting • Demand Response Programs via Digital Platforms • Advanced Metering Infrastructure (Smart Meters) and Data Analytics • Energy Management Systems (EMS) for Large Consumers (Industry 4.0 Energy Efficiency) • Predictive Maintenance for Generation and Grid Assets ***Policy / Regulatory Activities:*** • Introduce Time-of-Use Pricing building upon existing Demand Response Regulations • Build Institutional Capacity and Skills for Digitalization • Strengthen Cybersecurity and Grid Resilience Regulations • Implement Regulatory Sandboxes for Energy Innovation • Provide Financial Incentives and Support for Smart Grid Investments • Update Grid Codes and Technical Regulations for AI and DER Integration

<table>
<tr><th>Time range</th><th>Key Power Development Targets</th><th>AI & Digital Tech Application Strategy</th></tr>
<tr><td>2030–2035
Scaling Intelligent Systems & Smart Grid Control.</td><td>Offshore wind: 17 GW
Solar: 73 GW
Begin nuclear (4–6.4 GW) deployment
Large-scale energy storage (10–16.3 GW batteries, 6 GW pumped hydro)
Electricity export/import systems expansion</td><td>Technical Activities:
Virtual Power Plants (VPP) and DER Aggregation
AI-Powered Grid Resilience and Anomaly Detection
Distribution Grid Automation and Loss Reduction
AI for Grid Stability and Transmission System Optimization
Consumer-Side Intelligence
Smart Electric Vehicle (EV) Charging Management
AI-Driven Ancillary-Service Dispatch Optimization
Policy / Regulatory Activities:
Create Market Mechanisms for Grid Flexibility & New Services
Promote Public-Private & International Partnerships for Digital Innovation</td></tr>
<tr><td>2035–2050
Full AI-Integrated Smart Grid & Renewable-Centric System.</td><td>Total capacity: 774–838 GW
Solar: ~295 GW
Offshore Wind: ~139 GW
Onshore Wind: ~91 GW
Battery storage: 96 GW
Hydrogen, ammonia, biomass-fired retrofitting
Nuclear: 14 GW</td><td>Technical Activities:
AI Cybersecurity Frameworks (National-level digital security with behavior-based threat detection AI)
Fully Automated Grid Operation (AI agents for multi-objective dispatch optimization, carbon pricing, congestion relief)
Distributed Energy Resource (DER) Orchestration (AI-enabled DERMS)
Energy Market Intelligence (AI facilitates wholesale/retail markets, DPPA optimization, spot market analytics)
AI for Decarbonization and Emissions Tracking
Energy Storage Management AI (Predictive balancing of battery charge/discharge across seasons and demand peaks)
AI-Enabled Interconnection with Neighbouring Grids
Policy / Regulatory Activities:
Continuation and enhancement of all earlier policies with mature, adaptive frameworks supporting the fully integrated AI-driven grid and markets.</td></tr>
</table>

CHAPTER 01

Introduction & Study Approach

Chapter 1: Introduction & Study Approach

1.1. Rationale & Background

At the dawn of a decisive decade for climate action, the world's electricity systems are being reshaped by two mutually reinforcing revolutions: the rapid diffusion of variable renewables and the equally rapid ascent of data-driven intelligence. Solar arrays are installed on industrial rooftops from Da Nang to the Mekong Delta, while offshore wind farms advance along Central Vietnam's coastline. Yet the very success of these technologies magnifies the operational complexity of the grid, turning yesterday's unidirectional network into an expansive cyber-physical organism that must forecast, arbitrate and self-heal in real time. Against this backdrop, artificial intelligence (AI) is emerging not as a futuristic curiosity but as an indispensable tool able to assimilate petabytes of meteorological, market and sensor data, and to translate that into dispatch schedules, voltage-set-points and price signals that keep electrons flowing with millisecond precision.

Vietnam's leadership has already signalled that digital tools will be key in sustaining economic growth while honouring net-zero pledges. The revised Power Development Plan VIII (PDP 8) now targets up to 236 GW of installed capacity by 2030—more than half of which is expected to come from solar, wind and battery storage solutions that are by nature data-intensive and control-dependent[1]. Complementing PDP 8, Resolution 57-NQ/TW, adopted in December 2024, elevates science, technology, innovation and national digital transformation to the rank of strategic imperatives, tasking every ministry—including the Ministry of Industry and Trade (MOIT)—with operationalizing an "AI-ready" ecosystem across critical infrastructures[2]. At the multilateral level, Vietnam's engagement in the Just Energy Transition Partnership (JETP) underscores the same intent: leverage international technology and finance to accelerate a low-carbon, high-resilience electricity future.

Yet the IEA's 2025 flagship report, *Energy and AI*, introduces a note of caution. It calculates that global electricity demand from AI-driven data-centre loads could more than double to 945 TWh by 2030, rivalling Japan's current national consumption[3]. In Southeast Asia the projected surge is particularly steep, led by hyperscale facilities in Singapore, Malaysia and, prospectively, Vietnam's own emerging digital hubs. Thus, AI is put forward in a dual role: indispensable optimizer of a renewable-rich grid, but also an energy-hungry workload that threatens to eat into the very efficiency gains it helps to unlock. Reconciling that paradox demands a rigorous,

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[1] https://www.vietnam-briefing.com/news/vietnam-revises-pdp8-key-targets-of-the-national-power-development-plan.html

[2] https://sblaw.vn/resolution-57-nq-tw-on-breakthrough-development-of-science-technology-innovation-and-national-digital-transformation/

[3] https://www.iea.org/reports/energy-and-ai/executive-summary

evidence-based examination of *where* AI genuinely adds value to power-sector decarbonization, *how* its electricity footprint can be minimized through algorithmic and hardware efficiency, and *what* policy guard-rails can contain rebound effects.

The decision to commission the present study, with support from GIZ's Energy Support Programme, flows directly from this convergence of opportunity and risk. Vietnam's regulator, system operator and investors need a clear map of proven AI and broader digital solutions to evaluate which combinations merit pilot deployment or scale-up in Vietnam. They also need a transparent appraisal of the hidden pre-conditions: high-fidelity data streams, cyber-secure Operational Technology (OT)/ Information Technology (IT) architectures, skilled human capital and – no less – an enabling regulatory framework that can translate gigabytes of machine insight into bankable revenue streams and socially equitable tariffs.

In that sense, the Rationale of Chapter 1 is twofold. First, to position Vietnam within the global narrative of AI-enabled energy transitions, acknowledging both the accelerating momentum of digital innovation and the emergent constraints highlighted by the latest IEA evidence. Second, to anchor the forthcoming analysis firmly in the mandates of PDP 8, Resolution 57 and the Phase 1 Terms of Reference (ToR), thereby ensuring that every lesson distilled from international experience feeds directly into Vietnam's policy cycle—rather than remaining a detached academic catalogue. Only by aligning technological possibility with regulatory realism and societal priorities can the country convert AI's promise from abstract headline into measurable kilowatt-hour savings, avoided curtailment, and ultimately, avoided tonnes of CO_2.

1.2. Objectives Framed by TOR for Phase 1 Assessment

Phase 1 of the assignment—*Research and Comprehensive Analysis*—aims to act as both diagnostic and prospective. As outlined in the ToR, the main task is to "conduct a review of existing trends, studies and reports on AI and digitalisation in energy transitions globally" and "identify international case-studies and lessons learned related to benefits, policies, inputs and financing." Translating this into operational objectives, four tightly-coupled objectives are formulated.

Objective 1 – Establish a knowledge base.

The report investigates and analyzes peer-reviewed literature, grey papers and industry white books published in the past years — with particular weight given to the IEA's *Energy and AI* (2025), IRENA's *Digitalisation and the Energy Transition* series, the World Bank's *AI in Infrastructure* collection and IEEE flagship transactions. This aims to both present the state of the art but also provide the necessary data for the subsequent gap analysis.

Objective 2 – Extract best-practice archetypes.

Drawing on the results of the literature review, a set of up to ten exemplary case studies will be elaborated. The case studies will traverse geographies and market designs to illuminate multiple pathways toward the same decarbonization goal.

Objective 3 – High level analysis of cost vs benefits.

Because AI deployments impose non-trivial demands on data governance, cyber-security and electricity supply, benefits must be weighed against lifecycle energy use, capital intensity and social acceptability. A concise high-level benefit-cost analytical lens will therefore accompany each archetype based on existing literature, flagging both gains and "dark-corners" such as algorithmic bias, stranded-asset risk or rebound electricity demand.

Objective 4 – Prepare Vietnam-specific intelligence.

All findings will be cross-referenced to PDP 8 targets and to MOIT's ongoing digital-grid initiatives. This will allow immediate identification of high-leverage opportunities—say, AI-enhanced short-term solar forecasting for the Ninh Thuan–Binh Thuan solar clusters—as well as early warnings where pre-conditions (e.g., data latency, cyber standards) remain weak. The output will feed directly into the stakeholder consultation agenda and the preliminary roadmap requested under Task 3.

Delivering on these objectives will equip policymakers, system operators and financiers with a coherent evidence basem distilled into actionable next steps.

1.3. Scope and Boundaries

The analytical perimeter of this working document is intentionally constrained to maximise relevance and depth. **First, sectoral scope** is confined to the electricity supply-demand continuum: generation (centralised and distributed), transmission, distribution and end-use electricity services including e-mobility charging. Heat networks, gaseous fuels and industrial process optimization are considered only to the extent they exert material feedback on grid operation—for example through electric-boiler demand response or electrolyzer load shifting.

Second, technological scope spans the spectrum of digital solutions that either (a) embed AI/ML logic—supervised learning, reinforcement learning, evolutionary optimization, knowledge-based reasoning—or (b) provide enabling digital infrastructure without which AI cannot function, notably advanced metering infrastructure (AMI), IoT sensor webs, cloud/edge compute, 5G private networks and cyber-security frameworks. Conventional SCADA and deterministic automation are referenced as baselines but fall outside the primary objective unless augmented by AI modules.

Third, geographical scope adopts a genuinely global perspective while retaining a Southeast-Asian vantage point. Evidence from OECD jurisdictions offers examples of sophisticated market instrumentation and high-penetration RES balancing techniques; evidence from India, China, South Africa and Brazil highlights solutions developed under conditions of rapid load growth, regulatory flux and cost sensitivity. Low-income contexts enter chiefly where pay-as-you-go or micro-grid logistics reveal lessons for Vietnam's mountainous or islanded provinces. Regional alignment with ASEAN-level initiatives is highlighted where cross-border interconnection or data-centre clustering bears direct influence on Vietnam's grid stability.

Fourth, temporal scope centres on the 2025-2035 horizon, mirroring PDP 8's near- to mid-term planning window. Earlier pioneering deployments (e.g., Spain's wind-power forecasting in the 2000s) are cited minimally as historical context; speculative visions of post-2040 artificial general intelligence are explicitly excluded.

Fifth, evaluative boundaries are set to ensure intellectual rigour. Only deployments that report quantifiable performance indicators such as percentage improvement in solar forecast accuracy, reduction in SAIDI/SAIFI, or net-present-value impact are accepted as evidence of "best practice." Pilot demonstrations lacking post-implementation metrics are treated as emergent experiments rather than validated exemplars.

Finally, we need to also highlight **what the report does *not* cover**. Detailed cybersecurity penetration testing, full lifecycle environmental assessment of semiconductor supply chains, and the socio-psychological ramifications of AI-mediated labour displacement are not analysed in this report but can be part of Phase 2's Readiness Assessment. Likewise, the report will not prescribe vendor-specific solutions; its purpose is to illuminate functional capabilities and prerequisite conditions, leaving technology procurement choices to subsequent feasibility studies.

By drawing these boundaries, the study aspires to balance breadth—capturing the heterogeneity of international AI-in-energy practice—with depth, offering Vietnam's decision-makers a distilled collection of insights that map directly onto the nation's electricity-sector priorities and institutional realities.

1.4. Analytical & Literature-Review Methodology

Given the very short implementation period and resource availability for this project, it was decided to adopt a **lean-but-rigorous heuristic** that privileges *decision-usefulness* over encyclopaedic completeness. Three concentric rings frame the effort: (i) a streamlined search protocol that can offer immediate results; (ii) a rapid-evidence appraisal lens that prioritized material according to transferability and credibility; and (iii) a transparent statement of residual blind-spots so that subsequent readers may know where certainty ends and informed conjecture begins.

Operating under a constrained calendar introduces at least four non-trivial caveats:

1. **Selective saturation** – *The lean methodology captures salient but not necessarily exhaustive evidence. Niche sub-disciplines, quantum annealing for power flow analysis, for instance fall outside the radar unless referenced by a flagship body.*

2. **Grey-literature opacity** – *Utility white papers often hide the raw numbers behind NDAs. Where only percentage gains are quoted, "baseline unknown" will be annotated and the findings as directional, not definitive.*

3. **Energy-use uncertainty for AI** – *Dataset variance in GPU farm metering remains high; cost- benefit ratios involving AI energy have broad error margins.*

4. **Commercial neutrality but unavoidable exposure** – *Some vendors dominate literature by sheer publishing muscle. Inclusion does not equal endorsement; every citation is parsed for functionality, not brand prestige.*

The performed literature review, already highlights:

- **Proven AI use-cases ready for near-term pilots** *(e.g., 15-minute solar now-casting combined with adaptive ESS charge windows).*

- **Digital pre-conditions that cannot be sidestepped** *(e.g., sub-second SCADA latency for loop-flows on the 500 kV backbone).*

- **Financing archetypes whose paperwork fits MOIT's institutional bandwidth** *(e.g., results-based concessional grants blended with private ESCO equity).*

Anything beyond that moves into diminishing returns territory under the present contract's time and resource constraints. In short, the review is compact enough, yet sufficiently stocked with calibrated instruments to diagnose, prioritise and initialise Vietnam's first generation of AI-enabled power-sector interventions.

CHAPTER

02

Conceptual Framework: Digitalization, AI & Their Convergence

Chapter 2: Conceptual Framework: Digitalization, AI & their convergence

2.1. Introduction to digitalization

Historically, the architecture of electric-power systems has followed an essentially a linear blueprint. Sizeable, remotely sited thermal or hydroelectric stations feed bulk electricity into high-voltage transmission corridors, where one-directional flows descend to passive distribution feeders to supply equally passive end-users. Generation, being both dispatchable and forecastable, followed a basically stochastic demand curve, while the network's role was limited to passive transmission and distribution, instrumentation, telemetry, and automation scarcely expanding beyond rudimentary SCADA loops.

The large-scale penetration of variable renewable-energy sources (RES) — notably utility-scale wind-power plants and solar-photovoltaic arrays — has fractured that paradigm. The contemporary system now comprises a heterogenous portfolio. On one side conventional central stations co-exist with transmission-connected RES farms and an increase share of distribution-level distributed generation (DG). Consequently, electricity and information now circulate bi-directionally: supply is partially stochastic and geo-dispersed, demand is increasingly elastic and controllable, and formerly "silent" customers evolve into active market participants whose demand-side resources can be orchestrated for system services. Distributed energy storage, vehicle-to-grid electric vehicles, and ubiquitous two-way communications together dissolve the historic boundary between production and consumption. Centralised dispatch, while still indispensable, must therefore coexist with nested layers of decentralised, device-level intelligence.

To accommodate these dynamics driven by high RES shares, booming DG, prosumer engagement, and the imperative of market integration and security of supply — both transmission and, critically, distribution infrastructures must graduate to a smart-grid operating regime. That evolution hinges on pervasive digitalisation and advanced information-and-communication technologies capable of real-time sensing, analytics, and autonomous control. The International Electrotechnical Commission (IEC) states that the term Smart Grid has drifted into marketing language. Nevertheless, IEC Strategic Group 3 anchors the concept in the systematic modernisation of power networks through digital enablers[4]. In practice, a smart distribution grid becomes the operational crucible where bi-directional power flows, cyber-physical coordination, and distributed optimisation converge, thereby reconciling

[4] IEC, IEC Smart Grid Standardisation Roadmap, 2010

variable generation with secure, efficient, and participatory electricity delivery. ***Figure 1*** presents graphically the evolution of traditional grids of the past in the smart grids of the future. ***Figure 2*** presents the technology areas of the digitalized grids.

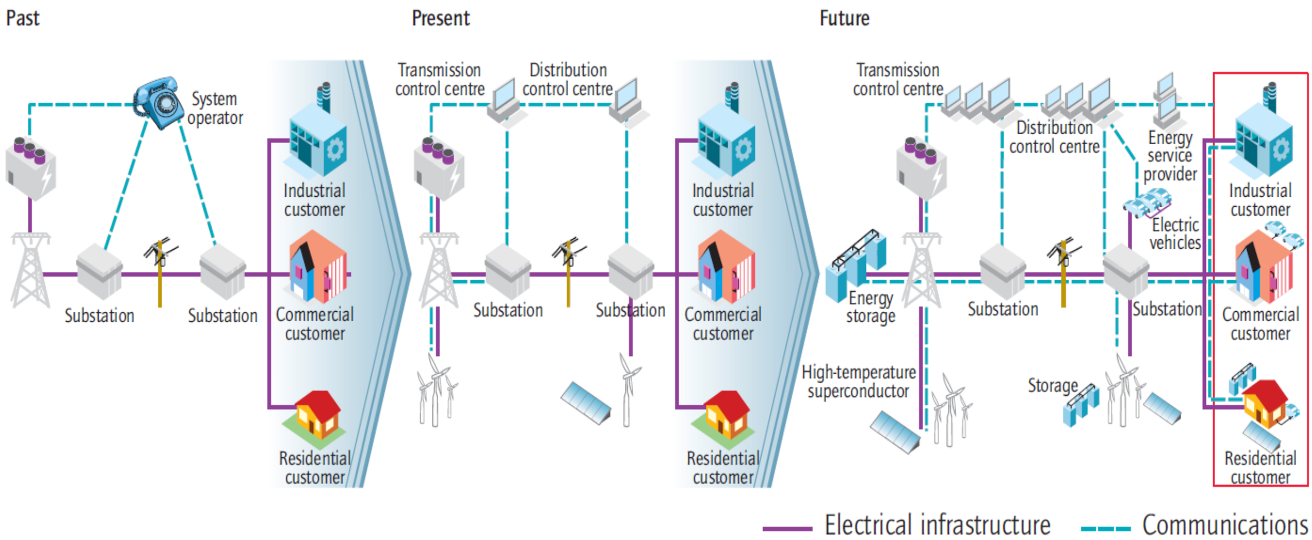

Figure 1: Evolution of transmission and distribution systems into smart transmission and distribution grids (Source: IEA, Technology Roadmap – Smart Grids, 2011)

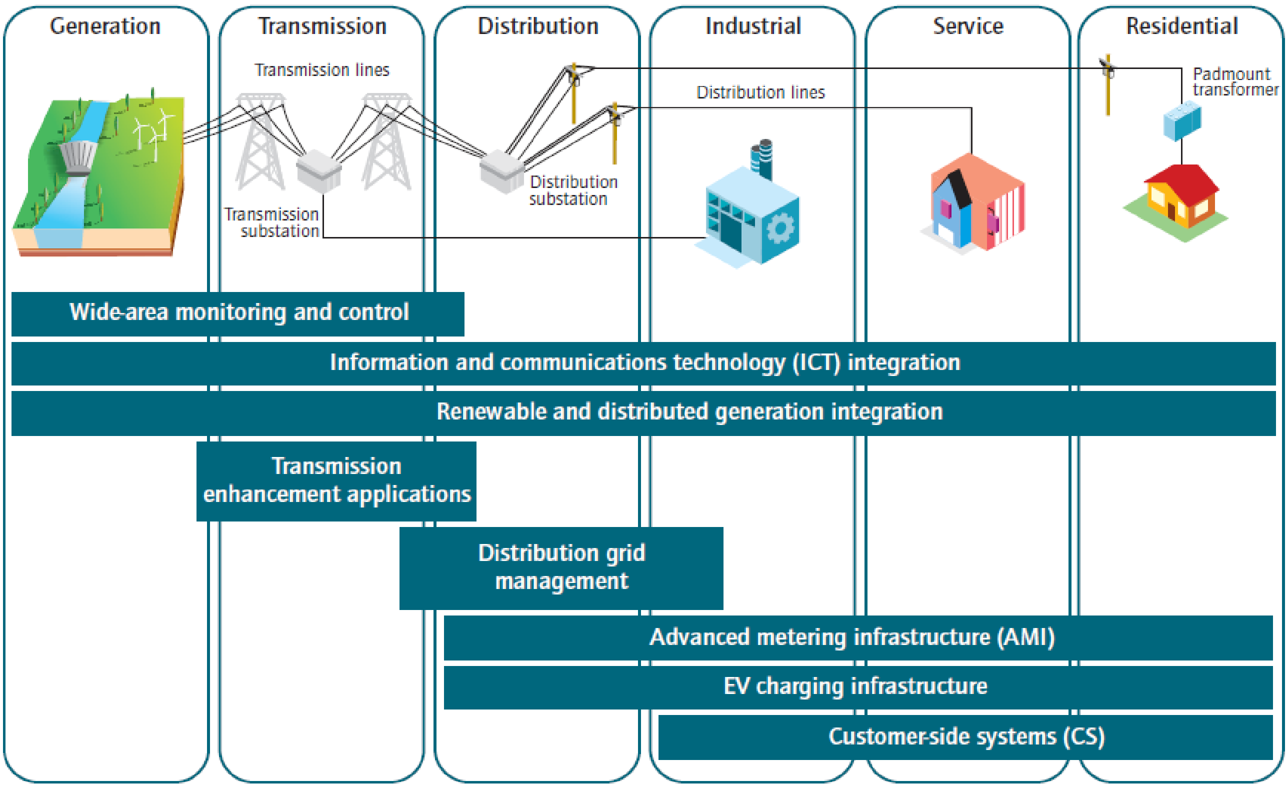

Figure 2: Smart Grid Technology areas (Source: IEA, Technology Roadmap – Smart Grids, 2011)

2.2. Electricity Grids Digitalization Activities

The following table presents a summary of actions related to grid digitalization activities, their expected impact, and their estimated costs and benefits.[5]

Table 1: Summary of smart distribution grid actions

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
0.1	Implement limited FLISR on worst performing feeders	Equip existing electrically operable switches (reclosers, load break switches) with faulted circuit indicators and loss of voltage indicators; if no switches exist, then these need to be installed (1½ switches per feeder); use local logic to determine when to operate switch in question (no comm. required)					Reduce amount of unserved energy Reduce fault investigation and switching time (labour savings)	$50,000 – $150,000	$50,000 – $75,000	Assumes feeders have at least one tie to backup source Low-end cost assumes some switches exist Benefits are derived from final customer outage cost savings valued at $10/kWh
0.2	Implement volt/VAR control	Add IED controllers to existing capacitor					Improve feeder voltage profile	$15,000 – $25,000	$10,000– $20,000	Cost estimate assumes two switched

[5] Madrigal M., Uluski R., Mensan Gaba K., Practical Guidance for Defining a Smart Grid Modernization Strategy – The case of distribution, Revised Edition, World Bank, 2017

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
	(including conservation voltage reduction) using local "stand-alone" controllers	banks and voltage regulators and control these devices using local measurements and control logic								capacitor banks are added to existing feeder along with new IED controllers for capacitor banks and voltage regulators; Benefits based on 1% voltage reduction at peak load with CVR factor = 0.7, and power factor improvement from 0.9 to 0.94
0.3	Apply Optimal Network Reconfiguration (ONR) software	Use off-line ONR software to identify feeder reconfiguration switching that may be performed to reduce circuit and phase imbalance in order to lower electricity losses					Reduce phase imbalance Balance load between feeders	$2,500 – $5,000	$2,000 – $4,000	Costs include labour to build models, run ONR software, and perform recommended switching actions (to new equipment) Benefits are reduced by losses, which are assumed to be 10%–15% less than present technical losses (estimated at 4% of total

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
										energy consumption)
0.4	Implement mid-line voltage regulators with reverse power flow and cogeneration features	Replace unidirectional voltage regulators with voltage regulators that can respond properly to reverse power flow due to feeder reconfiguration or due to high penetration of DG					Improve voltage profile	$8,000 – $12,000	$6,000 – $10,000	Costs include addition of voltage regulator with bidirectional voltage controls (with cogeneration feature) Benefits (including accommodation of more DG) are in the savings associated with not having to build new centralised generating units to serve load
0.5	Transition to Level 1	Replace electromechanical controllers, protection, and metering devices in substation with substation IEDs, along with substation remote terminal units or data concentrators that acquire, store, process, and transmit					Enable Level 1 application functions	$15,000 – $20,000 per feeder, plus $200,000 – $500,000 for basic master station in control centre	Specific benefits Identified under Level 1 actions	Assume 2-3 electromechanical devices per feeder (protective relay, meter IED, and possibly a voltage regulator) need to be replaced with substation IEDs; also need substation SCADA facilities and communication link to control centre and SCADA

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
		information acquired from IEDs to a control centre Add reliable and effective comm. facilities between the HV/MV substations and the distribution control centre (or equivalent centralised facility)								master station in control centre
1.1	Implement monitoring of protective relays for early detection of feeder outages	Add alarm points and displays for alerting DSOs of un-commanded change of state for substation circuit breaker					Detect customer outages before customer calls occur (customer satisfaction improvement)			Cost estimate assumes benefits based on 1% voltage reduction at peak load with CVR factor = 0.7, and power factor improvement from 0.9 to 0.94
1.2	Implement fault location application (distance to fault)	Acquire distance-to-fault information, relay targets, and other event information from protective relay IEDs, and report information to DSO via					Reduce fault investigation time (labour savings)			

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
		substation SCADA facilities								
1.3	Implement fuse-saving protection scheme	Implement software to enable control room operator to switch between preestablished relay setting groups to apply fuse-saving protection					Eliminate labour costs to replace fuses for temporary faults			
1.4	Implement intelligent bus failover application	Implement software in substation SCADA processor to allow automatic transfer of selected feeders for a substation transformer fault to backup transformer without overloading that transformer					Reduce labour costs for manual switching			
1.5	Implement equipment health monitoring (condition	Use substation SCADA processor to acquire equipment health data from protective relays					Lower equipment maintenance and repair costs by transitioning from routine			

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
	based maintenance)	and other substation IEDs; available information include circuit breaker timing and contact wear, substation battery performance, and device counters					scheduled maintenance to "as needed" maintenance			
1.6	Implement SCADA "rule-based" volt/VAR optimisation system	Use substation SCADA processor to control substation voltage regulator and substation capacitor bank for improved volt/VAR control (control still limited to substation devices due to lack of comm. with field devices— Level 2)					Monitor condition of substation volt/VAR equipment for early failure detection			Benefits vs standalone controller approach: can use on-line power flow (1.7 below) to identify electrical conditions at feeder extremities and thereby maximise benefits of volt/VAR optimisation by operating closer to limits Also has early failure detection, ability to modify volt/VAR optimisation objective based on system conditions, ability to disable following feeder

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
										reconfiguration or other abnormal condition Benefits based on 2% voltage reduction at peak load with CVR factor = 0.7, and power factor Improvement from 0.9 to 0.94.
1.7	Implement an on-line power flow software to be used by DSO	Implement an on-line power flow software that uses measurements from the head end (substation end) of the feeder to compute electrical conditions at all feeder locations (on-line power flow requires an "as operated" model of the electric system to operate correctly)					Enabler for many advanced distribution applications – greatly improved visualisation for feeder locations at which no sensors exist		No direct tangible benefits, but on-line power flow software enables advanced applications	Cost includes on-line power flow software purchase and implementation, model building, and maintenance No direct tangible benefits
1.8	Implement predictive fault location application function	Add short circuit analysis software that uses fault magnitude from substation IEDs to					Reduce fault investigation time (labour savings)			Cost includes software purchase and implementation costs

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
		pinpoint fault location								Benefit includes 5% to 10% improvement beyond what protective relay distance-to-fault calculation supplies
1.9	Detection of reverse power flow at substation end of feeder due to high penetration of DG	Monitor real and reactive power flow at the head end of the feeder to detect possible adverse consequence of high penetration of DG, such as reverse power flow and high phase imbalance								Benefit is that the allowable penetration of DG on a given feeder may increase due to improved capability to monitor some of the potential adverse consequences of high DG penetration
1.10	Transition to Level 2	Add a comm. network for supporting two-way communications between substation and field devices for remote monitoring and control of feeder equipment					Enables Level 2 functions and projects	$15,000 – $30,000 per feeder	Specific benefits identified under Level 2 actions	Transition costs include addition of two-way communication facilities between control centre/substation and feeder devices (switchgear, voltage regulators, switched capacitor banks, distributed

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
										sensors) installed outside the substation fence Estimate based on comm. facilities to 5–10 field devices per feeder, plus necessary repeaters, collectors, data concentrators, routers, and other equipment needed to implement the comm. network
2.1	Implement FLISR application	Add automated switches, fault detectors or faulted circuit indicators, and software for implementing the FLISR functionality					Reduction in manual switching activities and fault investigation time (labour savings)	$100,000 – $150,000		Costs assume 2 to 3 new switches per feeder, comm. system interface, and fault detectors, plus FLISR software for substation or master station (software costs shared across many feeders) Outage duration improves by 50% to 60% Cost does not include cost to add

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
										backup source to existing feeder
2.2	Advanced substation bus failover	Add control of feeder switches to the intelligent bus failover application Feeders that cannot be transferred to remaining healthy transformer due to loading constraints will be switched to adjacent feeders using DA switches					Defer adding substation capacity to provide firm capacity (defer CAPEX)	$10,000 – $15,00		Cost includes additional software only Necessary switches and comm. facilities included in Level 2 transition costs
2.3	Coordinated volt/VAR control with conservation voltage reduction	Add control of switched capacitor banks and mid-line voltage regulators located out on the feeder (outside the substation fence) to the volt/VAR optimisation algorithm					Improved voltage profile			Costs include addition of comm. interfaces to volt/VAR devices located out on the feeder (controllable capacitor banks and voltage regulators added under 0.2 above) Benefits include coordinated control of volt/VAR devices located in

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvemen t	RES Integration	Other			
										substations and out on feeder
2.4	Improved on-line power flow	Improve the accuracy of results produced by on-line power flow (1.7 above) by using measurements acquired from feeder devices and distributed sensors					Enabler for many advanced distribution applications Greatly improved visualisation for feeder locations at which no sensors exist		No direct tangible benefits, but on-line power flow software enables advanced applications	Cost includes labour to modify feeder models used by on-line power flow software
2.5	Optimal network reconfiguration	Add automatic switching to ONR application (0.3 above) This will enable more frequent change of the feeder configuration to accomplish load balancing objectives					Reduction of manual switching activities (labour savings) by using remote controlled switches for feeder reconfiguration		.	Cost includes software modifications Automated switches and communication facilities were added during previous actions Benefits include loss reduction and improved phase balance
2.6	Monitoring and transfer tripping of DG units	Use two-way communication facilities to monitor and control the output of larger-scale					Improved power flow results due to accurate measurement of DG output			Costs include monitoring and control facilities plus comm. interface at large scale DG units out

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
		customer-owned DG								on distribution feeders Benefits include improvement in allowable DG on feeder, and operating advanced DA applications closer to established operating limits
2.7	Transition to Level 3	Implement active control of DERs (DG, DES, DR) located out on the feeder and at final customer sites (beyond the meter)						Specific benefits identified under Level 3 actions		Costs include implementation of controllers and associated comm. interfaces at DERs Assume that communications will be done through the Internet or through AMI comm. network (RF mesh or other media)
3.1	MG operation	Implement an MG EMS that is able to support parallel operation and island operation modes for the most critical loads					Increased revenue from participation in the electricity market	Cost of MG EMS components (hardware and software) Add switchgear to switch to island mode	Resiliency benefit for critical loads is intangible DR market benefit is about $40,000 per MW per year	Costs include MG master station (hardware and software) for managing available DERs to achieve specific

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
		Use this system to manage the operation of available DERs								business objectives Benefit include DR during peak load periods and ability to serve critical loads during power grid outages (intangible benefit)
3.2	DES enhanced FLISR	Deploy enhanced FLISR software that uses DES capabilities to reduce occurrences of blocked transfers by "standard" FLISR applications						Enhance standard FLISR software (2.1 above)	Fewer blocked FLISR load transfers (assume 10% blocked without DES; 5% blocked with DES)	Costs include software additions to incorporate management of available DES in FLISR application software Costs do not include installation of DES (assume existing DES is used) Benefits include fewer blocked load transfer during FLISR operations
3.3	DER-enhanced volt/VAR control and optimisation	Use smart inverter based DERs to improve volt/VAR optimisation on a given feeder					Improve voltage quality and reduce wear on electromechanical switching devices (load tap changers,	Add D-Statcom to distribution feeder with high penetration of distributed renewables	Accommodate more DG (20% or more) on given feeder by addressing voltage	Costs include installing D-Statcom that can respond rapidly to voltage fluctuations

Action No.	Action Name	Action Description	Benefit Type					Estimated Cost Range ($/feeder/year)	Estimated Benefit Range ($/feeder/year)	Comments
			Efficiency Improvement	Demand Reduction	Reliability Improvement	RES Integration	Other			
							switched capacitor banks)		and power fluctuations	Comm. not required as these devices operate autonomously Benefits include ability to accommodate more distributed renewables (wind, solar) on a given feeder

2.3. Defining Artificial Intelligence In The Power Sector

At first glance, “artificial intelligence” seems an extravagant label for what many grid engineers still experience as a scatter-plot of Python scripts and heuristic PID tunings. Yet history counsels caution: the steam engine, too, began life as a noisy contraption attached to a grain mill before it led the way for the industrial revolution. To speak coherently about AI in electricity, we must therefore step back from the wealth of algorithms and recover a conceptual compass—one that distinguishes marketing language from genuine cognitive capability, identifies the classes of problem each family of technique can or cannot solve, and clarifies where today’s “narrow” agents end and tomorrow’s still-hypothetical general intelligence might begin.

2.3.1. Four Classical Vantage-Points

In the past decades, AI research and applications embraces Russell & Norvig’s two-by-two matrix-thinking versus acting, humanly versus rationally-as a concise lens through which to survey the emerging AI landscape, and it remains equally instructive for power-sector applications. Systems that act humanly would aspire to pass a grid-specific Turing test: could an operator, scrutinizing SCADA trends at 02:00, be fooled into believing dispatch advice originated from a seasoned colleague rather than an LLM? Those that think humanly emulate cognitive pathways—Bayesian causal reasoning, mental simulation—offering value in model-based stability prediction. Systems that think rationally prioritize deductively valid inference (for example, symbolic contingency analysis), while those that act rationally pursue goal-directed behaviour under uncertainty—the hallmark of reinforcement-learning voltage controllers. Each trajectory has yielded fertile insights, and, crucially, each imposes a distinct burden of explainability, data volume and compute resources[6].

2.3.2. Narrow AI, General AI, and The Practical Horizon

In the contemporary power sector, virtually all deployments fall within the realm of **narrow AI**—systems laser-focused on a delimited task (for instance, classifying insulator defects in aerial imagery or forecasting solar irradiance fifteen minutes ahead). Their competence often surpasses human speed and consistency on that single axis, yet collapses if the problem formulation drifts. **Artificial General Intelligence (AGI)**, conversely, denotes the theoretical threshold at which an agent can perform any economically valuable cognitive task at or above expert level—solve optimal power flow, debate policy trade-offs and draft ISO tariff codes within a unified model[7]. **Superintelligence** starts at the point AGI is reached, since after it, AGI can evolve autonomously or even independently surpassing by large human intelligence. The point in time AGI is achieved is often called Singularity.

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[6] https://people.eecs.berkeley.edu/~russell/intro.html

[7] https://www.ibm.com/think/topics/artificial-general-intelligence

This is graphically presented in the following image.

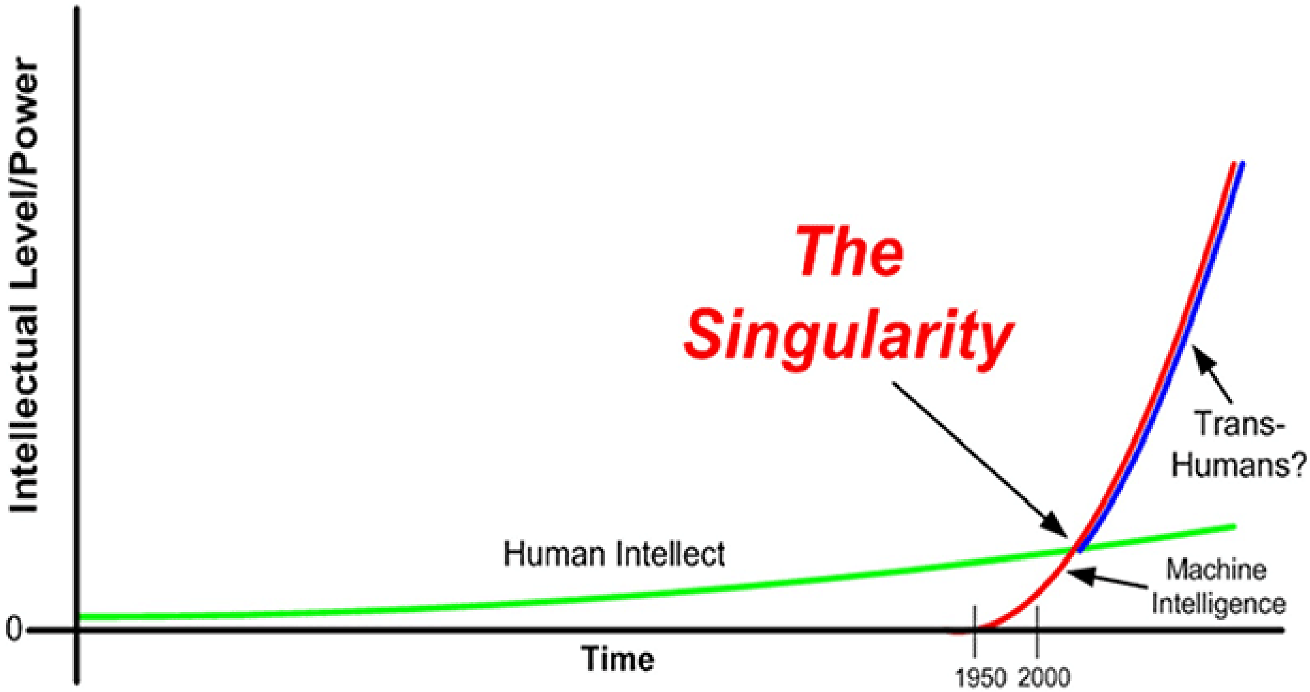

Figure 3. Singularity (source: https://beincrypto.com/singularity-ai-will-change-our-world/)

The importance for defining concretely what Artificial Intelligence is stems from the fact that expectations shape procurement. A system planner who equates today's narrow-AI trials with AGI "magic" risks overpaying for unproven black boxes, while a regulator haunted by AGI dystopias may throttle deployment of contained narrow models that could shave five percentage points off technical losses this fiscal year. Accordingly, this report adopts a **bounded-intelligence** baseline: every algorithm cited operates within explicit data guard-rails and domain-specific safety envelopes, and none approach self-improving super-intelligence. Nonetheless, it is sensible to recognise that modern transformer and graph-neural architectures scale non-linearly with compute; the energy appetite documented in the IEA's *Energy and AI* report foreshadows how quickly narrow tools can mutate toward broader agency if left unchecked.

We need not forget that ChatGPT 3.5 was released on November 30, 2022. That is less than 3 years ago. The average person got to use for free a large language model for the first time and this could be considered as the tipping point towards the future of AI. In this very short time period, research is implemented at an ever-accelerating pace. Advanced AI systems have already permeated a broad spectrum of research domains, serving as a catalyst for marked gains in productivity[8]. Moreover, recent investigations have demonstrated that digital "personalities"—autonomous agents engineered to emulate human behavioral patterns in virtual settings—can establish relational dynamics, coordinate complex tasks and respond to stimuli with a high degree of credibility[9]. Follow-on studies have examined the construction of individualized behavioral simulations via structured interviews coupled with AI inference engines, reporting predictive accuracies of approximately 85 percent when forecasting participant reactions[10]. Simultaneously, frameworks for fully autonomous research—built upon state-of-the-art large language models (LLMs) operating within multi-agent topologies—have been instantiated and continue to evolve, thereby enabling open-ended, self-directed scientific inquiry without human intervention[11]. While challenges still exist in such frameworks[12], the Sakana AI Scientist passed the peer-review process at a workshop in a top international AI conference[13]. While the acceleration of knowledge creation afforded by these tools is undisputable, empirical evidence indicates a paradoxical decline in researcher fulfillment, even as publication metrics climb—an outcome that highlights the inherent challenge of integrating AI seamlessly into routine scholarly workflows[14].

2.3.3. Foundation Paradigms and Their Electricity-Sector Applications

The accelerating connection of variable renewables, distributed energy resources (DERs), and bidirectional power flows has rendered the contemporary grid an intricate, data-saturated ecosystem, one whose dimensionality now exceeds the reach of classical optimization and heuristic rule sets[15]. Artificial Intelligence (AI) therefore emerges as the key approach for both strategic planning and real-time orchestration. Crucially, the mathematics underpinning the dominant AI paradigms - machine learning, probabilistic and Bayesian inference, large-scale optimization, multi-agent coordination, knowledge-based expert systems, and hybrid neuro-symbolic architectures - draw upon decades of peer-reviewed maturation, with post-2018 advances in cloud computing and edge digitalization sharpening their fidelity and tractability.

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[8] Villalobos-Alva, J.; Ochoa-Toledo, L.; Villalobos-Alva, M.J.; Aliseda, A.; Pérez-Escamirosa, F.; Altamirano-Bustamante, N.F.; Ochoa-Fernández, F.; Zamora-Solís, R.; Villalobos-Alva, S.; Revilla-Monsalve, C.; et al. Protein Science Meets Artificial Intelligence: A Systematic Review and a Biochemical Meta-Analysis of an Inter-Field. *Front. Bioeng. Biotechnol.* 2022, *10*, 788300.

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[15] https://www.iea.org/commentaries/why-ai-and-energy-are-the-new-power-couple

For policy makers, six paradigms now constitute a pragmatic toolkit:

1. Machine Learning (supervised, unsupervised, reinforcement)
2. Probabilistic & Bayesian Methods
3. Optimisation (meta-heuristics to convex programmes)
4. Multi-Agent Systems
5. Knowledge-Based & Expert Systems
6. Hybrid Neuro-Symbolic and Graph-Neural Approaches

Each contributes discrete value to decarbonization, reliability, efficiency, and resilience agendas, collectively providing an evidence base for data-driven governance in digitalized grids.

Machine Learning in Power Systems

Machine Learning (ML) comprises algorithmic structures able to infer latent patterns from data and iteratively update their internal representations, thereby providing rigid, ex-ante programming. The combination of supervised (label-driven), unsupervised (cluster-seeking), and reinforcement (trial-and-error reward) learning leads to adaptivity indispensable for grids subject to stochastic weather, volatile demand, and ageing assets. From early regression techniques through multilayer perceptrons to contemporary deep networks, the discipline's framework is scientifically mature and demonstrably capable of utilizing terabyte-scale sensor streams[16]. Key applications include:

- Forecasting of Demand and Variable Supply
- Predictive Maintenance and Asset Health
- Automated Visual Inspection
- Operational Optimization via Reinforcement Learning
- Consumer-Side Analytics and Market Integrity

Machine-learning applications now span the electricity value chain from generation forecasting to retail analytics, demonstrating that AI applications are not prospective novelties but operational realities iterating toward ever higher precision. For regulators and planners, the policy implication is clear and is to integrate mature AI paradigms into grid codes, investment plans, and reliability standards.

[16] https://www.pacw.org/ai-in-electric-power-systems-protection-and-control

Probabilistic & Bayesian Methods

Electricity networks are, by nature, stochastic systems which include intermittent renewables, random equipment contingencies, and oscillating demand profiles. Probabilistic and Bayesian analytics confront that indeterminacy by substituting deterministic point estimates with full probability distributions, thereby mapping likelihood rather than binary certainty. Its practical implementations span classic Monte-Carlo reliability assessments, Bayesian networks for causal inference, and Bayesian optimization for decision-making under uncertainty. In operational terms, grid operators migrate from the ask of "Will event X occur?" to the richer query "With what probability will event X manifest within the planning horizon?", a paradigm shift that yields more resilient dispatch and expansion plans. Key applications include:

- Probabilistic Forecasting
- Risk-Based Grid Planning and Adequacy
- Real-Time Operation and Reliability Management
- Bayesian Optimization and Tuning

Probabilistic and Bayesian approaches allow regulators to articulate resource-adequacy targets in explicit loss-of-load probabilities, going beyond traditional reserve-margin heuristics. Jurisdictions with deep renewable penetration, such as the United Kingdom and Germany, already employ probabilistic adequacy and forecasting schemes to retire fossil capacity with confidence, all while safeguarding reliability[17]. For emerging systems, Bayesian methods provide an approach to integrate scarce local data with expert knowledge, progressively refining planning benchmarks as observability improves. Computational burden and workforce upskilling remain non-trivial, yet falling compute costs and growing academic - industry collaboration are rapidly lowering the barrier to entry.

Optimization

Optimization frames grid questions - economic dispatch, network reinforcement, storage siting—as mathematical problems that seek minima (cost, emissions) or maxima (welfare, security) subject to physicotechnical constraints. The methodological spectrum runs from linear and mixed-integer formulations, through nonlinear and stochastic variants, to meta-heuristics such as genetic algorithms and particle-swarm optimization. Decades of refinement have rendered commercial solvers extraordinarily potent, and hybridization with machine-learning surrogates is now driving leaps in speed and scalability. Key applications and use cases include:

- Economic Dispatch and Unit Commitment
- Optimal Power Flow (OPF)

[17] https://www.iea.org/articles/energy-transitions-require-innovation-in-power-system-planning

- Planning and Investment Optimization
- Real-Time Control Optimization
- Multi-Objective and Heuristic Optimization

Optimization is the most direct connection between AI and cost-efficiency. By extracting maximum service from existing assets, it liberates capital for low-carbon reinvestment. The same machinery minimizes curtailment, manages storage dispatch, and performs security-constrained economic dispatch, thereby aligning decarbonization, reliability, and affordability objectives. A recent survey underscores that distributed and hierarchical optimization architectures are indispensable for high-DER futures[18]. Policy action should therefore focus on mainstreaming advanced optimizers, especially in systems where deterministic or manual scheduling still prevails, and on codifying regulatory incentives that reward utilities for the provable efficiencies yielded by optimal power-flow reconfigurations.

Multi-Agent Systems (MAS) & Distributed Intelligence

Multi-Agent Systems decompose the monolithic grid controller into swarms of autonomous yet communicative agents, each representing a device, microgrid, prosumer portfolio, or even a market participant. Inspired by decentralized natural and economic systems, MAS architectures scale effectively with increasing DER and electromobility, avoid single points of control failure, and natively encode heterogeneous ownership and incentive structures. Key applications include:

- Distributed Energy Resource Coordination
- Microgrids and Self-Healing Grids
- Grid Market Simulation and Smart Markets
- Voltage and Frequency Control with Distributed Agents

The application of MAS and Distributed Intelligence has concrete benefits. Reliability is increased through distributed fault response: numerous local controllers act synergistically to stabilize voltage or frequency before a central dispatcher can intervene. Efficiency gains accumulate from fine-grained demand-side optimization, while decarbonization benefits stem from the seamless orchestration of rooftop PV, electric vehicles, and behind-the-meter storage. Field pilots, from peer-to-peer microgrids in Africa to swarm electrification schemes in Asia, demonstrate that sophisticated MAS control is feasible even in resource-constrained contexts, provided interoperable standards and cyber-secure communication protocols are in place.

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[18] https://www.mdpi.com/1996-1073/18/7/1837

Knowledge-Based & Expert Systems

Long before data-hungry neural nets dominated practice, electric-utility engineers were already encoding their heuristics into knowledge-based or expert systems: rule engines whose inference cores translate if-then statements into repeatable operational advice. A structured architecture couples a knowledge base which includes facts, ontologies and contingency tables with an inference engine that navigates those rules to deliver diagnoses or recommended actions. The underlying science, first-order logic, production-rule firing and truth-maintenance has been technically achieved since the 1980s, which explains why contemporary decision-support dashboards and semantic grid "knowledge graphs" still trace their lineage to this paradigm. Key applications and use cases include:

- Fault Diagnosis and Restoration Guidance
- Protection and Control Settings
- Maintenance and Asset Management
- Operator Training and Advisory Systems
- Knowledge Graphs and Semantic Integration

Two aspects ensure secure ongoing relevance. The first aspect is reliability, through codifying veteran operator know-how which ensures that best practice persists even as senior staff retire or as utilities in emerging markets fast-track competence by "importing" expertise in software form. The second aspect is transparency because every recommendation can be traced to a specific rule, regulators obtain an immediate audit trail which critical when explaining, e.g., the logic that triggered selective load-shedding. Pure rule bases, however, struggle with unknown unknowns and require laborious upkeep as grid topologies evolve. Hence the sector is migrating toward hybrid constructs that integrate data-driven learners onto symbolic frameworks which retain explicability while widening the envelope of adaptive behavior. Still, policy frameworks that support systematic knowledge capture today (before the last generation of analogue-era engineers retires) will secure an extremely high return in operational safety, training, and institutional memory.

Hybrid Neuro-Symbolic & Graph Neutral Approaches

Neuro-symbolic AI fuses pattern-extracting neural networks with the rule-bound reasoning of symbolic logic, thus integrating statistical generalization to codified domain constraints. Graph Neural Networks (GNNs) extend this union by embedding the grid's native topology, nodes, edges and flows directly into the learning base, allowing the algorithm to "think" in the language of Kirchhoff rather than pixels or sequences. Such hybrids are already tackling problem classes resistant to single-paradigm tools. Consider real-time contingency analysis: a GNN can instantaneously flag topological stress, while an overlaid symbolic layer checks the candidate remedial actions against voltage-security rules, preventing the black-box agent from proposing inadmissible set-points. Likewise, large-scale EV-charging orchestration benefits when a deep learner maps emergent demand patterns and a symbolic planner enforces feeder ampacity limits—ensuring flexibility need not compromise safety. Key applications and use cases include:

- Graph Neural Networks for Grid Analysis
- Neuro-Symbolic Reasoning for Grid Management
- Knowledge Graphs with Machine Learning
- Advanced Planning Tools

For regulators wary of *black-box* automation, the hybrid offers a compromise between neural components which identify anomalies and symbolic clauses which narrate why an alert matters ("low voltages in node cluster X coinciding with corridor-Y overload, an indication of contingency class Z"). Programmes such as ARPA-E's grid-event detection initiative testify to public investment momentum, and early studies report tractable, real-time risk assessment on continent-scale models[19]. The policy horizon now includes validation protocols for GNN outputs, mandatory explainability for control-room AI, and cybersecurity guidelines that safeguard both learning modules and rule stores.

[19] https://arxiv.org/html/2405.07343v1

2.4. Synergies of AI & Digitalization

The accelerating transformation of the electricity sector into a responsive, low-carbon cyber-physical organism rests on the coupling of digitalization and artificial intelligence (AI). Though often treated in isolation, the two constitute a mutually reinforcing couple: digitalization provides the data-rich foundation, i.e., sensors, connectivity, and scalable compute, whereas AI builds upon this foundation to realize foresight, optimization, and autonomous control. For policy makers and system planners, the inter-dependencies and boundary constraints within this synergistic relation is indispensable for arranging an efficient, secure, and socially equitable energy transition.

Digitalization, broadly defined as the adoption of digital technologies to alter business and societal processes, provides the foundational infrastructure that enables the collection, transmission, storage, and processing of huge quantities of data. AI implementations, spanning statistical learning, deep neural inference, and reinforcement agents, translate these datasets into granular load-shaping forecasts, state-estimation enhancements, and probabilistic contingency advisories. The resulting feedback loop converts raw data logging into actionable intelligence, improving at the same time grid efficiency and reliability.

The AI–digital nexus operates as a positive feedback engine. Digitalization collects and provides data; data empowers AI; AI insights, in turn, substantiate further digital investment. Equally critical is cyber-resilience. Expanded attack surfaces accompany universal connectivity. Here, AI fulfils a guardian role, statistical and graph-based models scrutinize network traffic for subtle deviations, diagnosing malware or intrusion attempts at latencies infeasible for human operators. In order to ensure effective security of

Notwithstanding its transformative promise, the AI-digital symbiosis is bounded by data-quality thresholds, computational scalability, and workforce skill gaps. Sparse or biased datasets can propagate error through even the most sophisticated algorithms, mandating robust data-governance regimes. Edge-to-cloud compute architectures must be dimensioned to process petabyte-scale telemetry without compromising latency-sensitive control loops. Finally, the human capital capable of configuring, auditing, and continuously refining AI pipelines must be cultivated through targeted skilling programmes.

Realizing the full potential of AI and digitalization in the electricity sector requires careful navigation of several boundary conditions and challenges. These can be summarized in the following five categories:

1. **Data poverty and signal noise.** *Infrastructural deficits such as sporadic AMI roll-outs, unreliable IoT back-haul, problematic cellular coverage, still plague many emerging markets. Where telemetry is incomplete or corrupted, even state-of-the-art algorithms*

end up providing probabilistic guesswork. Robust, inclusive digital infrastructure is therefore pre-conditional, not optional.

2. **Interoperability gridlock.** *Proprietary protocols and vendor-locked data schemes fragment the cyber-physical estate, constraining AI pipelines that depend on seamless cross-platform integration. Only concerted, preferably multilateral standard-setting can dissolve these siloes and unlock scale economies.*
3. **Digital inequity.** *Urban-centric optic fiber rings and high-end devices concentrate AI benefits in rich urban centers, amplifying socioeconomic asymmetries. Equitable roll-out of broadband and edge compute to peri-urban and rural feeders is essential if the digital energy transition is to be both just and politically durable.*
4. **Cyber-attack surface expansion.** *Every new sensor, inverter, or API widens the threat space. AI-enabled intrusion detection must evolve at the pace of adversarial innovation, while regulators tighten compliance rules and incentivize continuous security patching.*
5. **Regulatory inertia.** *Static rule books struggle to accommodate self-learning algorithms and dynamic market participation. Agile governance which includes sandboxes, outcome-based performance metrics and adaptive licensing, will be required to safeguard consumer rights and grid stability without killing innovation.*

The main high-level strategic policy levers can be summarized in:

- **Infrastructure investment:** *Channel capital toward resilient, high-bandwidth digital infrastructure to guarantee dense, low-latency data streams.*
- **Standardization & Interoperability:** *Champion regional and global harmonization standards to eradicate interoperability dead-zones.*
- **Capacity Building:** *Embed AI and data-governance literacy across utilities, regulators, and policymakers via comprehensive capacity building pipelines.*
- **Cyber-resilience mandates:** *Enforce regulatory requirements for cybersecurity and support innovation in AI-based security solutions to protect increasingly digitalized grids from cyber threats.*
- **Regulatory agility:** *Institutionalize sandbox regimes and iterative rule-making so novel digital tools can be tested and optimized under controlled risk environment.*

AI and digitalization, when synergistically integrated, promise transformative improvements in the electricity sector's efficiency, reliability, sustainability, and resilience. Their interdependency underscores a clear policy direction: investments in digital infrastructure and AI capacity must proceed hand-in-hand. Addressing boundary conditions such as data availability, interoperability, digital equity, cybersecurity, and regulatory agility will be crucial. Strategic policy frameworks that recognize and systematically support these synergies and interdependencies are therefore indispensable for realizing a sustainable, digitally enabled, and

CHAPTER

03

Global landscape & Emerging Trends

Chapter 3: Global Landscape & Emerging Trends

3.1. Introduction

Digitalisation of power systems has undergone a remarkable acceleration in recent years, propelled by considerable and fast declines in sensor, computing and connectivity costs. Between 2015 and 2022, global expenditures on digital electric-infrastructure increased by over 50%, now constituting nearly one-fifth of total grid investment. Distribution networks have been the principal locus of this surge—accounting for approximately 75% of digital grid spending—as utilities deploy smart meters, automation devices and advanced control systems at scale. Indeed, the global installed base of smart electricity meters surpassed one billion units in 2022—a tenfold increase since 2010—while billions of connected sensors and IoT endpoints now furnish sub-minute visibility into grid conditions and end-use consumption. This pervasive data layer underpins an unprecedented level of situational awareness and command over network operations[20].

The motivation for this digital transformation is inseparably linked to the imperatives of clean-energy integration towards the energy transition. Large shares of variable renewables—solar photovoltaics and onshore/offshore wind—demand sophisticated, flexible grid management frameworks. Advanced digital platforms and AI algorithms now perform probabilistic forecasting and real-time balancing of supply and demand, thereby smoothing the integration of renewables without compromising reliability. Concurrently, these tools optimize generation dispatch, network delivery and end-use efficiency, yielding both cost and emissions reductions. As the International Energy Agency observes, digital technologies in power systems "hold tremendous potential to forecast and match supply and demand, thereby cutting costs, improving efficiency and resilience, and reducing emissions"[21]. For instance, AI-based analytics now predict solar and wind output with higher fidelity—thus enabling tighter scheduling and reducing curtailment losses[22]. On the demand side, big-data platforms and machine-learning models uncover latent opportunities for load shifting and conservation—spanning intelligent building management systems to adaptive industrial process controls[23].

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[20] https://www.iea.org/energy-system/decarbonisation-enablers/digitalisation

[21] Ibid.

[22] https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector/

[23] https://iotworldmagazine.com/2024/10/10/2495/ai-in-the-energy-sector-emerging-market-trends-projects-and-forecasts-2024-and-2025-2030-in-uk-europe-asia-india-china-japan-and-brazil

Digitalisation has also become a strategic priority across jurisdictions. In 2022, the European Union formalized its Action Plan on "Digitalising the Energy System"[24], incentivizing investments in smart-grid architectures, data-interoperability standards, cybersecurity frameworks and digital-innovation pilots for enhanced efficiency and consumer engagement. In the United Kingdom, Ofgem—together with industry partners—convened an Energy Digitalisation Taskforce whose 2022 recommendations catalysed a "digital spine" initiative, designed to enable real-time data exchange and advanced analytics across the entire transmission and distribution nexus[25]. Across the Atlantic, U.S. utilities and regional transmission operators, under Department of Energy auspices, are deploying a suite of AI-enabled tools to improve grid resilience and operational flexibility[26]. Notably, FERC Order 2222 (2020) has dismantled barriers to the participation of distributed energy-resource aggregations—virtual power plants—in wholesale market mechanisms[27]. In Asia, the State Grid Corporation of China employs AI-driven forecasting models to predict renewable output from meteorological inputs and dynamically adjust dispatch schedules across its 1.1 million km network. India's major renewable developers similarly leverage AI for performance optimization of solar and wind farms[28], while Gulf Cooperation Council states, South Africa, Brazil and other emerging markets have initiated smart-grid and AI deployments as part of broader electrification and modernization drives[29]. Market analysts project that global expenditures on AI-based energy-management solutions will ascend from approximately USD 3.5 billion in 2024 to over USD 12 billion by 2030, driven by utility and industrial adoption for grid integration, renewables forecasting and efficiency enhancements[30]. These investments are based on ambitious climate-action frameworks—such as Europe's Green Deal and national AI strategies—that explicitly champion digital-innovation in the energy domain.

Despite the pronounced leadership of advanced economies, developing regions are increasingly exploring digitalisation and AI to leapfrog legacy architectures[31]. In markets beset by elevated technical losses, limited analytics capacity and rapid demand growth, AI-enabled tools offer a path to more sustainable, resilient power systems. However, significant gaps persist: the IEA cautions that much of the current progress remains confined to high-income countries, and that realising digitalisation's full promise will necessitate intensified capacity-building and capital flow into low- and middle-income regions. Moreover, cross-cutting policy and regulatory frameworks must evolve to address data privacy, cybersecurity and equitable

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[24] https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_6229

[25] https://www.gov.uk/government/publications/energy-system-digital-spine-feasibility-study

[26] https://www.governing.com/infrastructure/can-the-grid-keep-up-with-ai-and-data-demands

[27] https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet

[28] https://iotworldmagazine.com/2024/10/10/2495/ai-in-the-energy-sector-emerging-market-trends-projects-and-forecasts-2024-and-2025-2030-in-uk-europe-asia-india-china-japan-and-brazil

[29] https://www.ifc.org/content/dam/ifc/doc/mgrt/emcompass-note-81-05-web.pdf

[30] https://iotworldmagazine.com/2024/10/10/2495/ai-in-the-energy-sector-emerging-market-trends-projects-and-forecasts-2024-and-2025-2030-in-uk-europe-asia-india-china-japan-and-brazil

[31] https://www.ifc.org/content/dam/ifc/doc/mgrt/emcompass-note-81-05-web.pdf

access to digital solutions[32]. Nonetheless, the trajectory is unmistakable: digital technologies—and AI in particular—are becoming integral to power-sector planning, operations and asset management worldwide. One analysis even suggests that, by 2030, AI-driven applications could abate global power-sector emissions by 10–15 percent through targeted efficiency and optimisation gains[33], thereby reinforcing their pivotal role in achieving Paris-Agreement objectives.

While artificial intelligence (AI) represents a significant tool for optimizing grid operations and renewable integration, recent insights from the International Energy Agency also underline a parallel challenge: AI technologies themselves are rapidly becoming significant energy consumers, with global electricity use from AI-driven data centres set to quadruple by 2030[34]. Recognizing this dual role of AI—as both consumer and optimizer of energy—is critical for a balanced approach to the energy transition.

3.2. Public Sector Initiatives and Policy Frameworks

Governments and regulatory authorities serve as the principal architects of the electricity sector's digital metamorphosis, crafting the policy scaffolding, financing innovation and safeguarding the public interest. Below, key examples are highlighted that showcase leadership by governments, international organizations, and regulatory bodies.

3.2.1. Public Strategies and Action Plans

The European Union's 2022 Action Plan on Digitalising the Energy System is a key policy that synchronises digitalisation with the EU's clean-energy objectives[35]. It prescribes mechanisms for open data access and robust connectivity, orchestrates coordinated investments in smart-grid assets, empowers consumers through advanced metering and demand-response tools, and fortifies cybersecurity and digital resilience of energy infrastructure. Crucially, the Plan envisages a common European energy data space underpinned by interoperability standards, thereby enabling both utilities and agile new entrants to innovate on a level playing field. In parallel, Member States such as Germany and France have embedded energy-digitalisation targets within their national AI strategies and post-pandemic recovery frameworks[36].

In the United Kingdom, government leadership—complemented by the Ofgem-supported Energy Digitalisation Taskforce—has further been codified in the National AI Strategy (2021)[37]

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[32] https://www.iea.org/energy-system/decarbonisation-enablers/digitalisation

[33] https://www.mdpi.com/1996-1073/17/24/6271

[34] https://www.iea.org/reports/energy-and-ai

[35] https://ec.europa.eu/commission/presscorner/detail/en/qanda_22_6229

[36] https://www.iea.org/energy-system/decarbonisation-enablers/digitalisation

[37] https://www.gov.uk/government/publications/national-ai-strategy

and the Ten Point Plan for a Green Industrial Revolution[38], which jointly elevate AI-driven energy innovation to a strategic priority. One tangible outcome is the "digital spine" concept: an architecture to ingest millions of new data points—from EV chargers to solar inverters and smart appliances—and to orchestrate real-time grid coordination via AI analytics[39]. This shift reflects a broader regulatory ethos that treats data itself as critical infrastructure.

3.2.2. Regulatory Reforms for Smart Grids and DERS

Regulatory bodies worldwide are recalibrating market rules to accommodate distributed intelligence. In the United States, FERC Order No. 2222 (2020) dismantles barriers to aggregated distributed energy resources—rooftop solar arrays, battery systems, smart thermostats and electric vehicles—by granting virtual power-plant aggregators parity with conventional generators in wholesale markets[40]. At the state level, performance-based ratemaking pilots now reward utilities for demonstrable improvements in efficiency, reliability and innovation rather than for capital expenditure alone, thereby incentivising deployment of analytics and automation that optimise grid performance.

Meanwhile, dynamic-rating mandates are gaining traction: regulators in the U.S. and Europe are evaluating requirements for Dynamic Line Rating on transmission corridors, urging operators to leverage real-time weather and sensor data—often interpreted through AI models—to unlock up to 30 percent more transfer capacity under favourable conditions[41].

3.2.3. Public Funding and Programmes

Direct government investment catalyses R&D and deployment of AI-enabled grid technologies. In Europe, Horizon Europe grants are underwriting digital-grid pilots ranging from AI-based congestion management in Italy to blockchain-enabled peer-to-peer energy trading in Spain. In China, State Grid Corporation's "Ubiquitous Power Internet of Things" initiative has received extensive subsidies to establish a nationwide smart-grid data platform[42]. Japan's R&D programme similarly invests in AI for next-generation energy management, aiming to transition to a fully digitised grid by 2030[43].

The U.S. Department of Energy's Grid Modernization Initiative and ARPA-E programmes have channelled funds into AI-enhanced reliability projects, advanced sensor networks and

[38] https://www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

[39] https://www.gov.uk/government/publications/energy-system-digital-spine-feasibility-study

[40] https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet

[41] https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector

[42] https://www.sciencedirect.com/science/article/pii/S004873332100264X

[43] https://iotworldmagazine.com/2024/10/10/2495/ai-in-the-energy-sector-emerging-market-trends-projects-and-forecasts-2024-and-2025-2030-in-uk-europe-asia-india-china-japan-and-brazil

autonomous control systems[44,45]. In 2022, DOE inaugurated the Interconnection Innovation e-Xchange (i2X) to apply AI methods for streamlining interconnection studies for renewables[46]. Collaborative ventures—such as the DOE-Google-PJM Interconnection partnership—are now using machine learning to accelerate generation interconnection analysis and network modelling[47].

These public investments not only de-risk emerging technologies but often yield open-source tools and best-practice repositories for the broader sector.

3.2.4. International and Regional Collaboration

Multilateral institutions facilitate cross-border diffusion of digitalisation insights. IRENA's Innovation Landscape reports enumerate how AI and big-data analytics can accelerate variable-renewable integration[48], while the IEA's Clean Energy Transitions Programme partners with emerging economies to pilot smart-grid and demand-side digital solutions[49]. Regionally, ASEAN's Plan of Action for Energy Cooperation (APAEC) 2016–2025 explicitly identifies IoT, AI, big data and cloud computing as cornerstones for modernising generation, transmission and distribution[50]. Under APAEC, the ASEAN Energy Database System (AEDS) provides a unified, web-based data platform to underpin AI-driven policy and investment decisions[51]. Moreover, ASEAN-EU-Japan-World Bank training initiatives and pilot deployments further develop smart-grid competencies across Southeast Asia.

3.2.5. Cypersecurity and Standards

While championing innovation, public-sector actors simultaneously address the digital attacks threat. The EU's Action Plan mandates heightened cyber-defence protocols for critical energy infrastructure and prescribes minimum security standards for data communications[52]. Singapore and the United States have linked grid-modernisation funding to compliance with rigorous cybersecurity benchmarks[53,54]. Data-privacy safeguards—embodied in EU's General

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44 https://energycommunities.gov/funding-opportunity/accelerating-interconnection-through-ai-ai4ax/

45 https://www.nga.org/publications/advanced-grid-technologies-governor-leadership-to-spur-innovation-and-adoption/

46 https://www.energy.gov/eere/i2x/interconnection-innovation-e-xchange

47 https://blog.google/inside-google/infrastructure/electric-grid-ai

48 https://www.irena.org/publications/2019/Sep/Artificial-Intelligence-and-Big-Data

49 https://www.iea.org/programmes/clean-energy-transitions-programme

50 https://asean.org/wp-content/uploads/2023/04/ASEAN-Plan-of-Action-for-Energy-Cooperation-APAEC-2016-2025-Phase-II-2021-2025.pdf

51 https://aeds.aseanenergy.org/

52 https://solarquarter.com/2024/12/03/eu-action-plan-drives-digitalisation-in-energy-sector-with-new-strategic-initiatives

53 https://dr.ntu.edu.sg/bitstream/10356/142915/2/Strengthening%20Cybersecurity%20in%20Singapore%20Challenges%20Responses%20and%20the%20Way%20Forward.pdf

54 https://industrialcyber.co/utilities-energy-power-water-waste/new-us-cybersecurity-implementation-plan-for-energy-modernization-rolled-out/

Data Protection Regulation (GDPR) and analogous statutes—govern smart-meter and consumer-data handling, reinforcing public trust in digital services. To promote interoperability and avert vendor lock-in, governments and standards bodies (IEC, IEEE etc.) are promoting open protocols for device and data exchange. For example, the UK's standardized smart-meter data API for authorized third parties[55] and the Australia common data formats for DER integration [56] exemplify policy-driven integration of diverse grid assets.

Collectively, these strategic frameworks, regulatory reforms, funding mechanisms and standardization efforts constitute the ecosystem within which AI & digital innovations can flourish — always aligned with societal imperatives for sustainability, resilience and equitable access.

3.3. Private sector innovations and case studies

Private-sector ingenuity - from traditional utilities and grid operators to nimble startups and technology conglomerates - has been instrumental in translating AI and digitalisation into operational power-sector solutions. Many of the prominent AI applications in electricity originate in industry initiatives, often underpinned by public-sector partnerships. This dynamic is highlighted below through four thematic case studies.

3.3.1. Utility Analytics and Smart-Grid Deployment

Electric utilities have emerged as early adopters of predictive analytics and real-time monitoring to forestall equipment failures and enhance service reliability. In the United States, Exelon has collaborated with technology providers to mine smart-meter and grid-sensor data for signs of incipient transformer faults—enabling condition-based maintenance that has demonstrably reduced unplanned outages[57]. In Singapore, SP Group's in-house digital-analytics division, in collaboration with academic researchers, has engineered a "Grid Digital Twin" of the nation's transmission and distribution network[58]. This virtual replica builds upon live telemetry from thousands of assets to assess transformer health and prescribe optimized maintenance schedules; by 2025, the system is scheduled to oversee all 18 000 distribution transformers under SP Group's purview[59]. Independent analysis by McKinsey underscores the economic rationale for such platforms, estimating that AI-driven predictive-maintenance regimes can

[55] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/591322/09022017_-_Smart_Meters__Data__Growth_DR_-_updated.pdf

[56] https://www.aemo.com.au/-/media/Files/Electricity/NEM/DER/2019/Technical-Integration/Technical-Integration-of-DER-Report.pdf

[57] https://www.industryweek.com/technology-and-iiot/energy/article/22024617/exelon-teams-up-with-ge-for-big-data-to-benefit-utility-customers

[58] https://www.ema.gov.sg/news-events/news/media-releases/2023/leveraging-digital-solutions-to-future-proof-singapore-energy-grid

[59] Ibid.

yield 10–25 percent savings in O&M and replacement expenditures[60]. Similarly, Uruguay's state utility UTE, in partnership with government agencies, piloted machine-learning models to forecast wear in wind-farm components—resulting in higher turbine availability and reduced downtime. Collectively, these efforts exemplify a financing model in which upfront investments in AI capabilities are recouped through significant reliability gains and O&M cost reductions [61].

3.3.2. AI Startups and Tech Companies in Energy

A vibrant ecosystem of technology firms is introducing advanced AI tools into grid operations and market functions. Alphabet's DeepMind subsidiary achieved a 20 percent uplift in the economic value of its own Google-operated wind farms by refining output forecasts and scheduling delivery to the grid[62]. Building on this success, Google has since partnered with PJM Interconnection to accelerate generator interconnection studies and network planning using AI-driven workflows[63]. IBM, through the U.S. DOE's SunShot initiative, has deployed hybrid-AI solar-forecasting solutions that report roughly 30 percent improvements in forecast accuracy[64]. Among startups, AutoGrid, Stem and Next Kraftwerke have pioneered virtual-power-plant platforms that leverage machine learning to aggregate distributed resources—customer-sited batteries, EV chargers and thermostats—and dispatch them in real time for grid services. Notably, German Next Kraftwerke's VPP coordinates thousands of small generators and loads to bid ancillary services, demonstrating that aggregated DERs can reliably furnish frequency regulation[65]. Tesla Energy's "Autobidder" algorithm further illustrates private-sector impact: this AI-powered trading and control system optimized the 100 MW Hornsdale Power Reserve in Australia, generating revenue through rapid response to frequency deviations and price signals[66]. Tesla has since extended this model to virtual power plants, showing how proprietary AI can underpin novel commercial offerings in flexibility markets.

3.3.3. Renewable Energy Project Optimization

Developers of utility-scale solar and wind assets are applying AI to every phase of project lifecycles. In India, ReNew Power uses machine-learning algorithms to analyze high-resolution weather forecasts and dynamically adjust panel orientation or turbine pitch—thereby enhancing capacity factors and narrowing forecast error distributions[67]. In Japan, SoftBank Energy has similarly deployed AI-driven control systems to stabilise output from its solar parks, addressing

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[60] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

[61] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

[62] https://deepmind.google/discover/blog/machine-learning-can-boost-the-value-of-wind-energy

[63] Ibid.

[64] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

[65] https://www.next-kraftwerke.com/

[66] https://www.utilitydive.com/news/teslas-australian-virtual-power-plant-propped-up-grid-during-coal-outage/568812

[67] https://iotworldmagazine.com/2024/10/10/2495/ai-in-the-energy-sector-emerging-market-trends-projects-and-forecasts-2024-and-2025-2030-in-uk-europe-asia-india-china-japan-and-brazil

the grid-stability imperatives of a heavily electrified economy[68]. Furthermore, algorithms that orchestrate co-located solar, wind and battery storage assets are being trialled in Australia and California: by continuously evaluating real-time price signals and state-of-charge metrics, these platforms decide when to store excess generation versus dispatch it, maximizing project revenues and providing firm capacity to the grid[69].

3.3.4. Consumer Applications and New Business Models

Behind the meter, private innovators are transforming end-use assets into dispatchable grid resources. Octopus Energy in the United Kingdom has rolled out an AI-driven retail platform for its smart-meter customers: by analyzing wholesale price trajectories and renewable generation forecasts, the system automatically schedules domestic loads—EV chargers and heating systems—during periods of surplus, delivering bill savings and grid-balancing services to approximately 100 000 households on its "Agile" tariff[70]. In North America, aggregators such as OhmConnect and Voltus employ AI to predict individual load-curtailment potential and dispatch demand-response events, monetizing "negawatts" in capacity and ancillary markets[71]. Additionally, millions of smart thermostats—Google Nest and Ecobee among them—now collectively act as a virtual power plant, with an ad-hoc VPP of residential HVAC controls delivering over 100 MW of peak relief during California's 2022 heat wave[72]. These digital negawatt[73] models are financed through venture capital and service-fee structures, enabled by regulatory frameworks that sanction dynamic pricing and third-party aggregator participation.

Across these domains—asset management, grid optimisation, renewable-project engineering and demand-side innovation—private enterprises have demonstrated that, given an enabling policy and regulatory landscape, AI-infused solutions can scale rapidly to address complex power-sector challenges. Crucially, the most effective deployments intertwine private technological expertise with public-sector co-funding and grid-operator collaboration, thereby ensuring that digitalisation advances are aligned with broader objectives of reliability, affordability and decarbonisation.

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[68] Ibid.

[69] https://www.mdpi.com/1996-1073/17/17/4501

[70] https://iotworldmagazine.com/2024/10/10/2495/ai-in-the-energy-sector-emerging-market-trends-projects-and-forecasts-2024-and-2025-2030-in-uk-europe-asia-india-china-japan-and-brazil

[71] https://www.brattle.com/wp-content/uploads/2024/04/Californias-Virtual-Power-Potential-How-Five-Consumer-Technologies-Could-Improve-the-States-Energy-Affordability.pd

[72] https://x.com/teslaenergy/status/1849196315994931243

[73] A negawatt is a unit of power saved as a direct result of energy conservation measures

3.4. Focus on ASEAN

In the context of Southeast Asia's accelerating power-sector transformation, the Association of Southeast Asian Nations (ASEAN) region serves as a key laboratory for the integration of artificial intelligence and digital technologies. With electricity demand in member states rising at an estimated 3–4 percent per annum to serve over 650 million inhabitants, ASEAN has progressively positioned digitalization as an essential accelerator within its energy transition agenda.

Under the ASEAN Plan of Action for Energy Cooperation (APAEC) 2016–2025, digitalization is explicitly recognized as a cross-cutting enabler spanning renewable integration, demand-side management, and system resilience. As articulated in APAEC Phase II, the trend of electrification and digitalization will bring about revolutionary changes, including through smart grids and distributed power, and ASEAN will look at the opportunities given by the introduction of Fourth Industrial Revolution and IoT, as well as the integration of new technologies such as AI and big data in energy systems[74]. To operationalize this vision, the ASEAN Centre for Energy (ACE), in collaboration with USAID and the US-ASEAN Business Council, issued in 2019 the report "Digital Technology for ASEAN Energy", which mapped priority power-sector challenges—urban grid congestion, supply-demand balancing on islands, elevated non-technical losses, and intermittent solar integration in Thailand and Vietnam—against targeted digital solutions[75]. Recommendations ranged from AI-enhanced transmission-planning algorithms for the emerging ASEAN Power Grid to advanced metering analytics in high–electricity-theft jurisdictions. Following ministerial endorsement made reference to the fact that recommendations to help ASEAN respond to the risks and opportunities of digitalization in the energy sector are expected[76]. ASEAN bodies have embedded digitalization into initiatives such as the ASEAN Smart Grid Initiative, fostering peer-to-peer exchange on smart-grid pilots[77].

A cornerstone achievement is the ASEAN Energy Database System (AEDS), maintained by ACE. AEDS aggregates harmonized power-system and broader energy data from all ten member states on an ongoing basis, thereby furnishing a robust dataset for AI-driven modeling and benchmarking[78]. Complementary capacity-building partnerships—with the IEA, IRENA, and the Asian Development Bank—have yielded workshops on grid digital twins, AI-augmented

[74] https://asean.org/wp-content/uploads/2023/04/ASEAN-Plan-of-Action-for-Energy-Cooperation-APAEC-2016-2025-Phase-II-2021-2025.pdf

[75] https://asean.org/wp-content/uploads/2023/04/ASEAN-Plan-of-Action-for-Energy-Cooperation-APAEC-2016-2025-Phase-II-2021-2025.pdf

[76] https://asean.org/wp-content/uploads/2021/08/AMEM37_JMS-Final.pdf

[77] https://aseanenergy.org/publications/smart-grid-in-asean-overview-and-opportunities-to-support-the-asean-renewable-energy-aspirational-target/

[78] https://asean.org/wp-content/uploads/2021/08/AMEM37_JMS-Final.pdf

planning, and cyber-secure operations[79]. Moreover, the ASEAN Climate Change and Energy Project (ACCEPT), in collaboration with Norway, explicitly targets enhancements in data-analytics proficiency to align energy-sector developments with climate objectives[80].

At the national level, differentiated stages of adoption are evident:

- **Vietnam** has adopted a Smart Grid Roadmap 2021–2030 through its Ministry of Industry and Trade, emphasizing grid upgrades for renewable integration and widespread smart-meter deployment. EVN's pilot smart-meter rollouts in urban centers and distribution-automation tests are complemented by USTDA–facilitated study tours to the U.S. on smart-grid and cybersecurity best practices[81]. Vietnam's projected US$ 120 billion energy-sector investment need by 2030 includes anticipated allocations for digital-grid management and cybersecurity, as well as plans for establishing a modern EMS/SCADA dispatch center primed for AI integration.

- **Singapore** has advanced a comprehensive grid digitalization strategy via the Energy Market Authority and SP Group, deploying the region's inaugural Grid Digital Twin alongside a Distributed Energy Resource Management System pilot[82]. These platforms leverage AI to furnish real-time visibility and control of PV assets, storage, and electric vehicles, thereby safeguarding grid stability while accommodating high renewable penetrations. The annual Singapore International Energy Week promotes responsible AI and grid-resilience themes, underscoring a policy commitment to digital-grid leadership.

- **Thailand** has executed self-healing grid pilots in Pattaya and Phuket and is scaling AI-enhanced production-cost models for dispatch and reservoir management under high-renewables scenarios[83]. Regulatory sandboxes for peer-to-peer energy trading employing blockchain-based smart contracts and AI forecasting demonstrate a path toward community-level market innovation[84].

- **Malaysia** reports over 1.8 million smart meters installed by Tenaga Nasional Berhad as of 2023, with full rollout slated by 2026. An Advanced Distribution Management System, infused with outage-diagnosis AI, is under deployment. Concurrently, new data-center PUE regulations incorporate AI-driven cooling optimization[85], while a strategic alliance

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[79] https://asean.org/wp-content/uploads/2023/04/ASEAN-Plan-of-Action-for-Energy-Cooperation-APAEC-2016-2025-Phase-II-2021-2025.pdf

[80] https://accept.aseanenergy.org

[81] https://www.ustda.gov/ustda-supports-strengthening-securing-vietnams-power-sector

[82] https://www.ema.gov.sg/news-events/news/media-releases/2023/leveraging-digital-solutions-to-future-proof-singapore-energy-grid

[83] https://en.imsilkroad.com/p/311090.html

[84] https://www.mdpi.com/1996-1073/15/3/1229

[85] https://aseanenergy.org/post/harnessing-artificial-intelligence-for-a-greener-data-center

with Envision Digital is pioneering AI and digitalization solutions for the energy transition[86].

- **Indonesia**, facing a mosaic of isolated grids, has initiated Java distribution-automation pilots and microgrid-controller tests in the east. A forthcoming ERIA call seeks AI-based demand-forecasting proposals to refine ASEAN-wide generation planning, anticipating that the future ASEAN Power Grid will depend on AI-mediated flow controls for cross-border exchanges[87].

Collectively, ASEAN's digitalization trajectory reveals that leading economies are already realizing reliability and efficiency dividends, while others benefit from tailored capacity-building and donor-supported pilots. International partnerships (USAID, GIZ, ADB) and public-private collaborations (ACE-Huawei's iCooling white paper[88] and the ASEAN Energy Data Centre) underscore a regional ethos of cooperative leapfrogging. For Vietnam, active participation in ASEAN platforms and replication of Singapore's digital-twin frameworks or Thailand's sandbox methodologies will be instrumental. As ASEAN advances toward a coordinated, intelligent, and decentralized power topology, it affirms the conviction that AI and digitalization will pave the way for a more decentralized, intelligent, and sustainable energy future in the region.

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86 https://www.prnewswire.com/in/news-releases/envision-digital-forms-industry-first-partnership-with-malaysian-government-agency-to-accelerate-carbon-neutrality-goals-825117463.html

87 https://www.eria.org/research/call-for-proposals--asean-power-grid-integrates-new-technologies--enhancing-flexibility-and-resilience-for-low-carbon-energy-transition

88 https://aseanenergy.org/post/the-asean-centre-for-energy-and-huawei-release-a-white-paper-to-shape-the-future-of-data-center-sustainability/

CHAPTER

04

Key AI Applications & Case Studies

Chapter 4: Key AI applicants & Case Studies

Economies have elevated artificial intelligence and digital platforms from niche experiments to indispensable enablers across five critical domains: renewable integration and planning; grid optimization and network management; demand-side management including virtual power plants; predictive maintenance and asset management and energy storage with electric-vehicle integration. In each sphere, algorithmic innovations from classical machine-learning models to emerging large-language frameworks are unlocking novel efficiencies, bolstering system resilience, and driving cost reductions. The following synthesis articulates defining methodologies, exemplar deployments, and distilled lessons for policymakers.

4.1. Renewable Integration & Grid Planning

The most consequential application of AI in modern power systems lies in facilitating the seamless incorporation of variable renewable energy (VRE). AI enhances every stage of the project lifecycle - from resource assessment and permitting to operational forecasting and dispatch.

- **Intelligent Resource Planning.** Machine-learning algorithms now process vast multisource repositories—historical meteorology, topography, network capacity and land-use constraints—to pinpoint optimal sites and capacities for new wind and solar installations. In one study, an AI-driven planning tool outperformed conventional feasibility analyses both in computational efficiency and in projected annual energy yield[89]. Likewise, the State Grid Corporation of China employs proprietary AI software to simulate thousands of integration scenarios for new VRE deployments at the provincial level, thereby defining project portfolios that minimize curtailment[90].

- **Regulatory Streamlining via LLMs.** Recognizing the bottleneck that environmental reviews impose, the U.S. Department of Energy has piloted large-language-model assistants to analyze prior impact statements and permit applications, generating draft documents that significantly reduce administrative lead times. Early pilots indicate that LLM-based assistants could significantly cut the time and cost for obtaining permits by automating document review and preparation[91].

- **Operational Forecasting & Scheduling.** Once commissioned, VRE plants depend on precise short-term forecasts to support reliable dispatch. Hybrid AI frameworks—merging neural networks with physical weather models utilize live sensor feeds, satellite imagery and ensemble forecasts to achieve 20–30 percent improvements in solar and wind prediction accuracy[92]. Germany's TSOs routinely incorporate such AI forecasts in day-ahead reserve calculations, realising cost savings through fewer balancing interventions[93]. In the United States, DOE-backed SunShot projects demonstrated a 30 percent enhancement in PV forecasting, enabling higher renewable penetration without stability compromises[94]. These gains yield direct economic dividends: DeepMind's ML-tuned wind forecasts boosted Google's farm revenues by approximately 20 percent through optimised market bidding[95]. Similarly, ERCOT's adoption of AI-based wind prediction has materially reduced reliance on fast-ramping gas turbines[96].

- **Coordinated Curtailment & Storage Dispatch.** Advanced AI systems can decide real-time trade-offs - deciding whether to curtail wind output or to charge co-located batteries - by evaluating millions of data points per second, a scale unattainable by human operators. In Spain, Acciona's AI platform synthesises weather, price signals and maintenance schedules to optimise dispatch across its renewable portfolio, achieving both higher aggregate generation and fewer negative-price events[97]. Looking regionally, ASEAN stakeholders anticipate employing AI-powered demand-supply forecasting to harmonise cross-border power flows and minimise VRE curtailment within the emerging

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[89] https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector

[90] https://iotworldmagazine.com/2024/10/10/2495/ai-in-the-energy-sector-emerging-market-trends-projects-and-forecasts-2024-and-2025-2030-in-uk-europe-asia-india-china-japan-and-brazil

[91] https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector

[92] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

[93] https://www.enlit.world/digitalisation/how-elia-is-using-ai-to-optimise-its-operations/

[94] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

[95] https://deepmind.google/discover/blog/machine-learning-can-boost-the-value-of-wind-energy

[96] https://dl.acm.org/doi/abs/10.1145/3307772.3331024

[97] https://www.sevensquaretech.com/smart-energy-platforms-spain-acciona-energy/

ASEAN Power Grid[98].

Outcomes & Best Practises

The cumulative effect of AI-enabled integration is evident in grids operating reliably with instantaneous VRE shares of 50–70 percent (notably in parts of Europe and Australia). Ireland's TSO, for example, credits advanced AI forecasts and automated control schemes for maintaining stability at wind penetrations up to 75 percent—a threshold once deemed prohibitive, while at the same time a 95 percent target for 2030 has been set [99]. Moreover, AI-guided siting and forecasting have deferred the need for incremental transmission or storage infrastructure by aligning generation with network capabilities. Key best practices include:

1. **Data Transparency:** Public platforms in Denmark and Spain publish real-time weather and grid telemetry, catalysing a competitive market of AI forecasters[100].

2. **Market-Linked Forecasting:** Mandating day-ahead VRE forecasts—preferably AI-generated—and rewarding accuracy fosters continual algorithmic refinement and data exchange with grid operators[101].

3. **Integrated Control-Room Deployment:** Embedding AI outputs into SCADA and Energy Management Systems ensures that improved forecasts translate directly into operational decisions[102].

In sum, AI has evolved from a niche research topic into an indispensable instrument for renewable-rich power systems, with global best practices underscoring the importance of open data, seamless integration and economic alignment between forecast precision and market signals.

[98] https://www.eria.org/research/call-for-proposals--asean-power-grid-integrates-new-technologies--enhancing-flexibility-and-resilience-for-low-carbon-energy-transition

[99] https://www.eirgrid.ie/about-us/our-strategy-2020-2025

[100] https://investindk.com/insights/free-data-initiative-companies-can-now-apply-ai-to-danish-meteorological-data

[101] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Jul/IRENA_Advanced_weather_forecasting_2020.pdf?la=en&hash=8384431B56569C0D8786C9A4FDD56864443D10AF

[102] https://helendarmi-hd.medium.com/scada-and-smart-energy-grid-control-automation-1f319a179be2

4.2. Grid Optimization & Network Management

Modern transmission and distribution (T&D) networks—spanning thousands of kilometres and encompassing heterogeneous assets—pose formidable operational challenges, demanding millisecond-scale balancing of supply and demand. The advent of digitalisation and AI is redefining how T&D systems are monitored, controlled and optimised, with three principal objectives: boosting reliability, maximising utilisation of existing infrastructure and unlocking operational flexibility. These advances are essential to accommodate the variability of large-scale renewables and emerging load profiles without compromising system resilience.

- **Wide-Area Monitoring, Dynamic Control & Optimal Power Flow (OPF).**

Historically, wide-area network oversight depended on SCADA platforms and operator expertise. Today, AI-driven solvers address the non-convex Optimal Power Flow (OPF) problem—determining generator set-points and power flows that minimise losses or congestion under prevailing constraints. By training neural networks on extensive archives of historical system states, researchers at RTE (France) and NREL (USA) have demonstrated near-optimal OPF solutions in milliseconds, enabling real-time reconfiguration of transformer taps and phase-shifters to alleviate congestion around renewable clusters. Pilot implementations in the UK and Italy report uplifts in transmission utilisation and marked reductions in curtailment orders for wind farms[103].

Complementing OPF advancements, Dynamic Line Rating (DLR) replaces conservative static limits with real-time ampacity estimates derived from line-sag sensors and local weather inputs. AI models assimilate these data streams to predict safe conductor loadings—often increasing capacity by approximately 30 percent under favourable conditions[104]—thereby permitting more wind energy exports on cool, windy days. Utilities in Belgium and Texas (Oncor) have already deployed DLR, deferring new transmission investments and accelerating renewables integration[105].

- **Fault Detection, Outage Management & Self-Healing Grid.**

Rapid localisation and remediation of faults underpin network stability. High-speed PMU arrays—sampling voltage and current 30 times per second—now feed AI algorithms that detect disturbances and triangulate fault locations within minutes, a process that formerly required hours of manual analysis. Manitoba Hydro's collaboration with an AI vendor reduced fault-location times dramatically, speeding crew dispatch and shrinking outage durations[106]. At the distribution level, machine-learning models analyse smart-meter voltage dips to pinpoint downed conductors, guiding crews directly to the fault.

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103 https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector/

104 Ibid.

105 https://www.energy.gov/sites/prod/files/2016/12/f34/Oncor_DLR_Case_Study_05-20-14_FINAL.pdf

106 https://www.ifc.org/content/dam/ifc/doc/mgrt/emcompass-note-81-05-web.pdf

Building on this, automated "self-healing" architectures are emerging: intelligent distribution-management systems can isolate faulted sections and re-route power in seconds, maintaining supply to critical loads without operator intervention. During Hurricane Idalia (2021), AI-enhanced grids in Florida autonomously sectionalised damaged feeders, sustaining service to hospitals and emergency centres preventing over 17,000 power outages[107]. Similarly, voltage-control agents - coordinating capacitor banks, regulators and inverter set-points - have enabled a 1 MW pilot in Finland to realize "near-instantaneous grid balancing", illustrating AI's capacity to stabilise outputs amid rapid solar and wind fluctuations[108].

- **Cross-Border Coordination & Regulatory Oversight.**

In interconnected regions—from Europe's Continental Network to the envisioned ASEAN Power Grid—AI facilitates transnational flow optimisation. ASEAN's roadmap explicitly advocates predictive analytics for demand forecasting, fault detection and real-time operational tuning to harmonise cross-border exchanges[109]. Beyond operations, AI is reshaping regulatory surveillance. ACER's "ARIS" platform processes billions of market transactions, applying anomaly-detection algorithms to flag potential manipulation and enhance market transparency[110]. This underscores a broader trend: AI not only augments grid operations but also empowers regulators to uphold fair, reliable markets amid growing system complexity.

Key Outcomes & Best Practices

Utilities implementing AI-based OPF, DLR and fault-localisation routinely report reduced technical losses, higher load factors on existing lines and shorter outage restoration times. For example, Enel's rollout of AI-driven solutions has led to increased grid reliability, flexibility and resilience. Critically, these digital innovations unlock "virtual capacity," deferring capital-intensive network expansions—an outcome of particular value in capital-constrained markets. To realise these benefits, best practices include:

1. **Integrated Deployment:** Embed AI outputs within existing SCADA/EMS workflows to ensure operator confidence and rapid action.
2. **Human–Machine Collaboration:** Maintain human oversight over automated decisions, thereby preserving institutional knowledge and enabling trust in AI recommendations.
3. **Data Quality Assurance:** Invest in sensor calibration, time-synchronisation and data-governance protocols to underpin robust algorithmic performance.

[107] https://eepower.com/tech-insights/self-healing-grids-and-the-future-of-power-distribution

[108] https://www.powermag.com/ai-optimized-grid-balancing-pilot-launched-in-finland/

[109] https://www.eria.org/research/call-for-proposals--asean-power-grid-integrates-new-technologies--enhancing-flexibility-and-resilience-for-low-carbon-energy-transition

[110] https://www.emissions-euets.com/internal-electricity-market-glossary/655-aris

When executed within a coherent strategy—linking AI tools to operational objectives and regulatory frameworks—digital grid optimisation becomes a cornerstone of a resilient, efficient and renewable-friendly power system.

4.3. Demand Response & Virtual Power Plants (VPPs)

AI and digitalisation are unlocking new layers of flexibility on the demand side—an imperative for balancing grids with high shares of variable renewables. Two intertwined paradigms dominate: Demand Response (DR), in which consumers modulate their consumption in response to external signals; and Virtual Power Plants (VPPs), aggregations of distributed energy resources (DERs) that operate collectively as a unified power plant. In both cases, AI-powered platforms forecast load, automate device control and optimise aggregated resource dispatch.

1. AI-Powered Demand Response

Conventional DR relied on manual load shedding by industrial users or basic direct-load control of air conditioners. Today's implementations are far more granular and data-driven: machine-learning models ingest meteorological forecasts, historical consumption profiles and even social indicators (e.g. public events) to predict the timing and magnitude of peak-demand events. Aggregators translate these forecasts into dispatch signals—price signals or direct control commands—to smart thermostats, building-management systems and EV chargers, dynamically adjusting setpoints to achieve target load reductions with minimal user disruption.

A notable pilot is Singapore's Project OptiWatt, where a mobile application alerted households to defer usage; roughly half responded, yielding measurable peak-demand declines[111]. On a national scale, National Grid ESO (UK) executed the world's first AI-assisted demand Flexibility Service in 2022 The DFS is the largest demand response scheme to have taken place in the UK to date, with participation from 1.6 million households and businesses. *"Together participants delivered a total reduction of electricity use of 3,300MWh at key times, which is roughly the amount of electricity that 9.9 million households would use at peak times across a single hour".*[112]

2. Virtual Power Plants (VPPs)

VPPs extend DR by incorporating not only load flexibility but also DER assets—battery storage, rooftop PV, backup generators—into a cohesive dispatchable portfolio. AI assumes a key role, forecasting both resource availability (e.g. state-of-charge distributions across 10 000 home batteries and 500 EV chargers) and system needs (impending demand spikes or price excursions), then allocating commands to each asset to deliver precise power injections or load curtailments[113].

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[111] https://www.straitstimes.com/singapore/around-500-households-reduced-energy-usage-in-september-when-prompted-under-ema-pilot

[112] https://smarter.energynetworks.org/media/dvrblqk2/national-grid-eso-annual-nia-summary-202324.pdf

[113] https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector/

The Tesla Virtual Power Plant in South Australia exemplifies this approach: initially networking a small fraction of its 50 000 Powerwall-equipped homes, the platform automatically discharged hundreds of batteries within seconds of a coal generator trip, arresting a system-frequency dip AEMO acknowledged the VPP's decisive contribution to system restoration[114]. In California and Vermont, Tesla's VPPs similarly harness residential batteries to furnish emergency capacity—delivering over 20 MW during the 2022 heat wave[115], and exceeding 125 MW of aggregated capacity by 2023[116]. Such demonstrations have spurred regulators to formalise VPP procurement and remuneration mechanisms.

3. Benefits & Enabling Policies

Demand-side AI platforms generate value for all stakeholders. Consumers receive financial incentives—reduced tariffs through time-of-use shifting or direct payments—alongside enhanced reliability via battery backup. Aggregators monetize pooled flexibility in capacity markets, sharing revenues with participants; as the Brattle Group notes, "VPPs could make significant contributions to keeping the lights on while putting money directly in the pockets of consumers who participate"[117]. Grid operators gain a highly reliable, dispatchable resource that defers network and generation investments (each megawatt of reduced peak demand obviates equivalent capacity additions) and boosts resilience during contingencies.

These innovations rest on foundational enablers: near-ubiquitous smart-meter coverage (global deployments surpassed one billion by 2022)[118]; dynamic or time-of-use pricing models[119]; interoperability standards such as OpenADR; and interconnection codes (e.g. California's Rule 21) alongside market reforms like FERC Order 2222[120]. Regulatory sandboxes—exemplified by schemes in Singapore and the UK—further accelerate experimentation under temporary waivers[121].

Key Outcomes & Best Practices

Industry experience underscores that AI-driven DR and VPPs materially enhance grid flexibility and economic efficiency. Reported outcomes include peak-load reductions of several hundred megawatts, deferred capital expenditure on peaking plants and transmission upgrades, and elevated system resilience through distributed contingency support. Best practices distilled from global deployments include:

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[114] https://www.utilitydive.com/news/teslas-australian-virtual-power-plant-propped-up-grid-during-coal-outage/568812

[115] https://www.teslarati.com/tesla-california-vpp-virtual-power-plant-california-heat-wave

[116] https://x.com/teslaenergy/status/1849196315994931243

[117] https://www.brattle.com/wp-content/uploads/2024/04/Californias-Virtual-Power-Potential-How-Five-Consumer-Technologies-Could-Improve-the-States-Energy-Affordability.pdf

[118] https://www.iea.org/energy-system/decarbonisation-enablers/digitalisation

[119] https://plexigrid.com/singapore-is-unlocking-demand-response-for-big-energy-users

[120] https://www.ferc.gov/media/ferc-order-no-2222-fact-sheet

[121] https://plexigrid.com/singapore-is-unlocking-demand-response-for-big-energy-users

1. **Consumer-Centric Engagement:** Simplify participation with intuitive interfaces and transparent remuneration to maximise enrollment and response rates.
2. **Integrated Digital Architecture:** Seamlessly embed AI forecasts and dispatch signals within existing energy-management and utility control platforms to ensure reliability and operator trust.
3. **Data Governance and Interoperability:** Maintain high-quality, time-synchronised data streams and adopt open standards to accommodate heterogeneous devices and multiple service providers.
4. **Regulatory Co-Design:** Leverage sandboxes and stakeholder consultations to align market structures, tariffs and technical codes with innovative demand-side modalities.

By adhering to these principles, utilities and regulators can harness demand-side intelligence as a cornerstone of a renewable-rich, resilient power system—transforming passive loads into active grid assets and unlocking substantial economic and environmental benefits[122].

4.4. Predictive Maintenance & Asset Management

Ensuring the reliability of extensive power-sector infrastructure—from generation units and transformers to transmission corridors and circuit breakers—traditionally demands capital-intensive, calendar-based overhauls. The advent of AI and pervasive digital sensing, however, is catalysing a paradigm shift toward predictive, condition-based maintenance, thereby reducing unplanned outages, optimising expenditure and extending asset service life—imperatives for a resilient grid capable of assimilating renewable variability.

1. Sensor Deployment & Continuous Monitoring

The foundation of predictive regimes lies in ubiquitous, low-cost sensors and IoT endpoints that stream asset-condition metrics - temperature, vibration, oil acidity and more - into central data platforms[123]. Modern gas turbines, for instance, may feature hundreds of telemetry channels on bearings, combustion modules and exhaust systems; AI-powered anomaly detectors continuously mine these streams to flag deviations resonant with historical failure precursors. Leading OEMs such as GE and Siemens now offer these AI-driven monitoring services under performance-guarantee contracts, shifting maintenance procurement from fixed schedules to data-informed interventions.

2. Anomaly Detection & Failure Prediction

Wind-turbine fleets—often sited in remote, harsh environments—stand to benefit substantially from AI-augmented servicing schedules. By fusing SCADA logs, meteorological forecasts and acoustic signatures, machine-learning models can anticipate gearbox degradation, blade icing or generator overheating well ahead of manifest faults. A Uruguay pilot, co-sponsored by

[122] https://aseanenergy.org/aeds-categories/energy-digitalization

[123] https://www.ifc.org/content/dam/ifc/doc/mgrt/emcompass-note-81-05-web.pdf

government agencies, demonstrated just-in-time turbine maintenance scheduling that eliminated both needless inspections and disruptive breakdowns (irena.org). Thermal plants, likewise, employ AI to predict boiler-tube leaks and coal-mill stalls, thereby confining repairs to planned outages. A McKinsey analysis confirms that such predictive regimes yield 10–25 percent savings in maintenance costs and markedly lower forced-outage rates[124].

AI also informs asset-replacement decisions through remaining-useful-life (RUL) estimations. Distribution utilities calculate transformer-health indices—drawing on load histories, oil diagnostics and thermal excursions - to priorities the renewal of the riskiest units. Singapore's Digital Asset Twin initiative extends this concept: real-time virtual replicas of grid components feed AI engines that prescribe optimal renewal timelines, ensuring interventions are both timely and cost-effective[125]. Notably, SP Group's deployment of in-house analytics underscores the trend of utilities cultivating proprietary AI expertise rather than relying solely on vendor solutions [126].

3. Drones, Robotics & Computer Vision

Foot patrols and helicopter surveys are giving way to drone fleets equipped with high-resolution and infrared cameras, which systematically scan transmission lines and substations for conductor fatigue, vegetative encroachment and thermal hotspots. AI-based computer-vision algorithms then autonomously identify anomalies - cracked insulators, loose fittings or overgrown foliage - across terabytes of imagery. China's State Grid harnesses this workflow to monitor millions of towers, slashing inspection durations dramatically[127]. In California, similar systems preempt wildfire ignition by flagging at-risk vegetation for targeted trimming[128]. Japanese utilities pioneered in further augmenting substation inspections with climbing robots whose embedded vision models detect corrosion, oil leaks and gauge anomalies, thereby reducing personnel exposure to high-voltage hazards. This is to be applied also in Italy by Terna[129].

Key Outcomes & Best Practices

Predictive-maintenance initiatives have yielded quantifiable uplifts in grid reliability and cost efficiency. Utilities report significant declines in unplanned outages, reductions in maintenance expenditure, and extended mean time between failures. Safety metrics improve as AI flags hazardous conditions—such as excessive hydro-dam water levels in Canada—enabling preemptive interventions and minimizing field-crew exposure to danger. From an economic standpoint, deferred capital outlays for asset replacement and reduced spare-parts inventories liberate funds for modernization projects.

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[124] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

[125] https://www.ema.gov.sg/news-events/news/media-releases/2023/leveraging-digital-solutions-to-future-proof-singapore-energy-grid

[126] Ibid.

[127] https://www.frontiersin.org/journals/energy-research/articles/10.3389/fenrg.2024.1441540/full

[128] https://www.renewableenergyworld.com/news/another-california-utility-adopts-an-ai-enabled-wildfire-prevention-system/

[129] https://lightbox.terna.it/en/challenges/hibot-asset-maintenance

Best practices distilled from global leaders include:

1. **Robust Data Architecture:** Establish unified data lakes that harmonize sensor streams, maintenance logs and asset registries to underpin model accuracy.
2. **Hybrid Modeling for Explainability:** Combine physics-based simulations with AI to furnish transparent diagnostics that engender engineer confidence.
3. **Continuous Feedback Loops:** Integrate model outcomes and actual maintenance events into retraining pipelines, fostering self-improving prognostic systems.
4. **Human–Machine Integration:** Deliver AI insights through incumbent asset-management platforms and train operations staff to interpret and act on alerts swiftly.
5. **Strategic Leadership & KPIs:** Secure executive sponsorship and set measurable targets—such as percentage reductions in forced outages—to drive adoption and accountability.

By adhering to these guidelines, utilities can transform raw operational data into actionable intelligence, ensuring that asset-management strategies evolve from reactive to predictive—an essential transition for a reliable, future-ready power grid.

4.5. Energy Storage & Electric Vehicle Integration

As renewable penetration accelerates, energy-storage systems and electric vehicles (EVs) have become indispensable flexibility assets. Their optimal orchestration—balancing charge/discharge cycles, mitigating local grid stress and even driving materials innovation—relies heavily on AI and digital platforms.

1. Optimised Battery Dispatch

Large-scale batteries, pumped hydro and emerging storage technologies such as flow batteries and compressed air storage[130] smooth renewable variability by absorbing excess generation and redeploying it during demand peaks. AI algorithms excel at this multi-factor optimisation—ingesting real-time price signals, demand forecasts and VRE output to schedule charge/discharge in a manner that both maximises revenue and provides ancillary services. For instance, the 129 MWh Hornsdale Power Reserve in South Australia employs Tesla's Autobidder AI system to perform automated market bidding and rapid frequency-response dispatch[131]. Over its first year, the installation delivered roughly A$ 40 million in ancillary-service savings and achieved sub-100 ms reaction times to frequency deviations[132]. Likewise, AI-guided curtailment forecasting—anticipating midday solar surpluses—enables pre-emptive battery charging,

[130] https://www.sciencedirect.com/science/article/abs/pii/B9780128197233000986

[131] https://hornsdalepowerreserve.com.au/

[132] https://www.utilitydive.com/news/teslas-australian-virtual-power-plant-propped-up-grid-during-coal-outage/568812

demonstrably reducing wasted energy in regions such as California and China[133]. Critical to asset longevity, these AI frameworks also optimise cycling patterns to minimise degradation, thereby preserving battery value.

2. **Vehicle-to-Grid (V2G) & Smart Charging**

The exponential growth of EV fleets presents both challenges and opportunities. Without orchestration, unmanaged charging risks local overloads; with AI-enabled smart charging and V2G, parked EVs become a distributed storage network. Platforms by firms such as Nuvve (USA)[134] and Kaluza (UK)[135] predict plug-in events and driver mobility needs—drawing on historical usage and calendar data—to sequence charging and discharging in alignment with grid capacity and tariff structures. Field pilots report that users perceive no disruption, yet benefit from lower charging costs. In Denmark, Nissan Leaf V2G trials aggregated dozens of vehicles to deliver frequency-regulation services - each car dispatching a few minutes of charge or discharge under centralised AI coordination and earning owner compensation[136]. The UK's EV Energy Taskforce recommends nationwide smart-charging adoption by 2025, projecting multi-billion-pound savings in deferred network upgrades[137]. Regulatory frameworks are evolving in parallel: California's 2022 Vehicle-Grid Integration Roadmap endorses automated price signals and V2G standards, while ISO 15118-20 standardises EV-charger communications for seamless smart charging[138].

3. **Accelerating Innovation in Storage**

Beyond operational optimization, AI is hastening breakthroughs in storage technology itself. Machine-learning models now screen thousands of candidate electrolytes and electrode compounds—tasks once requiring years of trial-and-error—in a matter of months, thereby compressing the R&D cycle for next-generation batteries[139]. Parallel efforts under the U.S. JCESR program and Horizon Europe are applying data-driven methods to supercapacitors, hydrogen carriers and thermal storage, reflecting the strategic imperative of robust, cost-effective storage for the low-carbon transition.

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[133] https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector

[134] https://nuvve.com/

[135] https://www.kaluza.com/

[136] https://europe.nissannews.com/en-GB/releases/nissan-enel-and-nuvve-operate-world-s-first-fully-commercial-vehicle-to-grid-hub-in-denmark

[137] https://www.gov.uk/government/news/new-plan-for-smart-electric-vehicle-ev-charging-could-save-consumers-up-to-1000-a-year

[138] https://www.energy.ca.gov/programs-and-topics/programs/vehicle-grid-integration-program

[139] https://www.energypolicy.columbia.edu/can-ai-transform-the-power-sector

Key Outcomes & Best Practices

AI-native management of storage and EV fleets has delivered substantial grid benefits: reduced peak demand stress, enhanced frequency stability and higher utilization of renewable generation. Virtual storage deployments report ancillary-service revenue streams that defray asset costs, while smart charging pilots achieve high peak-load shaving compared to unmanaged EV charging. Critical best practices include:

1. **Data-Driven Forecasting:** Integrate high-resolution price, demand and resource predictions to inform dispatch algorithms.
2. **User-Centric Engagement:** Ensure seamless consumer experiences—transparent incentives and minimal lifestyle impact—to maximise participation.
3. **Lifecycle Optimisation:** Embed asset-health models to balance revenue generation against degradation, extending useful lifespans.
4. **Standards and Interoperability:** Adopt open protocols (e.g., ISO 15118-20, OpenADR) and align market rules (FERC Order 2222, VGI roadmaps) to enable cross-vendor, cross-domain coordination.
5. **Regulatory Sandboxes:** Leverage temporary waivers to pilot novel V2G and storage schemes, iterating before scaling.

By adhering to these principles, stakeholders can harness distributed storage and electric fleets as dynamic, reliable grid resources—fortifying resilience and accelerating the journey to a renewable-dominated power system.

4.6. Conclusion: Benefits, Challenges & The Way Forward

The survey of leading international practice presented in Chapter 3 confirms that artificial intelligence—together with the broader suite of digitalization tools—constitutes a decisive lever for accelerating power-sector transitions, insofar as it augments system visibility, compresses operating costs, and catalyzes the large-scale uptake of variable renewables. Around the globe, from OECD countries to rapidly industrializing ASEAN jurisdictions, algorithmic forecasting and optimization routines provide grid operators with an unprecedented temporal horizon on load-generation balance; the consequent ability to re-dispatch power flows pre-emptively has already translated into measurable gains in efficiency & reliability.

Concretely, utilities deploying AI-enabled asset-health analytics are reporting maintenance-budget savings alongside materially lower downtime and extended equipment lifetimes. Parallel advances in probabilistic wind- and solar-power forecasting allow balancing authorities to absorb ever-higher penetrations of non-synchronous generation without jeopardizing frequency stability. At the demand side, sophisticated virtual-power-plant architectures orchestrate distributed resources and remunerate end-users for real-time flexibility, thereby converting latent consumer behavior into monetizable grid services. The aggregate effect is a triad of policy desires fulfilled: deeper decarbonization, demonstrable affordability through avoided capital and operational expenditure, and enhanced security of supply via resilience-building redundancies.

Nevertheless, the realization of AI's full systemic value remains contingent upon a set of non-trivial preconditions. Foremost among these is data integrity - its availability, standardization, and governance—given that algorithmic outputs do not transcend the quality of their underlying inputs. Numerous network operators still grapple with fragmented data architectures characterized by heterogeneous temporal resolutions and incompatible schemas, a circumstance that impedes holistic analytics. The emergent best practice is therefore the construction of unified data platforms underpinned by common taxonomies; the European Transparency Platform, with its mandatory, standard-format utility submissions, exemplifies the levelling of informational asymmetries required for robust cross-system analysis (irena.org). Regulatory facilitation of open-data regimes—where the disclosure of non-sensitive parameters such as aggregated load curves or network topology is mandated—can, moreover, stimulate third-party innovation.

Furthermore, the unavoidable expansion of the cyber-attack surface accompanying digitalization renders cybersecurity a strategic imperative. High-profile incursions, including ransomware events targeting control-centre SCADA environments, have underscored the vulnerability of digitally integrated grids. Accordingly, contemporary policy frameworks—ranging from the EU Action Plan to Vietnam's Smart Grid Roadmap - embed explicit budgetary provisions for cyber-resilience measures. Crucially, the sector's defensive posture is itself becoming AI-driven: anomaly-detection algorithms now monitor network traffic in real time, flagging and isolating malicious signatures before critical functions are compromised.

A distinct layer of challenges to the digital-AI transition lies in human capital and organizational culture. Power-system engineering has long been anchored in a prudent, risk-averse tradition; accordingly, managerial skepticism and skill deficits frequently tend to slow the uptake of algorithmic solutions. Capacity-building therefore becomes of upmost importance. Upskilling incumbent staff in data science, recruiting hybrid "electro-informatic" talent, and perhaps most critically coaching an innovation ethos that sanctions controlled experimentation. Industry front-runners such as Enel and Singapore's SP Group now operate dedicated digital-innovation units whose responsibility is precisely to fuse domain engineers with data scientists, thereby bridging disciplinary siloes and accelerating prototype-to-deployment cycles. Public authorities can reinforce these efforts by underwriting specialist curricula and formalizing new competency standards across the energy workforce, a gap explicitly acknowledged in several jurisdictions. Complementary workshops and living-lab demonstrations - exemplified by ASEAN's regional programmes - have proven effective at diffusing AI literacy upward into senior decision-making echelons, fostering both trust and informed governance.

A second cluster of obstacles pertains to market architecture and incentive alignment. Where regulatory regimes remunerate utilities predominantly for capital formation rather than operational efficiency, the business case for asset-optimizing AI can be weak. Transitioning toward outcome-based regulation—rewarding metrics such as outage-minute reductions or renewable-energy hosting capacity naturally prompts network operators to exploit every available optimization lever, AI included. Some regulators have gone further, earmarking "innovation allowances" within revenue-cap frameworks. These are modest budgets that finance exploratory pilots and have already catalyzed a noticeable increase in AI experimentation.

Regulatory fragmentation compounds these incentive mismatches. Divergent technical standards across neighboring markets inflate compliance costs and deter vendors from scaling solutions; hence the current push for harmonized frameworks within blocs such as ASEAN, which promises to lower transaction costs and deepen supplier competition.

Although most digital interventions exhibit favorable life-cycle economics, front-loaded capital requirements remain non-trivial. These span high-resolution sensors, telecom backbones, and secure IT infrastructure. Financing modalities have accordingly diversified; concessional loans and grants from international financial institutions (e.g. World Bank), public-private partnerships featuring "software-as-a-service" pricing to flatten upfront fees, and outcome-based contracts that share verified savings between vendor and utility. Certain operators e.g., in Malaysia and Singapore, have even established venture arms, externalized early-stage R&D risk while reserving rights to adopt validated technologies.

At the same time, ethical and fairness considerations must be foregrounded. Left unchecked, AI-enabled programmes risk entrenching inequities. For example, there is a risk in demand-response schemes that disproportionately enroll digitally savvy urban households while rural or low-income customers are sidelined. Policymakers can pre-empt such externalities by mandating inclusive design through e.g., subsidized smart appliances, tiered participation thresholds and codifying stringent data-privacy protections. Transparency likewise remains indispensable in a sector as socially consequential as electricity. Regulators increasingly require explainability for algorithms that influence tariff formation or market clearing; the European Agency for the Cooperation of Energy Regulators (ACER) offers a pertinent precedent, deploying AI for anomaly detection in wholesale markets while reserving final adjudication for human analysts—a governance model that reconciles computational vigilance with democratic accountability.

Anticipating the coming decade, it is evident that the convergence of deep-decarbonization mandates, accelerating decentralization, and the wholesale electrification of transport and heat will inflate the power sector's operational state-space to a degree that conventional planning and dispatch paradigms can no longer accommodate. In that enlarged problem set, artificial intelligence is destined to migrate from boutique pilot to routine backbone, an analytical counterpart as ubiquitous as SCADA once became in twentieth-century control rooms.

The maturation of distributed and collaborative machine-learning architectures (federated learning across multiple utilities, for example) will permit data-rich model training without compromising proprietary boundaries. Simultaneously, reinforcement-learning agents are expected to graduate from advisory roles to closed-loop control, manipulating real-time set-points so as to stabilize networks characterized by high inverter-based resource penetration. At the upstream planning horizon, generative AI platforms can already ingest extensive technical corpora to auto-draft grid codes or enumerate least-regret expansion portfolios, thereby telescoping months of human desk analysis into hours.

The future autonomous digital grid operator is beginning to crystallize as a supervisory entity in which algorithmic engines perform routine operational optimization, reserving only non-standard or ethically fraught interventions for human judgement. Because such autonomy assumes broad and diverse data, international cooperation is indispensable whether to construct a global solar-irradiance forecasting engine shareable by all jurisdictions, or simply to exchange lessons learnt on failed pilots so that lessons are not learned twice. The ASEAN community, with its historically collaborative ethos, is well placed to curate that knowledge commons.

Finaly, for Vietnam and comparable systems, a sequenced yet forward-leaning trajectory is advised. Initial attention should gravitate toward "no-regret" sensor and communications upgrades - advanced metering infrastructure, SCADA modernization, secure data lakes, while parallel capacity-building programmes instruct data-science literacy within utilities and regulators alike. Controlled urban pilots such as city-scale smart grids employing AI for fault location and demand-response orchestration can then validate algorithms under bounded risk before national rollout under an incentive-aligned regulatory envelope. Active membership in regional finance and technical consortia will further socialize costs and de-risk adoption.

In sum, AI and associated digital technologies are not a panacea. Yet they are the key tools for moving forward to advanced smart low-carbon grids. Empirical evidence from Europe's anticipatory policy frameworks, Chinese and U.S. technological breakthroughs, and ASEAN's multilateral initiatives converges on a single point: when granular data and intelligent algorithms are fused with rational, open-minded regulation and skilled human oversight, the resulting power system is demonstrably more efficient, resilient, and sustainable. Governments and industry actors should therefore embrace an active stewardship role setting clear guardrails on transparency, ethics, and inclusivity, so that the accelerating AI-driven digitalization of electricity economies delivers equitable gains to consumers, competitive advantages to markets, and decisive progress toward climate-stabilizing objectives.

CHAPTER

05

Current Status of AI & Digital Technology Applications in The Electricity Sector in Viet Nam

Chapter 5: Current AI & Digital Technology Applications in Viet Nam's Power Sector

5.1. Overview of Viet Nam's Power Grid

The Vietnamese power system is organized into five main functional components, each managed by specific entities under the Vietnam Electricity (EVN) Group or independent stakeholders. The structure is summarized as follows:

- **Generation:** *Electricity is generated from a variety of sources, including hydropower, thermal power (coal and gas), and an increasingly significant share from renewable energy sources such as solar and wind. This segment is managed by EVN's three power generation corporations (EVNGENCO 1, 2, and 3), as well as by private and foreign-invested independent power producers (IPPs).*
- **Transmission:** *The high-voltage transmission network, operating mainly at 220kV and 500kV levels, is responsible for transferring electricity from generation plants to regional and local distribution networks. This network is operated and maintained by the National Power Transmission Corporation (EVNNPT), a subsidiary of EVN.*

- **Distribution:** *Electricity is delivered to end-users through medium- and low-voltage networks. Distribution services are provided by five regional power corporations under EVN, namely: EVNHANOI, EVNHCMC, EVNNPC, EVNCPC, and EVNSPC.*
- **System Operation (Dispatching):** *The national and regional load dispatch centers (A0, A1, A2, and A3), now is National System and Market Operator is responsible for real-time operation and balancing of the power system, ensuring system stability, reliability, and optimal operation.*
- **Retail and Customer Services:** *This function involves the management of metering systems, billing, and customer care. It is handled by local electricity companies under the supervision of the respective power corporations.*

As of 2024, Vietnam's power system has reached a considerable scale with the following key statistics:

- **Total installed generation capacity:** *approximately 80,000 MW.*
- **Electricity access coverage:** *over 99.7% of households nationwide are connected to the grid.*
- **Share of renewable energy:** *more than 20% of the total electricity generation is derived from renewable sources.*
- **Length of 500kV transmission lines:** *approximately 7,800 kilometers, forming the backbone of the national grid.*

Despite significant progress in expanding the power infrastructure and diversifying energy sources, the Vietnamese electricity sector is currently facing several critical challenges:

- **Integration of Renewable Energy:** *The rapid growth of intermittent renewable energy sources such as solar and wind power presents new challenges for grid stability and system dispatch, particularly during peak generation hours.*
- **Aging Distribution Infrastructure***: In many areas, the distribution network remains outdated and lacks automation, limiting the ability to respond quickly to operational issues and increasing vulnerability to technical losses.*
- **Demand for Higher Reliability***: As energy consumption increases, so does the demand for high service reliability and lower technical and non-technical losses.*
- **Shortage of Skilled Workforce in Digital Technologies***: There is a growing need for human resources with expertise in digital transformation, artificial intelligence, and advanced data analytics to support smart grid development and modern system management.*

5.2. Summary of AI & Digital Technology Projects in Viet Nam's Electricity Sector

In recent years, the Vietnamese electricity sector has made substantial progress in the adoption of artificial intelligence (AI) and digital technologies across a wide range of operational domains. Key electric utilities—including EVNNPT, EVNHCMC, EVNHANOI, EVNSPC, EVNCPC, and EVNNLDC (now as NSMO)—have launched numerous initiatives aimed at modernizing infrastructure, improving operational efficiency, and enhancing customer service. The key areas of application are outlined in the Table below.

Table 2. Key areas of AI and digital technology applications in Vietnam's electricity sector

Applications	Initiatives & Details
Remote Metering & Automated Data Collection (AMI)	- Meter Data Management System (MDMS) (EVNNPT-Transmission metering scope): Collection of metering data and management of power output/loss. - By 2024, more than 12 million remote monitoring meters have been installed by EVNHCMC, EVNHANOI, and EVNSPC. - Implementation of MDMS (Meter Data Management System) for automated data collection, integrated with AI analytics to detect abnormal consumption behaviors. - GIS-based management of remote metering devices by EVNHCMC, with 99% of smart meters monitored digitally. - EVNHANOI is researching, building and testing the Advanced Metering Infrastructure (AMI) using smart electronic meters and integrated into backend systems such as CMIS, MDMS, online payment gateway, customer service notification portal, CRM, customer care application/web.... This is to modernize the metering system and bring new experiences to customers, ensuring safe, continuous, reliable and high-quality power supply.... EVNHANOI researches the application of 4.0 industrial revolution technologies such as IoT, AI, Machine Learning, Big Data to modernize the power metering system....
Intelligent Equipment Monitoring & Operation	- AI Image Analysis from UAV/Camera (PTC2, EVNNPT): Automatic inspection, detection of damage, broken insulators, foreign objects on transmission lines and substation equipment; Optimization of inspection flight paths. - AI Camera Monitoring (Thermal/Visual Image) (PTC3, 500kV Duyen Hai, Thuong Tin substations-Trial): Monitoring equipment status, automatic detection of hot spots at substations. - Temperature Monitoring System/Sensors (EVNNPT): Real-time monitoring of joint and equipment temperature to assess and warn of potential failure risks. - AI-assisted Condition-Based Maintenance (CBM) (EVNNPT): Analysis of operational data to calculate equipment health index, forecast faults, and optimize maintenance schedules. - AI-integrated Inspection Robot (GENCOs, EVNNPT substations): Automation of operational monitoring, inspection of equipment at power plants (e.g., Son La Hydropower).

Applications	Initiatives & Details
	- Condition-Based Maintenance (CBM) using IoT sensors and AI analytics implemented by EVNHCMC for medium and high-voltage grids. - Drones with AI-powered image processing used for transmission line inspection and fault detection[140]. - Power Transmission Company 2 (PTC2) deployed AI applications in the transmission line surveillance camera system mounted on the tops of 500 kV-220 kV transmission line poles to enhance features and improve efficiency in monitoring and managing transmission line operations[141]. - Smart cameras deployed at substations (e.g., 220kV Tan Cang, 110kV Phuoc Long) for real-time monitoring, face recognition, and access management.
AI in Load Forecasting & Renewable Energy Integration	- AI for Power Plant Operation Optimization (EVN-Applied at power plants, e.g., Son La Hydropower): Using AI algorithms to improve accuracy, optimize water resources, and power output. - EVNNLDC (now as NSMO) applies deep learning neural networks for short-term load forecasting. - AI systems predict solar and wind power generation using satellite weather data (used by EVNSPC, EVNCPC). - Big Data and AI used to clean and convert SCADA data for use in the Electricity Market.
Customer Service & Internal Automation	- AI Meeting Synthesis (EVN/EVNNPT Headquarters): Automatic summarization and analysis of online meeting content (helps reduce errors and synthesis time). - AI in Communication Work (PTC1): Application of AI to produce multimedia communication content (e.g., Podcast by PTC1). - Process/Record Digitization (PMIS) (EVNNPT): Digitization of all equipment records, O&M processes (work order management, defect tracking, etc.) for centralized management on software (PMIS). - AI chatbots implemented by EVNHANOI, EVNSPC, and EVNHCMC for 24/7 customer support. - RPA (Robotic Process Automation) used for automating finance, payment, and HR processes. - EVNHCMC offers 100% online customer services through websites, apps, and the National Public Service Portal. - Deployment of SmartEVN mobile app for staff management and communication. - Implementation of BI (Business Intelligence) systems for executive dashboards and decision-making. - Digital signatures fully adopted by EVNHCMC and EVNNLDC(now as NSMO) to manage internal documentation securely.

[140] https://tapchicongthuong.vn/hieu-qua-quan-ly-luoi-truyen-tai-tu-ung-dung-uav-va-cong-nghe-lidar-129807.htm

[141] https://baochinhphu.vn/ung-dung-tri-tue-nhan-tao-vao-he-thong-camera-quan-sat-tren-duong-day-102300928.htm

Applications	Initiatives & Details
	- EVNNLDC(now as NSMO) uses E-Office systems and structures operational data for both grid and market operations.
Grid Operation & Technical Management	- Transmission Line Management System (AI) (PTC2-Module development/PTC1, 3, 4-Extended deployment): Digitization of records, online information management based on GIS, automatic data editing, and support for maintenance/fault management on transmission lines. - Digital Substation / Unattended Operation (EVNNPT-New and Upgraded substations): Conversion of 220kV/500kV substations to remote control; application of digital substation technology for operational automation. - Lightning Warning Collection System (EVNNPT): AI analysis of lightning data, supporting quick fault location and lightning protection design. - Turbine Data Analysis (AI) (GENCOs): Using AI algorithms to improve accuracy, optimize water resources and power output (applied at Hydropower Plants). - Digitalization of 100% of technical management processes in PMIS and GIS platforms. - Full automation of medium-voltage grids, with remote control capabilities and SCADA/DMS centers in place. - Real-time management of SAIFI/SAIDI and energy loss metrics using SCADA and telemetry data. - Full DMS functionality (since 2017) in 6/15 distribution companies under EVNHCMC. - Deployment of the first 110kV digital substation in Cu Chi district. - Development of mobile field applications (e.g., GIS inspection, CRM-App, livestream security). - Use of EMS and DIM-AGC systems by EVNNLDC(now as NSMO) for grid simulation and generation control. - There has been research on developing the Measurement and Monitoring System for Substations and Low Voltage Grids (S3M-SGMV) to solve the problem of not automating the monitoring, warning and data collection process at substations and low voltage grids.... This system has been tested in practice and contributes to the digital transformation and development of smart grids.... - Researching the application of robot camera technology to monitor the operation of unmanned substations to overcome the limitations of traditional inspection methods....
Construction & Investment Management	- Implementation of the IMIS 2.0 investment management platform. - BIM (Building Information Modeling) used for Data Center projects with 3D models and virtual reality visualization. - Research on the application of Virtual Reality (VR), Augmented Reality (AR) and Building Information Modeling (BIM) technology in the design, construction and operation of power projects.... The combination of AR and BIM models helps to connect digital information with real-world projects in a visual way....

Applications	Initiatives & Details
Telecommunications & IT Infrastructure	- National Cyber Security Company (NCS): AI-powered Cybersecurity Product Ecosystem (Next Generation Firewall, NCS TI, NCS SOC/SIEM/SOAR). Increased threat recognition capabilities, reduced manual operation, and lessened reliance on foreign solutions. - Multi-Layered Defense (Firewall + EDR + TI): Deployment of Next-Generation Firewalls (NGFWs), AI-driven Endpoint Detection and Response (EDR) solutions, and Threat Intelligence (TI) platforms to protect systems. Prevention of sophisticated threats and provision of an early defense layer. -Behavioral Analysis (AI-integrated SIEM): Application of Security Information and Event Management (SIEM) integrated with AI to process large volumes of log data and detect anomalies in real-time. Addresses information leakage and OT attack detection by identifying behaviors that deviate from normal activity. - Security Orchestration, Automation, and Response (SOAR): AI integration with the SOAR platform enables the system to automate incident response actions (e.g., isolating a server, blocking malicious IPs) according to pre-defined playbooks. Reduced burden on CS personnel, faster response times (from hours to minutes), and continuous 24/7 monitoring assurance. - Managed Security Service Provider (MSSP) Model: Enterprises utilize MSSP services from partners. These partners use AI technology for monitoring and incident handling. - Management Records Digitization: Digital conversion of all equipment records, operating procedures, and related documents on systems like PMIS. - IoT Device Monitoring Management: Deployment of robust management systems for IoT devices (sensors, AI cameras, UAVs) with strict control procedures. - Operation of Tier-3 rated Data Centers (ANSI/TIA-942-B:2017). - Advanced transmission infrastructure enables real-time grid monitoring and automation. - Establishment of Security Operations Center (SOC) for IT and OT cybersecurity monitoring. - Deployment of IoT Gateways for underground grid fault signal collection. - Use of advanced technologies: cloud computing, virtualization, hyper-converged infrastructure (HCI), ESB integration. - Upgraded network and server infrastructure with enhanced cybersecurity protocols.

5.3. Data Demonstrating the Impact of Digital & AI Technologies

The integration of digital technologies and artificial intelligence (AI) has delivered measurable improvements across multiple areas of Vietnam's electricity sector. The results achieved in key domains such as smart metering, maintenance, load forecasting, customer service, and internal governance are presented in the table below, demonstrating the tangible benefits of digital transformation efforts led by major power corporations.

Table 3. Key results of AI and digital technology applications in Vietnam's electricity sector

Impact Area	Key Results
Smart Metering & AMI	- Remote data collection rate surpassed 97% in 2024, cutting operational costs. - AI-based consumption analysis led to a 25% increase in electricity theft detection.
Maintenance &Operation Efficiency	- EVNHANOI reduced average annual outage time from over 500 minutes (2017) to around 170 minutes (2023). - EVNHCMC reached SAIDI of 35 minutes in 2022. - Overload-related incidents decreased from 15% to 6–8%. - Manual inspection of transmission lines dropped by 35% due to drone usage. - Power restoration via FLISR occurs in under 1 minute. - Achieved 100% unmanned 110kV substations and fully automated medium-voltage networks.
Load & Renewable Forecasting Accuracy	- Short-term load forecasting accuracy improved from 88% to over 95%. - Renewable energy utilization rates increased from 75–80% to over 90%.
Customer Service Improvements	- Over 90% of customer requests resolved on the same day. - Customer satisfaction index reached 8.8/10 (EVNHANOI, 2023) and 9/10 (EVNHCMC). - Over 99% of EVNHCMC's transactions were processed electronically. - 100% online services available via web/app at EVNHCMC.
Internal Management & IT Governance	- All management KPIs at EVNHCMC are displayed on BI dashboards. - 100% of responsible personnel use digital signatures securely. - EVNHCMC was the first enterprise in Vietnam certified at digital transformation level 3/5 by the Ministry of Information and Communications. - 3.6-point increase in Smart Grid Index from 2021 to 2022 (reaching 71.4/100), ranked 47/94 globally, 2nd in ASEAN.

5.4. Conclusion

Implementing artificial intelligence (AI) and digital technologies has significantly enhanced operational efficiency, service quality, and the integration of renewable energy sources in Vietnam's electricity sector. These advancements underscore the critical role of digital transformation in modernizing grid infrastructure and improving customer engagement.

Continued investment is essential to maintain this positive trajectory, particularly in upgrading digital infrastructure, developing a skilled digital workforce, and strengthening international partnerships.

EVNHCMC has set a target to reach digital transformation maturity level 4 out of 5 by 2025. The utility also seeks to further elevate its Smart Grid Index to meet or exceed global standards, reinforcing its commitment to innovation and sustainable energy development.

CHAPTER

06

High-level Policy, Regulatory & Financing Investigation

Chapter 6: High-level Policy, Regulatory, and Financing Investigation

Vietnam's policy and regulatory framework is undergoing rapid transformation to support its twin goals of energy transition and digital modernization. Vietnam has issued a comprehensive set of national strategies, technical standards, and legal instruments that collectively promote the development of a smart, reliable, and decarbonized power system. The major components of the evolving landscape across national planning, operational regulation, and legal/investment structures are presented below.

6.1. National Strategies and Long-term Planning

Vietnam's electricity sector is undergoing a fundamental transformation, guided by a series of national strategies and long-term planning documents that prioritize modernization, digitalization, and the application of advanced technologies. These strategies underscore the government's commitment to building a smart, efficient, and sustainable energy infrastructure capable of integrating renewable energy and meeting future demands.

Resolution No. 55-NQ/TW (2020) on the Strategic Orientation for National Energy Development of Vietnam to 2030, with a Vision to 2045 sets out the overarching goal of developing the energy sector in a harmonious manner across all sub-sectors, supported by a synchronized and intelligent infrastructure. It emphasizes the upgrading and construction of an advanced and modern power transmission and distribution grid. The resolution aims to build a smart, efficient power grid capable of regional connectivity. The goal is to achieve a fully developed, modern energy infrastructure system with significantly enhanced regional and international connectivity by 2045. The resolution also emphasizes accelerating digital transformation in the energy sector, implementing a national program on smart energy infrastructure development, modernizing the power dispatching system, gradually implement the application of automated and intelligent technical monitoring technologies; conduct research and apply ultra-high voltage and direct current transmission technologies in the power sector; improve regulatory mechanisms, develop comprehensive databases, and implement national energy statistics to support the effective management and administration of the energy sector.

Resolution No. 29-NQ/TW (2022) on continuing to promote the industrialization and modernization of the country by 2030, with a vision to 2045, outlines the strategic orientation for the development and application of smart technologies and artificial intelligence (AI) as a core driver of national competitiveness. The resolution emphasizes the need to accelerate research, development, and wide application of advanced technologies such as AI, the Internet of Things (IoT), Big Data, blockchain, and automation across key sectors including energy, manufacturing, agriculture, transportation, finance and banking, and smart cities. It also calls for the development and improvement of an innovation ecosystem, the promotion of comprehensive digital transformation, and the enhancement of digital infrastructure and high-quality human resources to ensure a sustainable and effective path toward industrialization and modernization in the context of the Fourth Industrial Revolution.

Resolution No. 57-NQ/TW (2024) marks a pivotal milestone in Vietnam's national strategy for the development of science, technology, innovation, and digital transformation. The resolution emphasizes the promotion of research and application of artificial intelligence (AI) across key sectors and fields (e.g. healthcare, education, public administration, finance and banking, transportation, environment, energy, high-tech processing and manufacturing industries). In the energy field, AI is oriented to be applied in optimizing power system operations, managing energy consumption, developing smart grids, and integrating renewable energy sources. The goal is that by 2030, Vietnam will be among the top three Southeast Asian countries in AI research and development, and by 2045, it will become a regional hub for digital technology industries, significantly contributing to sustainable socio-economic development.

Resolution No. 68-NQ/TW (2025) – Promoting Private Sector Development positions Vietnam's private sector as the primary driver of national economic growth and a key force in advancing science, technology, innovation, and digital transformation. It supports the successful implementation of Resolution No. 57-NQ/TW (December 22, 2024), which outlines Vietnam's digital development goals. A key emphasis of Resolution 68 is the modernization of public administration through technologies such as artificial intelligence (AI) and big data, especially in approval and licensing processes. By promoting the digitization of regulatory procedures, the resolution enhances transparency, accelerates permitting, and improves coordination for energy and infrastructure projects. It also strengthens institutional support for the adoption of AI across the energy sector—from policy design to operational execution—aligning closely with Vietnam's national digital strategy.

The amended Electricity Law of 2024, along with **Decrees No. 58/2024/NĐ-CP** and **56/2024/NĐ-CP**, sets forth clear and specific directions to promote the comprehensive modernization of the power sector, with a strong focus on the development of smart grids and digital transformation. The law and accompanying decrees mandate the application of advanced technologies, automation, and digital solutions across all stages of the electricity supply chain—from generation, transmission, and distribution to system operation and electricity market management. The development of smart grid systems is encouraged to enhance the integration of renewable energy sources, optimize power system operations, and improve energy efficiency. The regulations call for the establishment of centralized electricity data systems and encourage the application of artificial intelligence (AI), big data, blockchain and 5G technologies, and digital solutions in technical management, load forecasting, and customer service.

As the **revised Power Development Plan VIII** (PDP8) issued on April 15, 2025 (**No. 768/QĐ-TTg**), the development and application of smart grids are identified as a core strategic direction to modernize the national power system, ensuring safe, stable, and efficient operation. The transmission grid will be developed in sync with the progress of power source construction and the growing demand from localities, utilizing modern technologies that meet international standards and are ready for regional interconnection. Plan details on power generation capacity and the volume of transmission grid can be seen at Table A1 and Table A2 in the Annex. Smart grids are particularly oriented toward effectively integrating large-scale renewable energy sources through the research and application of advanced technologies such as HVDC, SVC, SVG, FACTS devices, BESS, and DLR to enhance operational efficiency and system flexibility. The plan also outlines scientific and technological solutions, including the renovation and upgrading of transmission and distribution systems, modernization of data systems, automation, and control systems to support dispatching and electricity market operations. PDP8 promotes the adoption of cutting-edge technologies such as artificial intelligence (AI), the Internet of Things (IoT), and advances digital transformation within the power sector. It also calls for gradual implementation of both incentivized and mandatory measures to renew technologies and equipment in electricity-intensive industries, aiming to build a modern, smart, and sustainable power system.

Since 2012, the Vietnamese Government has concretized its goal of modernizing the national power system, enhancing operational efficiency, improving electricity supply reliability, and increasing the integration of renewable energy by approving the Smart Grid Development Roadmap in Vietnam (**PM Decision No. 1670/QĐ-TTg** dated November 8, 2012). The roadmap is divided into three phases: Phase 1 (2012–2016) focused on developing the legal framework and implementing pilot programs; Phase 2 (2017–2022) expanded the application of smart grid technologies across the entire power system; and Phase 3 (post-2022) aims to develop advanced smart grids with deep integration of digital and automation technologies. The MOIT detailed the roadmap's objectives through the Comprehensive Smart Grid Development Project (**MOIT Decision No. 4602/QĐ-BCT** dated October 26, 2016), which includes three component projects emphasizing the application of modern technologies such as automated control systems, smart meters, advanced energy management, and IT solutions. In 2023, based on the evaluation of the 10-year implementation of Decision No. 1670, the MOIT submitted its **Proposal No. 6068** to the Prime Minister recommending the Smart Grid Development Project for the 2023–2030 period, with a vision to 2045. This proposal outlines the continued development of a modern smart grid to support the energy transition and ensure national energy security. It also sets a gradual application of artificial intelligence (AI), big data, and the Internet of Things (IoT) in monitoring and forecasting energy consumption, load, equipment and system failures, equipment condition assessment, power system operation, asset management, customer service, and cybersecurity. However, the Government has instructed the MOIT to review and re-evaluate the proposal to develop necessary tasks and approve them under its jurisdiction for implementation, ensuring the achievement of Decision no. 1670's objectives.

A summary of the policy and the associated AI and digital technologies is provided in Table 4.

Table 4. Policy and the associated AI and digital technologies

	Policy / Regulation	Year	Key Objectives & Directions	Related AI & digital technologies
1	Smart Grid Development Roadmap (Decision No. 1670/QĐ-TTg)	2012	Set phased smart grid objectives for generation, transmission, distribution, and retail	Provides national framework for digital and smart technologies in grid modernization
2	Comprehensive Smart Grid Development Project (Decision No. 4602/QĐ-BCT)	2016	Implement smart grid technologies in distribution and retail electricity services	Enables deployment of AMI, demand response, system monitoring, and AI-based grid control
3	Resolution No. 55-NQ/TW	2020	Modernize and digitize energy sector; promote automation	Supports AI, SCADA, IoT, centralized energy data for smart grid operations
4	Resolution No. 29-NQ/TW	2022	Promote industrialization with AI, Big Data, IoT, and automation	Enables cross-sector digital infrastructure, including power grid transformation
5	Smart Grid Development Proposal Extension (MOIT Proposal No. 6068)	2023	Extend roadmap to 2045; apply AI, IoT, and Big Data for monitoring, forecasting, asset management, security	Recommends deeper digital integration and advanced analytics to support the energy transition and grid resilience
6	Resolution No. 57-NQ/TW	2024	Drive national science and digital innovation agenda	Prioritizes AI for power system management, market operation, and grid optimization
7	Resolution No. 68-NQ/TW	2025	Modernise public administration under national digital strategy	Supports AI and big data in approval and licensing processes; facilitates digitalization of energy governance
8	Revised Power Development Plan VIII (PDP8)	2025	Ensure efficient, modern, and renewable-friendly power grid	Incorporates HVDC, BESS, smart technologies, digital infrastructure expansion

6.2. Legal Framework for Investment

Vietnam's legal architecture is also evolving to support investments in both conventional and digital energy infrastructure. These legal instruments aim to improve transparency, reduce investment risk, and encourage private sector engagement in both grid infrastructure and digital energy services. Key regulatory developments include:

Electricity Law– 61/2024/QH15 (2024)

Serving as the cornerstone of Vietnam's power sector legislation, this law establishes the legal foundation for the energy transition, including the integration of renewable energy sources such as offshore wind. It mandates comprehensive planning for power generation and transmission infrastructure, which sets the structural parameters within which digital and AI solutions must operate. The law addresses technological requirements for project implementation and mandates information security and data confidentiality—setting the legal constraints for digital system deployment. Additionally, it provides the framework for power purchase agreements (PPAs), which rely heavily on accurate forecasting and grid reliability—key areas where AI can deliver significant value. Overall, the law defines the enabling legal environment for the adoption of digital and AI technologies in Vietnam's evolving power sector.

In addition to the Electricity Law, several other key laws regulate the investment and implementation of power projects in Vietnam:

- **Investment Law (61/2020/QH14):** *Provides the legal framework for both domestic and foreign investment activities, including conditions, incentives, and procedures for investing in the energy sector. It governs how AI and digital projects—especially those developed in partnership with private or international investors—can be financed and implemented.*
- **Law on Public-Private Partnership (PPP Law – 64/2020/QH14):** *Establishes the legal basis for PPP models in infrastructure development, including power generation and transmission projects. This law is particularly relevant for deploying large-scale digital infrastructure and smart-grid solutions, where public-private collaboration is critical.*
- **Construction Law (50/2014/QH13, amended by 62/2020/QH14):** *Governs the construction activities of power facilities, including permitting, safety, and quality standards. It plays a key role in ensuring that the integration of smart and AI-driven systems into physical infrastructure meets technical and regulatory compliance.*
- **Law on Planning (21/2017/QH14):** *Sets the foundation for national, regional, and sectoral planning, including the national power development plan (PDP). It ensures that digital and AI technologies are aligned with long-term infrastructure development strategies and harmonized with Vietnam's socio-economic planning goals.*

Together, these laws create a comprehensive legal and regulatory environment for the deployment of digital and AI technologies in power sector projects, from investment to planning, construction, and operation.

Decree 56/2025/ND-CP (2025) – Detailing Implementation of the Law on Electricity for Power Sector Development and Investment

This decree elaborates on electricity planning, grid development, and investment mechanisms under the Law on Electricity. Importantly, it introduces a dedicated chapter on digital transformation and the management of electricity-related data systems. It encourages the adoption of advanced technologies, including artificial intelligence, big data, blockchain, cloud computing, and 5G, for planning and managing the electricity sector. The decree specifies the structure of the national energy information system and defines the types of data required—such as technical specifications, production metrics, and primary energy data. It also prioritizes investment in renewable and new energy projects that align with Vietnam's energy transition goals, thereby explicitly linking digital innovation with the broader decarbonization agenda.

Decree 58/2025/ND-CP (2025) – Detailing Implementation of the Law on Electricity for Renewable and New Energy Development

This decree provides the detailed regulatory framework to support the development of renewable and emerging energy sources. It sets forth policy incentives and regulatory mechanisms to encourage investment in technologies such as offshore wind and other variable renewables. Implementation responsibilities are clearly assigned to relevant ministries, provincial People's Committees, and Vietnam Electricity (EVN). Notably, EVN is tasked with developing and deploying digital monitoring and control systems to manage renewable energy sources with fluctuating outputs. This regulation underscores the central role of digital solutions in maintaining system reliability and flexibility in a high-renewables environment and reinforces the legal mandate for leveraging digital transformation in achieving Vietnam's clean energy goals.

A summary of the key legal and investment framework and the associated AI and digital technologies is provided in Table 5.

Table 5. Key Legal and investment framework & the associated AI and digital technologies

	Policy	Year	Objectives	Related AI & digital technologies
1	Electricity Law – 61/2024/QH15	2024	Establish legal foundation for power sector and energy transition	Sets requirements for data security, planning, PPAs, enabling AI-based forecasting and digital grid management
2	Decree 56/2025/ND-CP	2025	Detail investment and planning under Electricity Law	Introduces digital transformation chapter; mandates AI, Big Data, 5G for energy data and planning systems
3	Decree 58/2025/ND-CP	2025	Promote renewable energy and new technologies	Requires EVN to adopt digital tools for variable RE integration; reinforces digital infrastructure for grid stability

6.3. Technical and Operational Regulations

To implement the national strategies, Vietnam has issued numerous technical regulations through MOIT Circulars and ERAV Decisions that provide detailed guidelines for the operation and control of grid infrastructure.

Circular 05/2025/TT-BCT (2025) *establishes the technical standards governing Vietnam's power transmission, distribution, and metering systems, with specific provisions for critical infrastructure such as Power System Stabilizers (PSS) and Battery Energy Storage Systems (BESS), which play a vital role in ensuring grid stability. It mandates the implementation of Data Concentrator Units (DCUs) and related systems for the acquisition and management of metering data, including data from energy storage facilities, while also defining standardized voltage levels across transmission and distribution networks. These technical specifications provide the foundational framework for the integration of digital technologies and artificial intelligence (AI) in system monitoring, control, and data analytics. A comprehensive understanding of these requirements is essential for leveraging AI and digital solutions to support regulatory compliance, enhance asset utilization, and improve the resilience and operational efficiency of the power grid.*

Circular 06/2025/TT-BCT (2025) *sets forth comprehensive regulations for the operation, dispatch, fault handling, black start, and restoration of the national power system, encompassing procedures for grid management and forecasting. It mandates the use of SCADA/EMS and SCADA/DMS platforms as the core digital infrastructure for system monitoring, control, and data exchange—forming the essential interface through which artificial intelligence (AI) applications must operate. The regulation outlines a range of forecasting requirements at daily, monthly, and yearly intervals, presenting clear opportunities for AI to enhance prediction accuracy and decision-making. Additionally, the prescribed processes for equipment status management and fault response offer potential for AI-driven predictive maintenance and automated operational support. The inclusion of personnel training requirements further underscores the relevance of digital and AI-powered simulation tools to strengthen workforce preparedness and system reliability.*

Decision 55/QĐ-ĐTĐL (2017) *establishes the technical and operational management requirements for SCADA systems within Vietnam's national power system, serving as a foundational regulation for real-time grid monitoring and control. It specifies detailed standards for Remote Terminal Units (RTUs), including protocols for data acquisition, transmission, and system reliability. The regulation also defines the necessary connectivity and architecture between central SCADA systems and associated SCADA/EMS and SCADA/DMS platforms, ensuring interoperability and system integrity. These technical specifications form the core digital infrastructure that enables the secure and efficient operation of the power grid. A thorough understanding of these standards is critical, as SCADA systems provide the essential data streams and control interfaces upon which advanced artificial intelligence (AI) and digital* *solutions for grid optimization, predictive analytics, and autonomous decision-making must be built.*

Decision 105/QĐ-ĐTĐL (2018) *defines the standard procedures for collecting, processing, and managing metering data within Vietnam's electricity market, establishing a critical foundation for grid operation, market settlement, and analytical functions. It specifies the architecture of Metering Data Collection Systems (MDCS) and Metering Data Management Systems (MDMS), confirming the presence of a structured digital infrastructure for handling metering data. The regulation also outlines procedures for estimating and interpolating missing data using SCADA systems and dispatch logs, highlighting potential applications for artificial intelligence (AI) to enhance data accuracy, completeness, and reliability. The availability of granular consumption and generation data implied by the decision provides a rich input stream for AI-driven applications such as load forecasting, demand-side management, and market behavior analysis. By formalizing data processes and ensuring consistency, this regulation paves the way for integrating data-centric AI solutions within a compliant and transparent regulatory environment.*

Decision 175/QĐ-BCT (2019) *approves the roadmaps and implementation plans for Demand Response (DR) programs, positioning DR as a key strategic initiative within the broader framework of Demand Side Management (DSM) to enhance power system efficiency and improve load factor. The decision emphasizes the deployment of enabling technologies such as Advanced Metering Infrastructure (AMI), Direct Load Control (DLC), and Response Automation Systems to support effective DR execution. It delineates the responsibilities of regulatory agencies and Vietnam Electricity (EVN) in developing the supporting legal framework, conducting training, and overseeing program implementation. This regulatory directive establishes a robust policy foundation for the integration of digital tools to enable active consumer engagement and real-time demand control. It also presents a high-potential domain for artificial intelligence (AI) applications, particularly in the areas of load forecasting, behavioral modeling, and automated DR control strategies, aimed at optimizing demand-side flexibility and enhancing overall system reliability.*

Decision 41/QĐ-ĐTĐL (2020) *establishes the operational management procedures for the information technology (IT) systems used in administering Vietnam's competitive electricity market. It delineates the digital infrastructure specifically dedicated to market operations, separate from the IT systems used for grid management. The regulation mandates the use of user accounts and structured reporting, indicating the availability of organized datasets related to market participants, bidding activities, and transaction records. This rich source of market data offers significant potential for artificial intelligence (AI) applications in areas such as electricity price forecasting, optimization of trading strategies, and anomaly detection. The decision highlights the growing digitalization across the entire power sector value chain, reinforcing the role of advanced digital and AI technologies in enhancing market transparency, efficiency, and responsiveness.*

Decision 67/QĐ-ĐTĐL (2021) *promulgates the standard procedure for forecasting power output and energy production from renewable energy sources, establishing a critical regulatory framework to support the integration of variable generation into Vietnam's power system. It mandates forecasting across multiple time horizons—daily, weekly, monthly, and yearly—along with explicit requirements for evaluating forecast accuracy. This regulation highlights a key application area for artificial intelligence (AI) and machine learning technologies, which are well-suited to enhance the precision and reliability of renewable energy forecasting. By defining both the operational necessity and performance assessment criteria, the decision provides a strong regulatory foundation for the deployment of advanced AI-powered forecasting tools, which are essential for maintaining grid stability and operational efficiency in a power system with high levels of renewable energy penetration.*

A summary of theTechnical Regulation and the associated AI & digital technologies is provided in Table 6.

Table 6. Technical Regulation and the associated AI and digital technologies

	Documents	**Year**	**Objectives**	**Related AI & digital technologies**
1	Decision 55/QĐ-ĐTĐL	2017	SCADA system standards and connectivity	Essential infrastructure for AI-based monitoring, control, and automation
2	Decision 105/QĐ-ĐTĐL	2018	Metering data system architecture and management	Enables granular data availability for AI-driven analytics, forecasting, and DSM
3	Decision 175/QĐ-BCT	2019	DR program roadmap and enabling technologies	Supports AMI, DLC, automation, and AI for load forecasting and demand flexibility
4	Decision 41/QĐ-ĐTĐL	2020	IT systems for competitive electricity market	Provides market data for AI applications like price forecasting and strategy optimization
5	Decision 67/QĐ-ĐTĐL	2021	Forecasting renewable generation procedures	Defines performance standards and timeframes for AI-powered RE forecasting
6	Circular 05/2025/TT-BCT	2025	Grid and metering technical standards	Establishes BESS, PSS, DCU standards; forms digital foundation for smart grid analytics
7	Circular 06/2025/TT-BCT	2025	Grid operation and restoration protocols	Mandates SCADA/EMS use, forecasting, and opens opportunities for AI in fault handling and training

6.4. Financing AI & Digitalization in Viet Nam's Power Sector

Realizing large-scale AI and digitalization investments in Vietnam will demand substantial capital and a robust policy framework. Vietnam currently encounters constraints in long-term financing vehicles and market-design mechanisms for digital infrastructure deployment[142]. The following sections deliver a structured examination of potential financing instruments, highlight recent domestic and international initiatives, and extract lessons from global examples, all with the goal of guiding Vietnamese policymakers and regulators in mobilizing funds and developing an ecosystem conducive to AI and digital technologies in the power sector.

6.4.1. Financing Mechanisms and Instruments

A mix of international, regional, and domestic financing mechanisms can support Vietnam's power sector digitalization. Key financing instruments include:

[142] https://caseforsea.org/vietnam

Multilateral Development Bank Concessional Loans

Concessional financing from multilateral development banks (MDBs) offers a foundation for grid modernization, pairing low-interest terms with extended tenors and grace periods. The World Bank's US $500 million Transmission Efficiency Project (2014) underwrote the construction of 1 000 km of high-voltage lines and implemented Smart Grid technologies to improve reliability and quality of electricity supply in Vietnam[143]. By lowering the cost of capital, these loans catalyze investments in advanced metering infrastructure (AMI), grid automation and SCADA upgrades. Likewise, the Asian Development Bank has channeled a US $600 million results-based loan to Indonesia's state utility, PLN, targeting distribution network resilience and operational performance[144]. Tethering disbursements to performance metrics ensures that digital-infrastructure rollouts deliver measurable reliability gains and establishes a template for Vietnam to secure similar MDB support for its own smart-grid ambitions.

Grants & Climate-Focused Funding

Grant financing and concessional climate funds finance pilot projects and capacity-building exercises that de-risk nascent technologies. GIZ-supported "Smart Grids for Renewable Energy and Energy Efficiency" (SGREEE, 2017–2022) provided technical assistance to Vietnam's Electricity Regulatory Authority (ERAV), effectively supporting the Smart Grid Roadmap's policy development and demonstration pilots. Concurrently, U.S. agencies including USAID and USTDA have implemented technology-transfer missions, such as USTDA's 2024 program that brought Vietnamese officials to the US to study cutting-edge U.S. technologies in grid cybersecurity and renewable integration[145]. At a global level, mechanisms like the Green Climate Fund (GCF) and Global Environment Facility (GEF) can finance early-stage applications of AI for grid stability or battery management systems, aligning carbon-reduction goals with investments in digital systems. These grant streams serve as critical enablers - absorbing first-mover costs and signaling government commitment to innovative digital transitions.

Blended Finance & De-Risking Instruments

Blended-finance structures leverage public and philanthropic capital to crowd in private investors, utilizing guarantees, insurance products and results-based payments to enhance risk-adjusted returns. The Just Energy Transition Partnership (JETP) for Vietnam, an initiative brought forward by G7 governments, has pledged US $15.5 billion in combined public and private finance to accelerate the country's green-energy shift, including the integration of digital grid solutions[146]. Credit enhancements take up roughly half of this funding in MDB loans and export-credit agency guarantees, while the remainder is sourced from private equity and institutional

[143] https://www.worldbank.org/en/news/press-release/2014/11/12/wb-vietnam-sign-500-million-loan-to-improve-energy-efficiency

[144] https://www.adb.org/news/adb-provide-indonesias-energy-sector-over-1-billion-loans

[145] https://www.ustda.gov/ustda-supports-strengthening-securing-vietnams-power-sector

[146] https://ec.europa.eu/commission/presscorner/detail/en/ip_22_7671

investors. Similarly, in 2022 GuarantCo extended a US $50 million partial credit guarantee to EVNFinance, enabling the issuance of Vietnam's inaugural green bond (VND 1 725 billion (≈ US $75 million)) for financing green-infrastructure capex[147]. By mitigating sovereign or utility credit risk, these de-risking instruments unlock private capital for smart-meter deployments, grid-edge storage systems and VPP platforms, setting a precedent for scalable blended-finance models.

Public–Private Partnership (PPP) Frameworks

Public–private partnerships mobilize private-sector efficiency and funding for digital-infrastructure projects, especially when public budgets are constrained. Vietnam's revised Electricity Law (2024) now authorizes private investment in sub-220 kV transmission and distribution assets which were previously state monopolies, paving the way for PPPs in smart-meter rollouts, EV-charging networks and data-centres for grid management[148]. Under build-operate-transfer (BOT) or concession arrangements, private firms can recover investments via availability payments or user fees, provided clear contractual frameworks and regulatory safeguards. India's national smart-meter program, for instance, leverages a "bulk procurement and lease" PPP model executed by Energy Efficiency Services Ltd., financing over 250 million meters and amortizing costs through utility tariffs[149]. Vietnam can pilot analogous structures - such as third-party smart-meter operators or VPP aggregators - thereby diversifying funding sources while securing long-term service quality.

Domestic Public Finance: EVN & Local Banking

Vietnam Electricity (EVN) remains a pivotal financier of grid modernization, deploying tariff revenues, retained earnings and government-backed debt to underwrite digital upgrades - ranging from SCADA enhancements to AMI rollouts and IT/OT integration. Yet, EVN's capital envelope is limited: from 2021–2025, only VND 4.38 trillion (≈ US $187 million) of state budget support was allocated against an estimated VND 94.9 trillion (≈ US $4 billion) annual grid-investment requirement[150]. Consequently, EVN and its subsidiaries must deepen engagement with domestic banks and bond markets. EVNFinance's green-bond issuance - underpinned by a partial guarantee - demonstrates the potential for "green" lending, while the Vietnam Development Bank (VDB) and commercial banks could establish dedicated credit lines for smart-grid projects, supported by interest-rate subsidies or priority-sector mandates. Such measures would channel domestic savings into AI-enabled grid infrastructure.

[147] https://guarantco.com/news/guarantco-provides-evnfinance-a-vnd-1150-billion-c-usd-50-million-partial-credit-guarantee-to-support-the-issuance-of-vietnams-inaugural-internationally-verified-green-bond/

[148] https://reglobal.org/vietnams-new-electricity-law-paves-the-way-for-accelerated-energy-transformation/

[149] https://sarepenergy.net/wp-content/uploads/2025/01/Case-Study-on-Smart-Metering-Market-Transformation-in-India.pdf

[150] https://vepg.vn/wp-content/uploads/2023/08/Options-for-private-sector-investment-into-Vietnams-grid-24042023-ENG.pdf

Private Capital Mobilization Strategies

Beyond PPPs, Vietnam can mobilize private capital through green and sustainability-linked bonds, venture capital vehicles and infrastructure-fund equity. Issuers - ranging from utilities to provincial governments - must adopt clear taxonomies and third-party verification (as exemplified by EVNFinance's international bond certification) to attract global ESG investors[151]. Domestic startups, such as SmartSolar, which secured US $1.85 million in seed funding for rooftop PV and AI-driven energy solutions[152], represent high-growth targets for climate-tech funds. Facilitating introductions between local innovators and impact investors, through government matchmaking platforms, can accelerate the scale-up of digital-energy applications. Asset recycling in non-core holdings (e.g., fiber-optic networks on transmission corridors) to fund digital upgradesm, offers another avenue to strengthen financial resources for smart-grid investments.

Digital Innovation Funds & Accelerators

Targeted innovation funds foster the incubation and demonstration of AI and digital solutions. Vietnam might tap ADB or World Bank facilities - such as the Asia Digital Transformation Fund - or collaborate with the ASEAN Innovation Network to implement pilot projects in AI-driven fault detection or blockchain-based energy trading. Public-private accelerators, typified by New Energy Nexus Vietnam (established in 2019), have already nurtured hundreds of clean-energy startups, supporting ventures in energy-management software and battery-analytics platforms[153]. Launching a Vietnam-focused "Energy Digitalization Challenge," with multi-donor sponsorship, could reward top local pilots and catalyze further funding. Though grant sizes are modest, their catalytic impact lies in de-risking early-stage concepts and validating business models for subsequent large-scale investments.

No single financing instrument can meet the needs of the full scope of Vietnam's digital-grid aspirations. A blended portfolio - combining concessional loans, grant funding, blended-finance vehicles, PPPs, domestic lending and private equity - will be necessary to marshal sufficient capital. Structuring these streams into coherent packages - for instance, utilizing a climate-grant to demonstrate an AI pilot, then scaling with an MDB loan and finally attracting private co-investment - ensures both financial closure and operational viability. Crucially, this capital must be deployed within a policy environment that aligns incentives, mitigates regulatory risk and empowers both public and private actors to innovate.

[151] https://www.cardanodevelopment.com/2022/guarantco-provides-evnfinance-a-vnd-1150-billion-c-usd-50-million-partial-credit-guarantee-to-support-the-issuance-of-vietnams-inaugural-internationally-verified-green-bond/

[152] https://vir.com.vn/smartsolar-bags-185-million-in-seed-funding-123943.html

[153] https://www.newenergynexus.com/chapter/vietnam/

6.4.2. International Experiences and Contextual Lessons

Developing and emerging economies worldwide offer lessons learnt for financing and deploying digital energy infrastructure. Four case studies - spanning Asia and Africa - demonstrate how tailored policy frameworks and innovative funding models can unlock private and public capital for large-scale smart-grid, metering and microgrid programmes. Each example yields a key principle directly applicable to Vietnam.

India – Smart Metering via Public–Private Partnership

India's National Smart Meter Programme, the largest of its kind globally, undertook the replacement of 250 million electromechanical meters with advanced digital devices under a Build-Own-Operate-Transfer (BOOT) architecture orchestrated by Energy Efficiency Services Ltd. (EESL). In this model, EESL - a government-owned energy service company - aggregates meter procurement and deployment, financing capital expenditures through commercial debt and bond issuances. Distribution utilities defer payments over an 8–10-year horizon, remitting service fees calibrated to recovered losses and enhanced billing revenues[154]. Initial pilots in 2013 validated technical feasibility and financial viability, paving the way for a rapid programme scale-up.

Key Lesson: *A well-structured PPP can support private-sector finance and technical expertise while addressing utility liquidity constraints. By deferring payments and linking them to verifiable performance improvements - such as collection-rate gains and loss reductions - India's BOOT mechanism mitigated upfront funding barriers. Vietnam might emulate this approach through an "Accelerated Smart Power Initiative," convening donors, private investors and EVN to install smart meters, automated distribution devices or EV-charging stations, with repayments sourced from efficiency dividends or regulated service fees. Strong government backing - similar to India's National Smart Grid Mission and unified technical specifications - will be essential to develop confidence among financiers and implementers.*

Nigeria – Independent Meter Asset Providers

Confronting chronic non-revenue losses, Nigeria's Electricity Regulatory Commission (NERC) introduced the Meter Asset Provider (MAP) scheme in 2018, permitting certified private entities to finance, install and maintain meters. Customers choose between upfront payment or installment plans incorporated into monthly bills. This partial privatization of metering attracted multiple MAPs and delivered millions of meters in its initial phase[155]. However, foreign-exchange shortages given the imported nature of meter hardware and periodic regulatory

[154] https://sarepenergy.net/wp-content/uploads/2025/01/Case-Study-on-Smart-Metering-Market-Transformation-in-India.pdf

[155] https://brooksandknights.com/wp-content/uploads/2021/09/UNDERSTANDING-THE-NEW-METER-ASSET-PROVIDER-AND-NATIONAL-MASS-METERING-REGULATIONS.pdf

delays hindered full roll-out, prompting a government-subsidized national meter-procurement programme by 2020[156].

Key Lesson: *Private-sector participation can accelerate critical digital-metering investments, but regulatory design must anticipate macroeconomic and operational risks - such as currency mismatches for imported equipment - and ensure consistent policy enforcement. Vietnam's regulators, when delegating battery storage installations or EV-charging networks to third-party operators, ought to embed contractual safeguards for payment guarantees, currency-hedging provisions and robust performance criteria. Concurrently, consumer-protection measures - capping upfront fees and guaranteeing quality standards - are vital to maintain public trust and sustainable uptake.*

Kenya – Pay-As-You-Go & Smart Mini-Grids

Kenya's electrification paradigm has been transformed by the convergence of mobile money and solar technology. Off-grid enterprises like M-KOPA fuse M-Pesa mobile payments with solar-home-system leases, allowing low-income households to acquire energy services via micro-instalments[157]. On-grid, Kenya Power deployed smart prepaid meters in the early 2010s, financed through a blend of internal resources and concessional loans, to reduce theft, improve revenue collection and enhance consumer autonomy[158]. In remote areas, concessional grants and MDB financing under the Kenya Off-grid Solar Access Project facilitated the development of digitally controlled mini-grids, integrating PV, storage and diesel backup via intelligent controllers[159].

Key Lesson: *Embedding digital payment systems within energy services not only expands access but also strengthens cash flows essential for financial sustainability. Vietnam can leverage its high mobile-penetration and fintech innovations to introduce prepaid smart-metering and mobile-top-up platforms, thereby enhancing bill compliance and consumer engagement. For rural electrification, smart microgrids, supported by concessional climate finance, can deliver reliable power to islands and hinterlands while demonstrating scalable business models for subsequent private-sector investment.*

Malaysia – Regulated Asset Base Model for Smart Grids

Tenaga Nasional Berhad (TNB), Malaysia's state-owned utility, has executed a comprehensive smart-grid strategy under a multi-year regulated-asset-base (RAB) framework. Targeting over 9 million smart-meter installations in Melaka and the Klang Valley by 2026, TNB channels

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[156] https://fij.ng/article/fg-has-spent-over-155m-to-close-metering-gap-since-2020-but-more-nigerians-now-lack-meters

[157] https://www.forbes.com/sites/tobyshapshak/2016/01/28/how-kenyas-m-kopa-brings-prepaid-solar-power-to-rural-africa/

[158] https://www.smart-energy.com/regional-news/africa-middle-east/smart-meters-africa-kenya-power-starts-pilot-for-high-end-consumers

[159] https://projects.worldbank.org/en/projects-operations/project-detail/P160009

approximately RM 9 billion (≈US $2.1 billion) annually into network modernization - of which digital components constitute a substantial share - secure in the knowledge that the Energy Commission's tariff methodology will incorporate depreciation and an approved return on these investments[160,161]. This regulatory certainty has enabled TNB to access bond markets and internal reserves to sustain long-term capital programmes.

Key Lesson: *A stable, transparent RAB mechanism - guaranteeing cost recovery and a fair return - empowers utilities to underwrite ambitious digital upgrades. Vietnam's ERAV can adapt this model by embedding AI-enabled distribution-management systems, advanced sensors and AMI within its regulated asset base, thereby legitimizing tariff increases that finance digitalization. Pilot projects - mirroring Malaysia's phased meter-rollout pilots - can de-risk technology adoption and facilitate stakeholder buy-in before national scaling.*

6.4.3. Current Initiatives & Funding Opportunities in Viet Nam

Vietnam has already started deploying a multifaceted agenda to mobilize funding for energy-sector digitalization, yet further opportunities remain to be seized.

Multilateral Development Bank Initiatives

Vietnam's longstanding partnerships with the World Bank and the Asian Development Bank (ADB) have consistently incorporated smart-grid and automation components alongside traditional network upgrades. The World Bank's US $500 million Transmission Efficiency Project (TEP, 2014–2020) financed 1 000 km of new lines and supported Smart Grid technologies for monitoring, control, and protection equipment to improve reliability and reduce outages[162], thereby seeding the country's first generation of SCADA enhancements and modern dispatch-centre tools. More recently, World Bank sector-reform loans have been structured to encourage wholesale-market introduction and advanced-metering trials, combining policy conditionality with capital investment. Meanwhile, ADB has financed urban network reinforcement in Hanoi and Ho Chi Minh City, embedding technical assistance for smart-grid roadmaps within these expansion projects, and is planned to channel a share of Just Energy Transition Partnership (JETP) resources, part of Vietnam's US $15.5 billion JETP framework, into grid digitalization and storage deployment[163]. Such blended programmes demonstrate how MDB financing can marry concessional capital with policy support, a model Vietnam can extend via targeted Results-Based Lending facilities that release funds as EVN achieves smart-meter rollout or renewable-forecasting-accuracy milestones.

[160] https://www.smart-energy.com/regional-news/asia/tnb-resumes-smart-meter-installations

[161] https://policy.thinkbluedata.com/sites/default/files/Electricity%20tariff%20regulatory%20implementation%20guidelines_0.pdf

[162] https://www.worldbank.org/en/news/press-release/2014/11/12/wb-vietnam-sign-500-million-loan-to-improve-energy-efficiency

[163] https://www.pv-tech.org/vietnam-to-accelerate-renewables-deployment-with-us15-5-billion-deal

Bilateral Donor Programmes & Pilot Projects

GIZ has supported the development of the Smart Grid Roadmap (2012–2022) through the SGREEE project, delivering policy-framework updates, pilot demand-response schemes and ERAV capacity building[164]. Concurrently, USAID's Vietnam Urban Energy Security initiative has piloted advanced building-energy management and demand-response platforms in Da Nang and Ho Chi Minh City, alongside grants for solar and wind forecasting to bolster NLDC operations[165]. JICA support has modernized control centres and introduced IoT-based monitoring[166], while the UK Prosperity Fund (2019–2021) financed feasibility studies for battery storage and smart-grid policy[167]. Though these bilateral interventions rarely mobilize large capex, they catalyze proof-of-concept demonstrations - enabling utility proposals for scaled financing under MDB or private-sector programmes. For instance, a successful GIZ-backed automatic-voltage-control trial in a mid-central province could be packaged into a follow-on World Bank loan for national deployment.

Just Energy Transition Partnership (JETP)

Declared in late 2022, Vietnam's JETP commits US $15.5 billion over three to five years to decarbonize the power sector. Although the JETP prioritizes renewable energy expansion and the gradual reduction of coal, the public-finance tranche of approximately US $7.75 billion is intended to support a broad set of transition needs, including power-grid upgrades, energy-storage solutions, and other enabling digital technical platforms. The forthcoming Resource Mobilization Plan (2024–2025) will detail allocations, offering a prime opportunity to designate a national smart-meter rollout or AI-driven energy-management-system pilots as flagship projects. Public capital - disbursed as concessional loans or grants via KfW, AFD and similar agencies - can de-risk early investments, while the private-finance component (≈US $7.75 billion) will seek guarantees and viability-gap instruments to underwrite commercial-scale digital solutions. Vietnamese regulators must therefore cultivate a pipeline of bankable "smart" proposals - in metering, storage, EV charging or VPP coordination - to ensure JETP financing accelerates AI and automation uptake rather than solely generation capacity[168].

Climate Funds: GCF & GEF

Vietnam qualifies for the Green Climate Fund (GCF) and the Global Environment Facility (GEF), both of which prioritize innovative, transformative pilots. ADB-administered regional GCF resources for e-mobility and battery storage in Southeast Asia could be tapped to underwrite Ho Chi Minh City's smart-charging infrastructure - paired with rooftop solar and behind-the-

[164] https://www.giz.de/en/downloads_els/Smart%20Grids_ENG_25-6.pdf

[165] https://news.tuoitre.vn/usaid-assists-da-nang-in-promoting-urban-energy-security-as-part-of-14mn-project-10361825.htm

[166] https://vietnamnews.vn/society/1694458/jica-project-provides-electricity-to-300-households-in-northern-province-yen-bai.html

[167] https://www.iisd.org/projects/sustainable-finance-advice-asean-low-carbon-energy-program

[168] https://www.pv-tech.org/vietnam-to-accelerate-renewables-deployment-with-us15-5-billion-deal

meter storage to reduce urban emissions. Similarly, GEF grants - though modest - could sponsor AI-based grid-stability demonstrations, aligning with GEF's mitigation agenda. Accessing these facilities demands rigorous proposal development and inter-ministerial coordination, but successful applications rely not only on funding but also on reputational capital that attracts parallel co-finance from bilateral and private sources.

Domestic Initiatives: EVN's Digital-Transformation Drive

EVN's self-initiated digital transformation - targeting full "digital-enterprise" status by 2025 represents a major internal financing effort[169]. Pilots include FPT-partnered IoT and AI applications in distribution networks and enterprise-resource-planning rollouts[170]. These programmes, underwritten by EVN's retained earnings and commercial bank lending, underscore the utility's commitment to modernization. Policymakers can bolster EVN by enabling temporary tariff increases or accelerated depreciation on digital investments, thus smoothing financial pressures. The Vietnam Development Bank (VDB) could further establish dedicated credit lines for grid modernization, extending preferential terms to EVN and eligible private partners. At the sub-national level, municipal "smart city" funds which are already financing smart-street lighting and AI-optimized solar rooftops in e.g., Da Nang[171] and Ho Chi Minh City[172]- can be aligned with EVN's digital agenda via central budget earmarks under the National Digital Transformation Programme 2025.

Regional Cooperation & South–South Partnerships

Vietnam's ASEAN membership unlocks regional funding channels such as the ASEAN Infrastructure Fund (AIF), which co-finances sustainable grid projects and could underwrite ASEAN-Power-Grid interconnection controls. The ASEAN Smart Cities Network likewise offers grant support for smart-energy applications in urban areas. Beyond ASEAN, partnerships with South Korea's Global Green Growth Institute supporting green bonds[173] - and Israel's cybersecurity expertise create additional avenues for knowledge transfer and potential co-investment[174]. South–South learning visits - drawing on India's smart-meter rollout or Brazil's distribution-automation experience - can be facilitated by multilateral agencies, equipping Vietnamese project designers with global best practices and expanding their access to non-traditional lenders, such as Indian infrastructure banks or Chinese development funds interested in smart-grid technologies.

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169 https://en.vietnamplus.vn/evn-contributes-to-realising-national-digital-transformation-goals-post238953.vnp

170 https://fpt.com/en/news/press-media/fpt-to-enter-into-a-partnership-with-evnspc-on-digital-transformation

171 https://kalaharijournals.com/resources/FebV7_I2_197.pdf

172 https://en.vietnamplus.vn/hcm-city-over-25-mln-usd-to-be-spent-on-rooftop-solar-systems-post313198.vnp

173 https://www.cardanodevelopment.com/2022/guarantco-provides-evnfinance-a-vnd-1150-billion-c-usd-50-million-partial-credit-guarantee-to-support-the-issuance-of-vietnams-inaugural-internationally-verified-green-bond

174 https://en.evn.com.vn/d6/news/Exchanging-experiences-on-cyber-security-between-EVN-and-Israeli-businesses-6-12-3480.aspx

6.4.4. Synthesis & Preliminary Analysis

Vietnam's regulatory ecosystem is undergoing a significant transformation to support the integration of artificial intelligence (AI) and digital technologies within its power sector. The latest policies, laws and regulations send one steady message: big growth in renewables must go hand-in-hand with smart grids, data systems, and AI. Together, the Law on Electricity (61/2024/QH15), the revised Power Development Plan (PDP8), and a number of technical regulations outline what has to be built, how it should run, and where digital tech fits in.

The key policy drivers include:

- **Energy mix targets:** *The revised PDP8 locks in high solar, on-shore wind, and off-shore wind goals for 2030 and 2050, requiring a digital-ready grid to manage higher shares of renewables and new technologies.*

- **National digitalization agenda**: *Resolutions 55-NQ/TW (2020), 29-NQ/TW (2022), and 57-NQ/TW (2024) collectively push AI, Big Data, and IoT integration across sectors, with energy as a central focus for modernization and innovation.*

- **Smart-grid direction:** *Decision 1670/QĐ-TTg sets a step-by-step path for an "intelligent power grid" with clear tasks: finish the legal rules, set the tech standards, and roll out the needed IT and telecom hardware.*

- **Tech push:** *Both PDP8 and Decree 56/2025 call for AI, IoT links, big-data tools, cloud, and 5G to make the above targets real.*

As far as the digital backbone is concerned the following is highlighted:

- **SCADA/EMS, SCADA/DMS, and AMI are mandatory:** *They these provide the core infrastructure for real-time monitoring, control, and fault response across the grid, and feed live data from power plants, lines, and meters straight to control rooms—raw material for any AI engine.*

- **Meter data rules:** *Decision 105/QĐ-DTDL describes how to gather, analyze, and store data, which is then utilized for demand forecasting and market tasks.*

- **Single sector database:** *In PDP8 a single database for technical and market data is foreseen, facilitating future analytics.*

The following table presents immediate applications of AI:

Table 7. Applications of AI

Area	What the rules say	How AI helps
Renewable forecasts	Document 67/QĐ-DTDL makes hour-ahead to day-ahead output forecasts compulsory.	Machine-learning decreases or even eliminates errors and optimizes dispatch.
Battery and grid devices	PDP8 lists BESS, synchronous communications and SCADA upgrades.	AI can optimize and automate charge/discharge and volt-VAR control.
Demand-response	Decision 175/QĐ-BCT sets a DR road-map using AMI and automation.	AI interfaces with users, sets bids and times events.
Market bids & prices	IT regulation 41/QĐ-DTDL backs the competitive market.	AI forecasts price and optimizes bids.
Asset health	Regulation 06/2025/TT-BCT covers dispatch, errors, and equipment status.	Predictive models warn before faults, improve SAIDI/SAIFI.

Some key recommendations for safe & smooth AI applications roll-out based on this analysis include:

- **Inter-system fit:** Voltage limits, Remote Terminal Unit (RTU) specs, cyber rules, and data formats are all prescribed; any AI module must plug into these without hacks.

- **Cybersecurity provisions:** New digitalization applications widen the attack surface, so the Law on Electricity now flags cybersecurity as a must-check item in every project.

- **Fair access:** Plans call for AMI and smart-grid links in both cities and rural zones, keeping digital benefits spread wide.

Vietnam's policy set does more than allow AI and digital tools, it actually expects them. The legal targets, the smart-grid path, the meter rules, and the market IT spec all create clear data streams and control points that AI solutions can utilize for roll out.

Finally, Vietnam's pursuit of an AI-enabled smart grid demands a carefully developed financing strategy. Annual investment requirements —estimated at VND ~95 trillion (USD ~4 billion)— surpass state and utility budget envelopes. Leveraging the USD 15 billion commitment under the Just Energy Transition Partnership (JETP) will therefore hinge on assembling a diversified capital stack, deploying innovative de-risking instruments, and aligning regulatory incentives with investor expectations. To utilize the full USD 15 billion JETP commitment and catalyze private co-investment, the following can be proposed:

1. **Blended Portfolio Architecture:** *Sequence grant-financed pilots into concessional MDB scaling, followed by targeted private equity—thereby optimizing risk-reward profiles.*

2. **Accelerated PPP Pilots:** *Launch an "Accelerated Smart Grid Initiative" modeled on India's BOOT framework to expedite smart-meter and EV-charging network roll-out.*

3. **RAB Adaptation:** *Incorporate AI/AMI assets into a Regulated Asset Base mechanism, furnishing EVN and private operators with regulatory certainty and stable returns.*

4. **Smart Energy Finance Unit:** *Establish a dedicated agency to develop bankable pipelines, coordinate MDB and donor engagements, and package propositions for ESG investors.*

5. **Regulatory Harmonization:** *Align tariff structures, tax incentives (e.g., accelerated depreciation), and priority-sector lending to sustain rapid digital-grid adoption without fiscal strain.*

6. **Inclusive Deployment Mandates:** *Ensure rural AMI coverage, robust consumer safeguards in MAP-like schemes, and fintech-enabled payment modalities to prevent digital exclusion.*

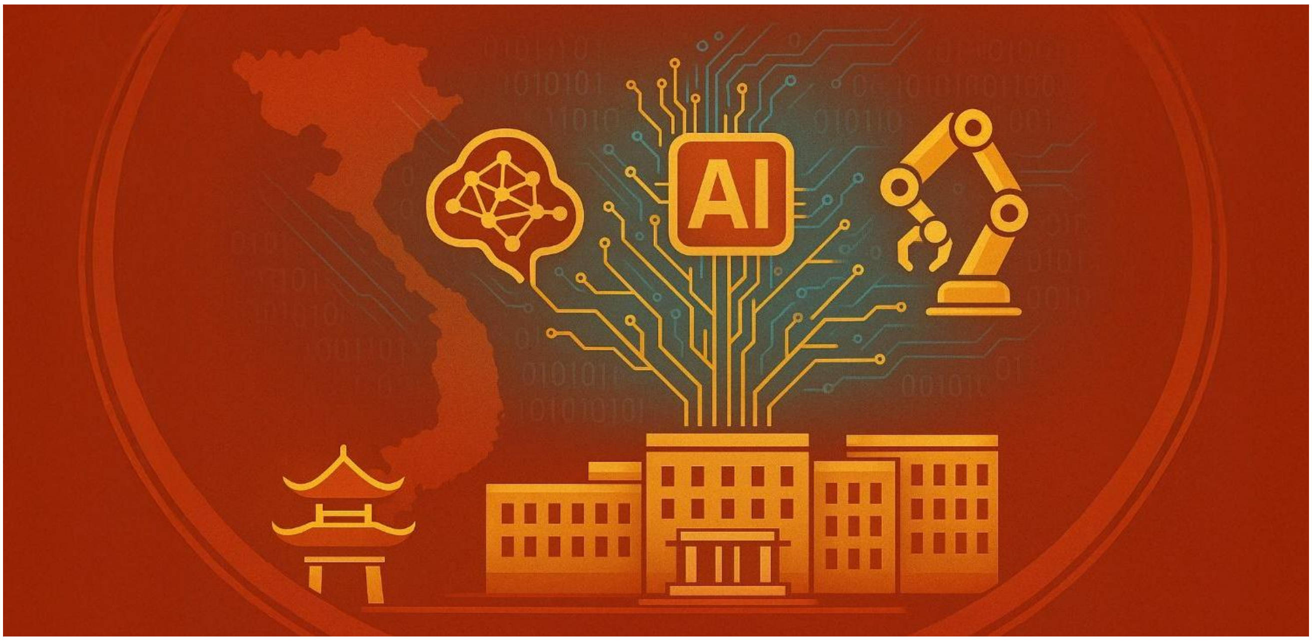
CHAPTER

07

Institutional Framework in Viet Nam

Chapter 7: Institutional Framework in Viet Nam

This chapter aims to present a preliminary analysis of the Institutional framework in Vietnam along with the proposed interaction with them in this project. Vietnam's power sector ecosystem spans government ministries, regulatory bodies, state-owned utilities, academic institutions, communities, development partners and private-sector actors. Each group possesses proprietary datasets, technical expertise or contextual perspectives vital to both the evaluation and ranking of proposed AI/Digital activities and the consensual validation of prioritized interventions. The following engagement plan identifies key stakeholders, specifies the types of inputs they can furnish, and proposes tailored interaction modalities (interviews, surveys, workshops, etc.), calibrated to deliver comprehensive intelligence within an initial one-month timeframe.



7.1. National AI Strategy & Structure

Vietnam's institutional framework for AI development is anchored by the National Strategy on Research, Development, and Application of Artificial Intelligence to 2030, promulgated through Prime Ministerial Decision No. 127/QD-TTg on January 26, 2021, and the Resolution No. 68-NQ/TW dated May 4, 2025. This strategic framework establishes Vietnam's ambition to become a regional AI innovation hub and delegates specific responsibilities across fifteen ministries and agencies. The strategy employs a phased implementation approach: research and development (2021-2025), scaled application (2025-2028), and comprehensive deployment

(2028-2030). This temporal structure provides institutional flexibility while maintaining strategic coherence across multiple government agencies.

Key Coordinating Institutions:

- **Vietnam Government Office:** *Provides overall strategic direction and inter-ministerial coordination through the National Committee for Digital Transformation.*

- **Ministry of Science and Technology (MoST):** *Leads AI research coordination and technical standards development through Decision 1290/QD-BKHCN establishing nine principles for responsible AI development.*

- **Ministry of Information & Communications (MIC) now has been merged to the Ministry of Science and Technology:** *Develops legal frameworks, data sharing mechanisms, and regulatory sandboxes for AI testing.*

- **Ministry of Planning and Investment (MPI) now has been merged to the Ministry of Finance (MOF):** *Operates the Vietnam National Innovation Center (NIC), which manages public-private partnerships and startup acceleration programs.*

7.2. Electricity Sector Governance Structure (Ministry of Industry and Trade - MOIT)

Vietnam's electricity sector governance operates under the Ministry of Industry and Trade (MOIT) as the principal regulatory authority. This centralized structure facilitates coordination between AI policy initiatives and electricity sector implementation. At the policy and regulatory level, the Vietnamese government plays a central role in setting the strategic direction and creating the legal and institutional frameworks for digital transformation and AI integration in the power sector. The key government agencies and their responsibilities include following specialized institutions:

Electricity Authority of Viet Nam (EAV): *Within MOIT, the Electricity Authority of Viet Nam (EAV), the newly established body from the emergence of the Electricity and Renewable Energy Authority (EREA) and the Electricity Regulatory Authority of Viet Nam (ERAV) is the State management agency of electricity sector and government policy advisor on e.g., National Power Development Master Plan (known as PDP), digital-transformation blueprints (such as the MOIT Digital Transformation Plan for the energy sector), and regulatory roadmaps. They can clarify the strategic priority accorded to demand-response schemes, smart-grid deployments and funding envelopes. EAV also maintains granular market-performance metrics such as tariff structures, ancillary-services arrangements, reliability indices (SAIDI/SAIFI), and demand-response trial* *results—as well as progress reports on the national smart-grid roadmap. Their assessment of regulatory feasibility and compliance risk is indispensable.*

National System & Market Operator (NSMO): *Formerly EVNNLDC, has recently been moved under MOIT: Operates the national SCADA/EMS platform and manages real-time grid operations for power systems. NSMO serves as the technical backbone for AI integration, hosting data analytics platforms and renewable energy forecasting systems.*

7.3. Viet Nam Electricity (EVN) and Subsidiaries

Vietnam Electricity (EVN) – Utility: *As the vertically integrated utility, EVN (and its subsidiaries: EVNNPT for transmission; five regional Distribution Companies; GENCOs for generation) holds operational load profiles, outage logs, loss data, procurement cost curves, and digital-project evaluations (e.g., AI in substations[175]). Their strategic digital-transformation roadmap will inform readiness assessments. The state-owned utility corporation implementing comprehensive AI adoption through Action Program No. 40, which establishes specialized databases and data centers supporting AI platforms for generation, transmission, and distribution optimization.*

National Power Transmission Corporation (EVNNPT): *Implements transmission-level automation and digital infrastructure. EVNNPT has achieved 78.8% automation of 220kV substations under unstaffed operation criteria, providing the foundation for AI-enabled grid management.*

Information & Communications Technology Company of Viet Nam Electricity (EVNICT): *A specialized unit managing internal digital transformation, cybersecurity, and data system modernization. This unit lead the design and deployment of enterprise platforms, market data systems, and AI-enabled analytics tools across EVN.*

Provincial and municipal Power Distribution Companies: *(e.g., PC Hanoi, PC Da Nang) and Provincial Departments of Industry and Trade (DOIT) can supply data on region-specific consumer demand patterns, distributed PV uptake, and grid constraints or theft hotspots.*

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175 https://en.evn.com.vn/d/en-US/news/EVN-is-one-of-State-owned-corporations-and-groups-performing-best-in-digital-transformation-60-163-500514

7.4. Supporting Actors: Research Institutes, Private Sector, Development Partners

Large electricity consumers (Industries representatives): *Through associations such as the Vietnam Association of Industrial Parks or Chambers of commerce, engage large commercial and industrial end-users to understand demand-response willingness, EMS adoption barriers and observed cost savings.*

Universities and Research Institutes: *Institutions such as VAST's Institute of Energy Science (ISTEE), Hanoi University of Science and Technology (HUST) and HCMC University of Technology provide independent evaluations—forecasting-model trials, EV-charging-pattern studies—and methodological guidance.*

Communities: *Entities like the groups of consumers and consumer-protection supply qualitative insights on public acceptance, environmental co-benefits and privacy concerns (e.g., reactions to smart-metering).*

International Donors and Development Partners: *Organizations (World Bank, ADB, GIZ, USAID, JICA, DEA) possess region-wide benchmarks, pilot-project evaluations and financing case studies (e.g., DEA's demand-response study[176]).*

Private Technology Providers: *Metering manufacturers, ESCOs and software vendors (e.g., EVNCPC EMEC, ATS, Hitachi, Siemens, AMI Tech, Alena Energy, Signergy, Schneider Viet Nam etc.,) can offer real-world cost estimates, implementation timelines and technical constraints.*

7.5. Stakeholder Contributions & Engagement Plan

To ensure the relevance, feasibility, and impact of the proposed AI and digital transformation initiatives, this section outlines the key inputs expected from various institutional stakeholders and the corresponding engagement strategies. The approach is designed to balance comprehensiveness with efficiency—leveraging both existing relationships and targeted outreach to gather critical data and perspectives within a constrained time frame. These interactions will help shape and validate prioritization criteria, identify practical constraints, and foster cross-sector alignment.

[176] https://ens.dk/media/5394/download

Table 8. Stakeholder collaboration plan

Stakeholder Group	Expected Inputs	Proposed Engagement
MOIT (EAV)	Official capacity-expansion targets; digital transformation strategies; regulatory drafts	Initial consultation meeting with EAV leadership; final validation workshop with MOIT
	Market performance metrics; DSM pilot results; smart-grid implementation progress	Technical consultation meeting with regulatory staff
NSMO	The national SCADA/EMS platform and manages real-time grid operations for power system. Plan for AI integration, hosting data analytics platforms for system & market operation	Consultation meeting to gather data and validate project relevance
EVN and Subsidiaries (EVNNPT, EVNHANOI, EVNNPC, EVNCPC, EVNSPC, EVNHCMC)	Load profiles; outage data; SCADA/DMS metrics; smart meter rollout; pilot evaluation data	Consultation meetings to gather data and validate project relevance
EVNICT	IT architecture; cybersecurity policies; API/data access protocols	
Provincial Utilities/ DOITs	Local load curves; PV penetration; grid constraints; theft statistics	Targeted online survey or teleconference with engineering teams in two selected provinces
Large Industrial Consumers	DR willingness; EMS adoption barriers; cost-saving experiences	Brief email questionnaire and participation in stakeholder workshop
Research Institutions	Published/unpublished studies; expert judgment on criteria	Inclusion of 2–3 experts on review panel; virtual roundtable (Phase 2)
Communities	Community feedback; environmental and social data	Stakeholder consultation session to validate social and environmental dimensions (Phase 2)
Development Partners	Global case studies; technology-cost databases; project outcomes	Data-sharing requests and presentations at multi-stakeholder workshop (Phase 2)
Private Sector Vendors	Technical specifications; price quotes; case-study data	Solicitation of brochures/proposals; invite 1–2 providers for cost/performance validation (Phase 2)

CHAPTER

08

AI / Digitalization Interventions For Viet Nam

Chapter 8: AI / Digitalization Interventions for Viet Nam

8.1. Preliminary List of AI / Digitalization Interventions

Below follows a preliminary list of proposed activities. The activities were chosen following the below considerations:

- **Alignment with Identified AI & Digital Technologies:** The proposed activities are directly informed by the AI applications & digital technologies discussed in the previous chapters.
- **High Impact and Cost-Effectiveness:** The activities were chosen for their potential to deliver significant results at relatively low cost.
- **Outcome-Oriented Design:** Rather than specifying particular AI models or methodologies (e.g., for forecasting), the activities are framed around desired outcomes, allowing flexibility in the choice of technical approaches during implementation.
- Two types of activities are considered and presented in separate lists. The first one is about technical projects and the second about proposed policy / regulatory activities.
- Following this initial identification, the most promising activities will be prioritized and mapped against the development milestones outlined in PDP8. This process will result in a phased Roadmap of AI and Digitalization Interventions, aligned with the power sector's planned evolution and investment timeline

Proposed Technical Activities (in alphabetical order):

- Advanced Metering Infrastructure & Data Analytics
- AI Cybersecurity Frameworks
- AI for Decarbonization and Emissions Tracking
- AI for Grid Stability & Transmission Optimization
- AI-Assisted Grid Operation at Control Centers

- AI-Enabled Interconnection with Neighboring Grids
- AI-Enhanced Load & Renewable Forecasting
- AI-Powered Grid Resilience & Anomaly Detection
- Consumer-Side Intelligence
- Demand Response via Digital Platforms
- Distributed Energy Resource (DER) Orchestration
- Distribution Grid Automation & Loss Reduction
- Energy Management Systems for Large Consumers
- Energy Market Intelligence
- Energy Storage Management AI
- Automated Grid Operation
- Predictive Maintenance for Generation & Grid Assets
- Smart EV Charging Management
- Smart Microgrids for Remote Areas & Resilience
- Virtual Power Plants (VPP) & DER Aggregation

These activities comprise a comprehensive set of digital innovations targeting Vietnam's needs. Many of them are independent (e.g., forecasting), but others are enablers for other activities (e.g., AMI is an enabler for Demand Response).

Proposed Policy / Regulatory activities (in alphabetical order)

- Build Institutional Capacity & Skills for Digitalization
- Create Market Mechanisms for Flexibility & New Services
- Implement Regulatory Sandboxes for Energy Innovation
- Introduce Time-of-Use Pricing
- Promote Public-Private & International Partnerships for Digital Innovation
- Provide Financial Incentives & Support for Smart-Grid Investments
- Strengthen Cybersecurity & Grid-Resilience Regulations

- Update Grid Codes & Technical Regulations for AI/DER Integration.

8.2. Ranking Methodology

To prioritize Vietnam's array of AI- and digital-grid innovations, we have adopted a simple, transparent multi-criteria ranking approach. The ranking of these activities is based on a multi-criteria assessment of strategic value, covering technical feasibility, cost-benefit, system and emissions impact, environmental and social co-benefits, and policy alignment. These scores help identify the most impactful innovations. Each activity is scored against five equally weighted criteria on a three-level scale (Low—Medium—High):

1. **Technical Feasibility & Readiness**
   • High = Proven pilots or mature international deployments;
   • Medium = Emerging pilots, Technology Readiness Level (TRL) 3–6;
   • Low = Conceptual or niche Research & Development (R&D).

2. **Economic Cost-Benefit**
   • High = Rapid payback (<3 years) or large savings;
   • Medium = Moderate cost-effectiveness (3–7 years payback);
   • Low = High capex or unclear Return on Investment (ROI).

3. **Impact on Energy System & Emissions**
   • High = Directly unlocks large renewables shares or cuts CO_2 significantly;
   • Medium = Moderate system efficiency or emissions benefit;
   • Low = Marginal impact.

4. **Environmental & Social Co-Benefits**
   • High = Broad consumer reach, job creation, resilience gains;
   • Medium = Modest community or ecological benefits;
   • Low = Limited co-benefits.

5. **Policy Alignment & Ease of Implementation**
   • High = Explicitly championed in PDP 8, smart-grid roadmaps or regulations and quick to deploy;
   • Medium = Indirectly supported or requires moderate regulatory change;
   • Low = New frameworks or lengthy rule-making needed.

<u>Scoring & Ranking:</u>

- Each activity receives one Low/Medium/High rating per criterion.
- Qualitative ratings are mapped to numeric values for clarity:
  - Low = 0
  - Medium = 0.5
  - High = 1
- All criteria are considered to be of equal value and as such the scores are added up and sorted from highest to lowest for the final ranking list.

8.3. Ranking Results

The first table presents the technical projects & the second one the policy / regulatory interventions.

Table 9. Ranking list of Technical Projects

Activity	Feasibility	Cost-Benefit	System & Emissions	Co-Benefits	Policy Alignment	Total Score	Rank
1. AI-Enhanced Load & Renewable Forecasting	1	1	1	0.5	1	4.5	1 (tie)
2. AI-Assisted Grid Operation at Control Centers	1	0.5	1	1	1	4.5	1 (tie)
3. Demand Response via Digital Platforms	0.5	1	1	1	1	4.5	1 (tie)
4. Virtual Power Plants (VPP) & DER Aggregation	0.5	1	1	0.5	1	4	4
5. Advanced Metering Infrastructure & Data Analytics	0.5	0.5	0.5	1	1	3.5	5 (tie)
6. AI Cybersecurity Frameworks	0.5	0.5	1	1	0.5	3.5	5 (tie)
7. Automated Grid Operation	0.5	0.5	1	1	0.5	3.5	5 (tie)

8. AI-Powered Grid Resilience & Anomaly Detection	0.5	0.5	1	1	0.5	3.5	5 (tie)
9. Distributed Energy Resource (DER) Orchestration	0.5	0.5	1	1	0.5	3.5	5 (tie)
10. Energy Market Intelligence	0.5	0.5	1	1	0.5	3.5	5 (tie)
11. AI for Decarbonization and Emissions Tracking	0.5	0.5	1	1	0.5	3.5	5 (tie)
12. Energy Storage Management AI	0.5	0.5	1	1	0.5	3.5	5 (tie)
13. AI-Enabled Interconnection with Neighboring Grids	0.5	0.5	1	0.5	0.5	3	13 (tie)
14. Distribution Grid Automation & Loss Reduction	0.5	1	0.5	0.5	0.5	3	13 (tie)
15. AI for Grid Stability & Transmission Optimization	0.5	0.5	1	0.5	0.5	3	13 (tie)
16. Energy Management Systems for Large Consumers	1	0.5	0.5	0.5	0.5	3	13 (tie)
17. Predictive Maintenance for Generation & Grid Assets	0.5	0.5	0.5	1	0.5	3	13 (tie)
18. Consumer-Side Intelligence	0.5	0.5	0.5	0.5	0.5	2.5	18 (tie)
19. Smart EV Charging Management	0.5	0.5	0.5	0.5	0.5	2.5	18 (tie)
20. Smart Microgrids for Remote Areas & Resilience	0.5	0	0.5	1	0.5	2.5	18 (tie)

Table 10. Ranking of the Policy / Regulatory activities

Regulatory Measure	Feasibility	Cost-Benefit	System & Emissions	Co-Benefits	Policy Alignment	Total Score	Rank
1. Introduce Time-of-Use Pricing	1	1	1	1	1	5	1 (tie)
2. Build Institutional Capacity & Skills for Digitalization	1	1	1	1	1	5	1 (tie)
3. Strengthen Cybersecurity & Grid-Resilience Regulations	1	1	0.5	1	1	4.5	3
4. Implement Regulatory Sandboxes for Energy Innovation	1	1	0.5	1	0.5	4	4
5. Create Market Mechanisms for Flexibility & New Services	0.5	1	1	0.5	0.5	3.5	5 (tie)
6. Provide Financial Incentives & Support for Smart-Grid Investments	1	0.5	0.5	0.5	1	3.5	5 (tie)
7. Promote Public-Private & International Partnerships for Digital Innovation	1	0.5	0.5	0.5	1	3.5	5 (tie)
8. Update Grid Codes & Technical Regulations for AI/DER Integration	0.5	0.5	1	0.5	1	3.5	5 (tie)

8.4. Integration with Revised PDP8 Development Timeline

The outcomes of the ranking process will serve as the foundation for developing a comprehensive roadmap of AI and digitalization interventions, structured to enable a phased and coordinated implementation aligned with the strategic milestones outlined in PDP8. This roadmap will provide stakeholders with a clear, actionable framework for aligning technical initiatives and policy measures to effectively drive Vietnam's power system modernization and digital transformation.

- **2025–2030 (Short-term priorities):** *Establish the digital and AI foundation by implementing pilot projects focused on AI-based forecasting, digital grid infrastructure deployment, and predictive maintenance pilots. Concurrently, regulatory groundwork will be laid to enable these innovations, setting the stage for larger-scale efforts.*

- **2030–2035 (Medium-term priorities):** *Scale up intelligent systems and smart grid control capabilities, including real-time wide-area energy management, AI-powered grid resilience, and enhanced interconnection coordination. Regulatory frameworks will be strengthened to support expanded data infrastructure, advanced demand response programs, and cross-border energy market integration.*

- **2035–2050 (Long-term priorities):** *Achieve AI integration across the power system through automated grid operations, advanced energy storage management, and distributed energy resource orchestration. The focus will also be on enabling sophisticated market intelligence, decarbonization efforts, and robust AI-driven cybersecurity frameworks to support a renewable-centric, resilient grid. This long-term strategy should be adaptive and regularly updated later to reflect ongoing technological advancements and emerging trends within the energy sector.*

It is important to note that while the ranking tables evaluate each activity based on strategic criteria—such as technical feasibility, cost-benefit, and impact—the timeline assignments (2025–2030, 2030–2035, 2035–2050) reflect practical and system-specific considerations. As such, a higher score does not necessarily mean earlier implementation, and vice versa.

Finally, it has to be mentioned that each of the Short- and Medium-term activities are presented in more detail in the following Chapter.

Table 11. Time Range and AI/Digitalization Roadmap until 2050

Time range	Key Power Development Targets	AI & Digital Tech Application Strategy
2025–2030 Laying the Digital and AI Foundation.	• Total capacity: 183–236 GW • Massive increase in solar, wind • (onshore/offshore), and storage systems • Introduction of nuclear energy • Key focus on LNG, domestic gas, and energy imports/exports	***Technical Activities:*** • AI-Enhanced Load and Renewable Energy Forecasting • Demand Response Programs via Digital Platforms • Advanced Metering Infrastructure (Smart Meters) and Data Analytics • Energy Management Systems (EMS) for Large Consumers (Industry 4.0 Energy Efficiency) • Predictive Maintenance for Generation and Grid Assets ***Policy / Regulatory Activities:*** • Introduce Time-of-Use Pricing building upon existing Demand Response Regulations • Build Institutional Capacity and Skills for Digitalization • Strengthen Cybersecurity and Grid Resilience Regulations • Implement Regulatory Sandboxes for Energy Innovation • Provide Financial Incentives and Support for Smart Grid Investments • Update Grid Codes and Technical Regulations for AI and DER Integration

Time range	Key Power Development Targets	AI & Digital Tech Application Strategy
2030–2035 Scaling Intelligent Systems & Smart Grid Control.	● Offshore wind: 17 GW ● Solar: 73 GW ● Begin nuclear (4–6.4 GW) deployment ● Large-scale energy storage (10–16.3 GW batteries, 6 GW pumped hydro) ● Electricity export/import systems expansion	***Technical Activities:*** ● AI-Driven Virtual Power Plants (VPP) and DER Aggregation ● AI-Powered Grid Resilience and Anomaly Detection ● Distribution Grid Automation and Loss Reduction ● AI for Grid Stability and Transmission System Optimization ● Consumer-Side Intelligence ● Smart Electric Vehicle (EV) Charging Management ● AI-Driven Ancillary-Service Dispatch Optimization ***Policy / Regulatory Activities:*** ● Create Market Mechanisms for Grid Flexibility and New Services ● Promote Public-Private and International Partnerships for Digital Innovation
2035–2050 AI-Integrated Smart Grid & Renewable-Centric System.	● Total capacity: 774–838 GW ● Solar: ~295 GW ● Offshore Wind: ~139 GW ● Onshore Wind: ~91 GW ● Battery storage: 96 GW ● Hydrogen, ammonia, biomass-fired retrofitting ● Nuclear: 14 GW	***Technical Activities:*** ● AI Cybersecurity Frameworks (National-level digital security with behavior-based threat detection AI) ● Automated Grid Operation (AI agents for multi-objective dispatch optimization, carbon pricing, congestion relief) ● Distributed Energy Resource (DER) Orchestration (AI-enabled DERMS) ● Energy Market Intelligence (AI facilitates wholesale/retail markets, DPPA optimization, spot market analytics) ● AI for Decarbonization and Emissions Tracking ● Energy Storage Management AI (Predictive balancing of battery charge/discharge across seasons and demand peaks) ● AI-Enabled Interconnection with Neighbouring Grids ***Policy / Regulatory Activities:*** ● Continuation and enhancement of all earlier policies with mature, adaptive frameworks supporting the integrated AI-driven grid and markets.

8.5. Implementation Risks

The table below presents a risk analysis for implementing AI / Digitalization Interventions for Vietnam.

Table 12. Risk Analysis

Risk	Impact	Likelihood	Mitigation Measure
1. Data Quality & Governance Failures Inaccurate or incomplete data undermines AI outputs.	High	Medium	Establish a centralized data-governance framework with standardized schemas, validation rules and audit trails; mandate minimum data-quality KPIs for all pilots.
2. Cybersecurity Breaches Grid digitalization expands the attack surface.	High	High	Enforce rigorous security standards (e.g., IEC 62443), continuous AI-driven anomaly detection, regular penetration testing, and incident-response drills.
3. Regulatory Uncertainty & Delay Slow rule-making stalls deployment.	High	Medium	Set clear, time-bound roadmaps for key regulations (TOU pricing, market-design), establish inter-ministerial "fast-track" working groups to draft and approve rules.
4. Skills & Capacity Shortages Lack of AI/digital expertise in utilities and regulators.	High	High	Launch national upskilling programs in partnership with universities and industry, establish "AI in Energy" certification, and embed digital-innovation units within EVN.
5. Vendor Lock-In & Interoperability Proprietary systems hinder scale-up.	Medium	Medium	Mandate open-API and data-exchange standards (e.g., OpenADR), require procurement tenders to specify multi-vendor compatibility, and pilot reference architectures.
6. Financing Gaps & Cost Overruns Capital shortfalls or cost escalations derail projects.	High	Medium	Structure blended-finance packages (grants + concessional loans + private equity), include cost-overrun clauses in PPP contracts, and build contingency reserves.
7. Algorithmic Bias & Black-Box Risks Opaque AI decisions reduce trust and compliance.	Medium	Medium	Require explainability standards for all AI modules, implement third-party model audits, and incorporate human-in-the-loop checkpoints for critical decisions.
8. Change Management & Organizational Resistance Staff pushback slows adoption.	Medium	High	Embed change-management practices: stakeholder workshops, pilot-to-scale roadshows, top-down sponsorship, and clear incentives tied to digital KPIs.
9. Digital Divide & Equity Concerns Rural or low-income areas lag in access.	Medium	Medium	Allocate dedicated funding and PPP models for rural AMI and microgrids, design simplified user interfaces and subsidize connection fees for underserved communities.
10. Technology Obsolescence Rapid AI advances render early deployments outdated.	Medium	Low	Adopt modular, upgradeable architectures, favor cloud/edge solutions with versioning, and

Risk	Impact	Likelihood	Mitigation Measure
			include renewal options in procurement contracts.
11. Supply-Chain Disruptions Hardware shortages delay roll-out.	Medium	Medium	Diversify supplier base, pre-qualify multiple vendors for critical equipment, maintain strategic inventory buffers, and negotiate priority-supply guarantees.
12. Physical Climate Risks Extreme weather damages digital assets.	High	Medium	Harden critical infrastructure (e.g., flood-proof substations), deploy redundant network paths, and integrate climate-resilience criteria into asset-management plans.

CHAPTER

09

Presentation of Activities

Chapter 9. Presentation of Activities

9.1. Introduction

This Chapter presents "Activity Cards" for each of the short- and medium-term activities of the roadmap. The Activity Cards consolidate Phase 1 outputs into a concise, standardized format to support stakeholder consultations and the way forward to Phase 2 of the assignment. This exercise does not delve into the detailed Phase 2 readiness assessment. It focuses on scoping and framing early actions that create a durable foundation for successive, more granular planning.

Two key methodological challenges were faced during the development of this work:

- **Rapid Evolution of AI Paradigms**

Narrow AI tools have been commercialized for decades, but the trajectory toward artificial general intelligence (AGI) still remains uncertain in terms of timing. ChatGPT 3.5 —launched November 30, 2022— demonstrates how fast capabilities can leap forward, yet the timing, governance needs and societal impacts of potential AGI or "superintelligence" cannot be predicted with certainty. Consequently, traditional road-mapping to long-term horizons (e.g., to 2050) is not well suited to digitalization and AI. Most probably, in just five years, entirely new architectures or use cases could render today's forecasts obsolete.

- **Focusing on Foundational Enablers**

To navigate this unpredictability, we emphasized activities that establish long-lived infrastructure and governance: hardware digitization (AMI, SCADA, communications), cybersecurity frameworks, ethical guidelines and data-governance regimes. These "building blocks" endure across technology generations, allowing successive AI applications, however novel, to plug into a ready ecosystem.

At the same time, inherent limitations were faced.

- **Cost Estimation Uncertainty**

Due to the pioneering nature of AI based pilots in the power sector and the overall lack of publicly reported budgets, definitive capex and opex figures are unavailable. While we cite illustrative cost ranges from comparable international programmes where possible, precise budget modelling lies beyond the scope of Phase 1 of this assignment.

- **Data & Reporting Gaps**

Many pilot projects lack transparent performance metrics or standardized reporting at least in the public domain. As a result, quantified benefits and risk-mitigation approaches are indicative rather than exact. The same applies to expected benefits presented, which are informed estimations of the consulting team.

The Activity Cards in this chapter represent best-effort synthesis of global best practices and analyses, but at the same time they are an initial foundation for this assignment. Phase 2 will refine cost models, readiness assessments and implementation schedules in close collaboration with the respective stakeholders, ensuring that Vietnam's AI-enabled digitalization unfolds on solid, future-proof foundations.

9.2. Technical Activities

This section presents "Activity Cards" for each of the technical activities.

Table 13. Activity T-1. AI-Enhanced Load & Renewable Energy Forecasting

Field	Details
Title	AI-Enhanced Load & Renewable Energy Forecasting
Short description	Deploy machine-learning and probabilistic forecasting frameworks to generate high-resolution short- and medium-term forecasts of system load and variable renewables, reducing balancing costs and unlocking higher VRE penetration.
Technical approach	Hybrid ML-physical models (neural networks + ensemble weather simulations), Bayesian methods for uncertainty quantification, and graph-neural forecasting to refine predictions under grid constraints.
Current status in Vietnam	● EVNNLDC uses deep learning for short-term load forecasting ● EVNSPC and EVNCPC apply AI with satellite weather data to predict solar & wind generation. ● NSMO (NLDC/EVN) has partnered with Solargis to forecast output from ~7 GW of solar and wind plants (140 solar, 40 wind farms) using satellite and meteorological data, aiding grid balancing and reducing intermittency issues. ● Rooftop solar (monitored at 100 kV substations nationwide) is forecasted at 15-minute resolution for up to 14 days ahead using AI. ● ATS JSC provides AI SaaS: SmartLF™ for multi-point load forecasting. SmartRGF™ for hour-ahead to week-ahead renewable energy generation forecasting using deep learning, interfaced with SCADA. ● Platforms like GridSense AI and EnergyOptimizer are deployed in Vietnam for grid management, predictive maintenance, hyper-local weather-based renewable output forecasting, and storage optimization
Real-world examples	• Germany TSOs achieve 20–30 % PV/wind forecast gains via hybrid AI frameworks[177]. • US DOE SunShot pilots improved PV forecasting by 30 % to enable greater renewable

[177] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_AI_Big_Data_2019.pdf

	dispatch[178]. • DeepMind wind forecasts boosted Google farm revenues ~20 % through optimized bidding[179]. • Ireland's TSO maintains stability at 75 % wind penetration with advanced probabilistic forecasts[180].
Expected benefits	• Short-term load forecast accuracy ↑ to > 95 %. • VRE utilization rates increase, deferring network upgrades and cutting CO_2. • Lower balancing-reserve procurement and penalty costs; improved market bidding outcomes..
Indicative duration per sub-activity	Based on an average smart-grid pilot duration of ~2 years[181]: • Scoping & design: 2 months • Data acquisition & pre-processing: 4 months • Model development & validation: 6 months • Pilot deployment: 8 months • Evaluation & calibration: 3 months • Scale-up planning: 2 months
Lead entity	Electricity of Vietnam (EVN) dispatch centers
Key stakeholders	MoIT; EVN subsidiaries; provincial DSMUs; development partners (e.g., GIZ)
Data requirements & sources	High-resolution AMI load data; VMGD meteorology; ESA or NASA satellite irradiance; historical dispatch logs.
Potential funding sources	Pilot CAPEX ≈ €6 million (avg. smart-grid budget) (sciencedirect.com)[182]; potential JETP, World Bank, ADB concessional financing.
Top 3 risks & mitigations	1. **Data-quality failures** → centralized governance, validation rules, KPI audits. 2. **Model drift** → continuous retraining loops, human-in-the-loop checks. 3. **Regulatory delays** → inter-ministerial fast-track working groups.

[178] Ibid.

[179] https://deepmind.google/discover/blog/machine-learning-can-boost-the-value-of-wind-energy

[180] https://www.eirgrid.ie/about-us/our-strategy-2020-2025

[181] https://www.sciencedirect.com/science/article/pii/S0301421516303639

[182] https://www.sciencedirect.com/science/article/pii/S0301421516303639

Key performance indicators (KPIs)	• Forecast MAE < 5 % • % VRE curtailment reduction • reserve-cost savings • model-retraining frequency • stakeholder satisfaction scores.
Monitoring & reporting	• Real-time EMS dashboards • monthly performance reports • quarterly stakeholder reviews • alerting for deviations > 10 %.
Capacity-building needs	• ML and Bayesian-methods workshops for EVN • Regulator briefings on AI capabilities • Exchange programs with international organizations.
Ethical & data-governance	• Compliance with data-privacy regulations • Anonymization • transparent model-explainability protocols.
Regulatory prerequisites	• Update PDP8 dispatch codes to accept probabilistic forecasts • MOIT dispatch-order amendments • data-sharing agreements between utility & meteorological agencies.

Table 14. Activity T- 2. Demand Response Programs via Digital Platforms

Field	Details
Title	Demand Response Programs via Digital Platforms
Short description	Deploy digital DR platforms (web/mobile) leveraging IoT endpoints and the OpenADR 2.0b protocol for automated and manual participation, issuing dynamic price or event-based signals to shift or curtail load, thereby providing system flexibility and enabling higher VRE integration.

Technical approach	Use a DR Management System (DRMS) integrated via OpenADR with the grid's EMS/NMS. IoT-enabled load controllers (smart plugs, thermostats). Dynamic-pricing signals (TOU, RTP, CPP). Aggregator-based customer enrollment. Real-time telemetry for dispatch and verification.
Current status in Vietnam	• Regulatory framework under Decision 17/QĐ-BCT (28 Jan 2019) and Decision 54/QĐ-DTDL (12 Jun 2019) provides DR event process guidance but lacks clear financial incentives. • EVN-HCMC ran a 2015 pilot (Curtailable Load Program & Voluntary Emergency DR) funded by its Science & Technology Fund[183]. • Existing TOU tariffs have differentials that can be improved in order to increase higher customer participation. • As of 2024, approximately 13,334 large industrial customers had signed voluntary DR commitments based on predefined load curtailment schedules. A total of 18,961 customers are participating in non-commercial DR programs, with an estimated total DR potential of 2,843 MW[184] • .Pilot programs with financial incentives have been implemented since 2023. These programs focus on peak shaving by large electricity users during high-demand months (e.g., May–June), aligned with Decision No. 175/QĐ-BCT (2019) by the Ministry of Industry and Trade.
Real-world examples	• Thailand: ERC's 2014 CPTR & EDRP pilot via Load Aggregator model; compensation set by avoided peaking-plant costs[185]. • US: Voltus C&I platform across PJM, CAISO, ERCOT, etc., enabling businesses to monetize load reductions with real-time dashboards[186]. • UK: Enel X Demand Side Response portal pays businesses for peak relief events[187]. • UK: Octopus Energy's Agile tariff (half-hourly dynamic pricing), integrated with smart devices for automated DR[188].
Expected benefits	• Peak-demand reduction of 2–5 % per event, deferring CCGT and T&D investments. • Lower ancillary-service and balancing costs. • Improved grid reliability and VRE accommodation.

[183] https://energypedia.info/images/b/b4/011_SGREEE-AA1_Promoting_Implementation_of_Demand_Response_Programs_in_Vietnam.pdf

[184] https://en.evn.com.vn/d/en-US/news/EVNs-business-and-customer-service-activities-in-2024-achieve-many-positive-outcomes-60-204-500388

[185] https://www.mdpi.com/1996-1073/16/8/3606

[186] https://www.voltus.co/demand-response/pjm

[187] https://www.enelx.com/uk/en/demand-response

[188] https://octopus.energy/smart/agile/

Indicative duration per sub-activity	• Scoping & design: 2 months • Platform development: 4 months • Integration & testing: 3 months • Pilot execution: 6 months • Evaluation & calibration: 3 months • Scale-up planning: 2 months
Lead entity	EVN Power Corporations (e.g., EVNHCMC) & the EVN Demand Response Implementation Unit
Key stakeholders	MoIT; ERAV; EVN divisions; large industrial/commercial consumers; DR aggregators; telecom providers
Data requirements & sources	• 15–60 min interval consumption from AMI • Real-time grid conditions via EMS • Dynamic tariff schedules from MDMS • Weather/temperature feeds for baseline adjustments
Estimated investment & funding	• Initial Pilot funded by EVN's Science & Technology Fund (2015) – there is a need to see if a new pilot has to be implemented or not. • Scale-up funding options include World Bank, ADB, GIZ concessional financing.
Top 3 risks & mitigations	1. **Low financial incentives** → shared-savings/tariff-adjustment models. 2. **Regulatory gaps** → fast-track MoIT-ERAV coordination to designate DR as an ancillary service. 3. **Customer fatigue** → aggregator-led enrollment, targeted marketing, clear benefit communication.
Key performance indicators (KPIs)	• Number of participating customers; % participation • MW curtailed per event • % peak shifted • customer satisfaction index • event compliance rate

Monitoring & reporting	• Real-time dashboards displaying aggregate load-shift, baseline vs. actual consumption, event participation rates and rebound effects
	• Automated alerts for missed event triggers or anomalous load patterns
	• KPI scorecards delivered monthly to the steering committee, covering:
	  ○ Peak reduction (%)
	  ○ Customer opt-in/opt-out rates
	  ○ Settlement accuracy
	• Quarterly impact reports benchmarking performance against targets and international best practices

Capacity-building needs	• Utility & aggregator training on platform configuration, event scheduling and settlement workflows • Regulator workshops on program oversight, compliance auditing and performance verification methodologies • Customer-education toolkits (webinars, e-learning modules) to build consumer literacy on DR mechanics and benefits • "Train-the-trainer" programmes for local consultants to cascade skills across provinces
Ethical & data-governance	• Informed consent protocols and transparent opt-in/opt-out mechanisms for end-users • Role-based access controls to segregate platform functions (dispatch, billing, analytics) • Data anonymization for aggregate reporting and research, preserving individual consumer privacy • Compliance with Law 86/2015/QH13 on critical-infrastructure data security and international privacy standards (e.g. GDPR-inspired principles)
Regulatory prerequisites	• Circular update to formally recognize digital DR platforms and define eligible event types • Metering & telemetry standards (e.g. ≥ 5-minute interval AMI) enshrined in DR regulation • Aggregator registration framework with licensing fees, performance-bond requirements and dispute-resolution processes • Settlement code amendments specifying baseline methodologies, verification protocols and penalty/liability clauses for non-performance

Table 15. Activity T-3. Advanced Metering Infrastructure (Smart Meters) & Data Analytics

Field	Details
Title	Advanced Metering Infrastructure (Smart Meters) and Data Analytics

Short description	Deploy an end-to-end AMI system (smart meters, communications (PLC/RF/cellular), Head-End System (HES), Meter Data Management System (MDMS)), together with analytics platforms (e.g., load profiling, anomaly detection, demand response) to enable two-way utility-consumer communication and data-driven network optimization.
Technical approach	Integrate interval-metering smart meters with HES and MDMS; apply machine-learning-based clustering and outlier detection for customer segmentation; use time-series analytics for real-time load forecasting and voltage anomaly detection.
Current status in Vietnam	• By Dec 2022, EVN had installed 24 667 754 electronic meters (≈81 % of total) and 23 292 310 remote-read meters (≈76.8 %)[189]. • An HCMC AMI pilot for large customers ran in 2017 but did not scale; AMR remains dominant[190]. • EVNHANOI has replaced 100% of mechanical meters with electronic meters with remote reading (AMR) by the end of 2021.[191] • EVNHCMC (Ho Chi Minh City) achieved 98–99% AMR coverage, integrating meters with GIS and customer apps for effective data and outage monitoring.[192] • EVN developed EVNHES – a remote data acquisition system that integrates various types of metering devices, laying the foundation for centralized AMR data. • SCADA, DAS, and GIS systems are widely deployed to monitor the grid, support grid operation, and digital asset management. • Customer-facing platforms (EVNHANOI App, EVNHCMC App, CMIS/CIS) support usage pattern analysis, early warnings, and interactive energy services.
Real-world examples	• Trilliant & SAMART delivered AMI (UnitySuite® HES + RF/cellular meters) for Thailand PEA, 15-min interval data, centralized dashboards[193] • Itron's AMI pilot in Pattaya (PEA) marked Thailand's first municipal rollout[194]. • Meralco (Philippines) piloted 40 000 smart/prepaid meters under its GRID+ program[195].

[189] https://www.energytransitionpartnership.org/wp-content/uploads/2024/04/D2-Current-status-1.pdf

[190] Ibid.

[191] https://en.evn.com.vn/d6/news/Smart-grid-development-in-Hanoi-66-163-2467.aspx

[192] https://en.evn.com.vn/d6/news/Efficiencies-from-automatic-meter-reading-technology-on-Ho-Chi-Minh-City-power-distribution-grid-66-163-3108.aspx

[193] https://trilliant.com/partnership-between-trilliant-and-samart-telcoms-reaches-first-milestone-with-the-successful-delivery-of-advanced-metering-infrastructure-for-provincial-electricity-authority-in-thailand/

[194] https://www.smart-energy.com/news/thai-utility-itron-ami-solution/

[195] https://www.smart-energy.com/regional-news/asia/smart-prepaid-meters-meralco-secures-regulatory-green-light-for-40k-rollout/

Expected benefits	• Meter-reading accuracy > 99 %; non-technical losses decrease[196] • Enable time-of-use tariffs and DSM, shifting peak load. • Faster outage detection (SAIDI decrease by up to 50 %), improved customer service, foundation for future DER integration[197].
Indicative duration per sub-activity	• Scoping & design: 2 months • Procurement & tender: 3 months • Meter rollout & comms setup: 6 months • HES & MDMS deployment: 4 months • Analytics development: 6 months • Pilot evaluation & calibration: 3 months • Scale-up planning: 2 months
Lead entity	EVN dispatch centers (EVNHANOI, EVNHCMC, EVNCPC)
Key stakeholders	MoIT; ERAV; EVN subsidiaries; provincial DSMUs; development partners (World Bank, JETP)
Data requirements & sources	• AMI interval data (15–60 min) from smart meters • Communications logs (RF/PLC/cellular) • MDMS exports for VEE, billing, aggregation • SCADA/EMS integration for network context
Estimated investment & funding	• Pilot CAPEX ≈ US$ 15 M (as part of the Distribution Efficiency Project's US$ 53 M for AMI/SCADA) [198]; • Potential co-financing: World Bank, ADB, EVN internal funds
Top 3 risks & mitigations	1. **High upfront costs** → phased roll-out & cost-sharing models 2. **Interoperability challenges** → adopt open standards (e.g., IEEE 2030.5) & vendor-neutral HES 3. **Data security/privacy** → end-to-end encryption, data-governance policies aligned with international best practice
Key performance indicators (KPIs)	• % of meters with successful remote read • Reduction in non-technical losses (%) • Time to detect outages (min) • Customer satisfaction index

[196] https://www.mdpi.com/1996-1073/14/7/1852

[197] https://netl.doe.gov/sites/default/files/Smartgrid/Results-from-DOE-ARRA.pdf

[198] https://documents1.worldbank.org/curated/en/896941579623652622/txt/Vietnam-VN-Distribution-Efficiency-Project.txt

	• Analytics model uptime (%)
Monitoring & reporting	• Real-time HES dashboards • Monthly MDMS-generated data-quality reports • Quarterly stakeholder reviews • Automated alerts for meter tampering or communications failures
Capacity-building needs	• Training for EVN field crews on smart-meter installation • MDMS/HES operator workshops • Data-science up-skilling for analytics teams • Regulator briefings on AMI benefits
Ethical & data-governance	• Data-privacy safeguards • Consent-based customer data sharing • Transparent model-explainability protocols • Compliance with Vietnam's Law on Cybersecurity and international norms
Regulatory prerequisites	• Amend metering regulations to recognize interval data tariffs • issue MOIT dispatch-code updates for two-way meter data • establish MDMS data-sharing agreements between EVN and ERAV

Table 16. Activity T-4. Energy Management Systems (EMS) for Large Consumers (Industry 4.0 Energy Efficiency)

Field	Details
Title	Energy Management Systems (EMS) for Large Consumers (Industry 4.0 Energy Efficiency)
Short description	Deploy integrated EMS combining ISO 50001-aligned software, IoT sensors, real-time dashboards, and advanced analytics, to optimize energy use in high-consuming industrial and commercial facilities, enabling automated control, demand response, and continuous performance improvement.
Technical approach	Integrate facility-wide submeters and IIoT sensors via OPC-UA/Modbus TCP into an EMS platform. Use ML-based load profiling and anomaly detection, digital-twin simulations for process optimization, and rule-based controls for HVAC, compressed air, and process heating/cooling loops.
Current status in Vietnam	• Under Decree 21/2011/ND-CP, major energy users (≥ 1 000 toe/yr) must adopt energy-management plans and annual/five-year targets. • Pilots in Vietnamese enterprises (e.g., a manufacturing plant's real-time monitoring

	system) achieved 191 923 kWh savings in 6 months (~ US$19 992)[199].
Real-world examples	• PT Pupuk Kalimantan Timur (Indonesia): ISO 50001 EMS saved 866 262 GJ and US$3.9 M in energy costs, with patented in-house efficiency innovations[200]. • Penske Turnersville Auto Mall (USA): EMS retrofit across 10 sites cut energy use by 20 % in 11 months[201].
Expected benefits	• Energy consumption reduction of 5–15 %. • Energy-cost savings • CO_2 emissions cut in proportion to kWh savings. • Enhanced compliance reporting and ISO 50001 certification readiness.
Indicative duration per sub-activity	• Scoping & design: 2 months • Procurement & sensor installation: 3 months • EMS platform integration & commissioning: 4 months • Analytics & dashboard development: 4 months • Pilot operation & evaluation: 3 months • Calibration & scale-up planning: 2 months
Lead entity	Large energy-using enterprises in partnership with the Vietnam Cleaner Production Centre (VNCPC) under MoIT.
Key stakeholders	MoIT/ERAV; DSMUs; EVN's large-consumer division; facility operations teams; development partners.
Data requirements & sources	• Facility submeters (15- or 60-min intervals) and IIoT sensors (temperature, flow, pressure). • SCADA/PLC data for process context. • Utility billing records. • Production schedules and weather data for benchmark modeling.
Estimated investment & funding	• Pilot CAPEX ~ US$ 250 000–500 000 per facility (software licenses, hardware, integration)[202]. • Potential co-financing: World Bank, ADB, bilateral programmes (JETP, GIZ).

[199] https://www.mdpi.com/1996-1073/16/13/5214
[200] https://www.cleanenergyministerial.org/content/uploads/2022/03/cem-em-casestudy-pt-pupuk-indonesia.pdf
[201] https://shellenergy.com/why-shell/case-studies/national-automotive-consolidator
[202] https://www.imarcgroup.com/vietnam-energy-management-system-market

Top 3 risks & mitigations	1. **Data-integration complexity** → adopt open standards (OPC-UA) and middleware. 2. **Low user adoption** → stakeholder workshops, change-management support. 3. **Cybersecurity threats** → enforce end-to-end encryption, ISO 27001 controls.
Key performance indicators (KPIs)	• % energy reduction vs. baseline • kWh saved per month • Energy-cost savings • System uptime (%) and data-quality index
Monitoring & reporting	• Real-time EMS dashboards with alerting. • Monthly energy-performance reports. • Quarterly management-review meetings. • Annual ISO 50001 internal audit.
Capacity-building needs	• Training on EMS operations and ISO 50001 framework • Data-analytics workshops for in-house engineers; change-management sessions for facility staff.
Ethical & data-governance	• Compliance with Vietnam's Cybersecurity Law • Anonymization of sensitive operational data • Clear data-access protocols • Transparent algorithms for stakeholder trust
Regulatory prerequisites	• Full adoption of Decree 21/2011 measures and MOIT Circulars on EMS standards. • Recognition of digital-EMS outputs in energy-audit reporting via updated regulations.

Table 17. Activity T-5. Predictive Maintenance for Generation & Grid Assets

Field	Details
Title	Predictive Maintenance for Generation and Grid Assets
Short description	Deploy IoT-enabled condition-monitoring sensors and machine-learning prognostic algorithms on generation units (e.g., turbines, hydropower, gas) and grid assets (transformers, switchgear) to forecast equipment failures weeks to months ahead, reducing unplanned outages and maintenance costs.

Technical approach	Utilize vibration, temperature, oil-chemistry and partial-discharge sensors integrated via IIoT networks to feed ML/deep-learning models (e.g., LSTM-based fault prognostics) and digital-twin simulations for anomaly detection and remaining-useful-life prediction.
Current status in Vietnam	● EVN's hydropower plants are under digital transformation with DCS/PMIS upgrades and Reliability-Centered Maintenance (RCM II) since 2020[203] ● EVN GENCO2 has signed an MoU with GE Digital to roll out predictive maintenance across its 4.4 GW hydro fleet [204] ● EVNHCMC began piloting Condition-Based Maintenance (CBM) in October 2019, in collaboration with TNB (Malaysia), starting with 4 substations at the 110 kV level. This approach helps identify equipment risks early and perform maintenance based on actual conditions instead of fixed schedules (e.g., every 3 years).[205] ● By 2020, 22 substations at 110 kV had CBM in operation across EVNHCMC and Northern/Central/Southern power companies. EVNNPT is also building CBM guidelines for 220 kV circuit breakers and transformers.[206] ● In a March 2024 technical conference, EVN emphasized CBM as a form of predictive maintenance, which improves asset reliability and allows early fault detection.[207] ● EVN has applied RCM at various thermal and hydropower plants. EVNGENCO3 began applying RCM in 2019, expanding the approach since 2021 to enhance unit availability and reliability.[208] ● EVNCPC deployed computer vision AI to detect grid faults, feeding data into PMIS (Power Management Information System).[209] ● Son La Hydropower Plant uses environmental sensors and AI to monitor electrical cabinets for early warnings.[210]

[203] https://en.evn.com.vn/d6/news/Automation-and-digital-transformation-solutions-in-hydropower-plant-operation-and-maintenance-66-163-2770.aspx

[204] https://www.linkedin.com/posts/gerenewableenergy_vietnam-evngenco2-digital-activity-7025792588783702016-rdGm/

[205] https://en.evn.com.vn/d6/news/Successfully-piloting-the-condition-based-maintenance-of-the-power-system-66-163-1855.aspx

[206] https://en.evn.com.vn/d6/news/Condition-based-maintenance-for-power-grid-equipment-9-130-2024.aspx

[207] https://en.evn.com.vn/d6/news/Repair-and-Condition-based-maintenance-CBM-of-the-power-grid-block-66-163-4011.aspx

[208] https://en.evn.com.vn/d6/news/EVN-deploys-many-solutions-to-improve-reliability-at-power-plants-66-163-3975.aspx

[209] https://globaltransmission.info/wp-content/uploads/2023/12/GTR-December-2023.pdf

[210] https://en.evn.com.vn/d6/news/How-does-Son-La-Hydropower-plant-use-robots-in-operation-66-163-3458.aspx

Real-world examples	• Duke Energy applies ML to monitor transformer networks, cutting outages by ~20 %[211]. • AGL Energy runs predictive models on wind/hydro assets. In just three years, AGL saved AU$18.7M in reduced forced outages and optimized maintenance [212]. • McKinsey finds PdM can reduce maintenance costs by up to 30 % and boost uptime by 5–15 %[213].
Expected benefits	• Decreased maintenance costs • Increased equipment availability • Decrease in unplanned outages • Asset life extension depending on asset class
Indicative duration per sub-activity	Indicative durations, based on typical PdM pilot ROI timeframes (12–24 months): • Scoping & design: 2 months • Sensor procurement & integration: 3 months • Data pipeline & integration: 4 months • Model development & validation: 5 months • Pilot deployment: 6 months • Evaluation & calibration: 2 months • Scale-up planning: 2 months
Lead entity	EVN Generation Companies (EVN GENCOs) and EVNNPT for grid assets
Key stakeholders	MoIT; ERAV; EVN GENCOs; EVNNPT; plant operators; development partners
Data requirements & sources	• High-frequency vibration & temperature sensor streams; partial-discharge monitors; oil-chemistry analysis; SCADA & CMMS log histories; standardized via IEC 81346 RDS schema (elderresearch.com).
Estimated investment & funding	• Pilot CAPEX ~ €200 k–600 k (sensors, software, integration, training)[214] • potential co-financing from ADB, World Bank, GIZ.
Top 3 risks & mitigations	1. **Data quality issues** → sensor QA frameworks and automated validation rules. 2. **Integration costs** → phased retrofitting and cost-sharing models. 3. **Organizational resistance** → targeted training and change-management programs.

211 https://www.sciencedirect.com/topics/engineering/duke-energy

212 https://www.aveva.com/content/dam/aveva/documents/perspectives/success-stories/SuccessStory_AVEVA_AGL_22-12.pdf.coredownload.inline.pdf

213 https://www.mckinsey.com/capabilities/operations/our-insights/digitally-enabled-reliability-beyond-predictive-maintenance

214 https://www.logicline.de/en/predictive-maintenance-a-comparison-of-costs-and-benefits

Key performance indicators (KPIs)	• Equipment availability (%) • unplanned outage frequency • maintenance cost savings (%) • mean time between failures (MTBF) • model accuracy metrics (precision/recall)
Monitoring & reporting	• Real-time ML dashboards with threshold-based alerts • Monthly PdM performance summaries • Quarterly stakeholder reviews • Reduction in false-alarm volumes
Capacity-building needs	• Sensor installation & maintenance workshops • ML & data-analytics training • Digital-twin operation sessions • Change-management support for maintenance teams
Ethical & data-governance	• Federated learning for data privacy • End-to-end encryption of IIoT networks • Compliance with Vietnam's cybersecurity law • Transparent model-explainability protocols
Regulatory prerequisites	• Incorporate PdM into EVN's Digital Transformation Master Plan (Resolution 68/NQ-HĐTV) • Update grid code to permit condition-based maintenance • Align with SGREEE project guidelines

Table 18. Activity T-6. Virtual Power Plants (VPP) & DER Aggregation

Field	Details
Title	Virtual Power Plants (VPP) and DER Aggregation
Short description	A Virtual Power Plant (VPP) is a cloud-based platform that orchestrates heterogeneous distributed energy resources (DER), including photovoltaics, battery energy storage, and flexible loads, via IoT-enabled communications and advanced optimization algorithms to function as a single dispatchable asset in energy and ancillary service markets.
Technical approach	Aggregation middleware integrates DER data streams (RTU/SCADA, inverter telemetry) with a central VPP control system implementing forecasting, economic-dispatch optimization, and real-time market bidding via protocols such as OpenADR or IEC 61850. It employs machine-learning for price and load prediction and rule-based orchestration for grid services.

Current status in Vietnam	• To date, Vietnam has no operational VPP deployments. the SGREEE-AA3 final report recommends an initial VPP testing phase focusing on large rooftop PV assets (≈460 MW in Gia Lai province) to improve visibility, forecasting, and remote-control capabilities for NLDC and Power Companies[215]. • Decree 80/2024 on direct electricity trading enables renewable generators to contract directly with large consumers, laying the regulatory groundwork for VPP-based PPA models.
Real-world examples	• South Australia VPP: Stage 1 delivered 5 MW dispatchable capacity from 1,000 home storage systems (9 MWh) under ARENA funding. There is a planned scale-up to 250 MW solar + 650 MWh storage[216]. • Next Kraftwerke (Europe): Aggregates > 7.5 GW of DER across Germany, Belgium, France, Italy, Switzerland, Poland and Austria for energy and ancillary services trading[217].
Expected benefits	• Enhanced flexibility since dispatchable DER portfolio matches conventional plant services. • CapEx deferral since peak-shift and ancillary-service provision can defer T&D and generation investments. • Monetization through energy arbitrage, capacity and ancillary markets reduces net costs for DER owners.
Indicative duration per sub-activity	• Scoping & design: 2 months • Platform development & validation: 6 months• Communications & integration: 4 months • Pilot deployment: 8 months • Evaluation & calibration: 2 months • Scale-up planning: 2 months
Lead entity	Power Companies (EVN subsidiaries) as VPP operators in coordination with NLDC; SGREEE-appointed VPP technology provider; ERAV and MoIT for oversight.
Key stakeholders	MoIT/ERAV; NLDC; EVN GENCOs & dispatch centers; distribution utilities (DSOs); DER aggregators; development partners.
Data requirements & sources	• DER telemetry (inverter, BESS SOC, EMS data) • Interval consumption (AMI) • NWP weather forecasts • Market price signals (Day-ahead, Intraday)

[215] https://www.esp.org.vn/wp-content/uploads/Virtual-Power-Plant_Final-Report.EN_.pdf

[216] https://arena.gov.au/assets/2017/02/VPP-SA-Public-Milestone-1-Report-Final-for-issue.pdf

[217] https://www.next-kraftwerke.com/

	• Remote-control via VPN/SSL (OpenVPN) per VHPready standards
Estimated investment & funding	• Pilot CAPEX ≈ AUD 20 million for a 5 MW demonstration (AGL scheme)[218] • Potential financing: ARENA grants, bilateral concessional loans (ADB, AFD)
Top 3 risks & mitigations	1. **Integration complexity** → open standards (OpenADR, IEC 61850) & modular middleware 2. **Regulatory uncertainty** → leverage Decree 80/2024; establish interagency working group 3. **Cybersecurity threats** → implement VPN-secure communications, multi-factor authentication, real-time threat monitoring.
Key performance indicators (KPIs)	• Profit increase (% over BAUP) • Revenues increase (% over BAU) • Imbalance energy reduction (% BAU) • Imbalance cost reduction (% BAU)
Monitoring & reporting	• Real-time VPP dashboards • Monthly performance & revenue reports • Automated alerts for threshold breaches • Quarterly stakeholder review workshops
Capacity-building needs	• Workshops on VPP control-room operation, DER telemetry integration, forecasting analytics, cybersecurity protocols • Exchange programs with established VPP operators
Ethical & data-governance	• GDPR-aligned privacy • Anonymization of customer data • Transparent algorithmic dispatch logs • Compliance with vietnam cybersecurity law
Regulatory prerequisites	• Issue ERAV guidelines for VPP connectivity & PPA trading under Decree 80/2024 • Establish technical regulations for DER aggregation (testing phase) per SGREEE-AA3 recommendations

Table 19. Activity T-7. AI-Powered Grid Resilience & Anomaly Detection

[218] https://en.wikipedia.org/wiki/Virtual_power_plant

Field	Details
Title	AI-Powered Grid Resilience and Anomaly Detection
Short description	Deploy AI-driven systems for real-time detection of equipment faults, cyber-physical threats, and operational anomalies, coupled with automated self-healing actions, to enhance grid resilience and minimize outage impact.
Technical approach	Edge-AI anomaly detection on PMU/SCADA streams using autoencoders, LSTM/CNN hybrids, and graph-based models. Digital-twin simulations for scenario-based threat modeling. Reinforcement-learning for automated fault isolation and topology reconfiguration.
Current status in Vietnam	● Drones with AI-powered image processing used for transmission line inspection and fault detection were deployed at EVN's subsidiaries[219]. ● Power Transmission Company 2 (PTC2) deployed AI applications in the transmission line surveillance camera system mounted on the tops of 500 kV-220 kV transmission line poles to enhance features and improve efficiency in monitoring and managing transmission line operations[220]. ● EVN has integrated AI across its operations: from digital assistants and meeting summarization to power plant and grid management systems[221]. ● EVNNPT (National Power Transmission Corporation) employs AI-powered UAVs (drones) for inspecting 220–500 kV transmission lines. The AI analyzes thermal and visual data to identify faults, wrong-way violations, and equipment issues, with continuous model training[222]. ● AI is being deployed to automatically detect line faults and abnormal equipment conditions, enhancing grid resilience[223]. ● EVNHCMC (Ho Chi Minh City Power) implemented sophisticated IoT and FLISR-enabled SCADA systems. These use automated algorithms (likely AI-like methods) to detect, isolate faults, and restore power—reducing outage duration and frequency significantly (SAIDI/SAIFI dropped ~95%)[224][225].

[219] https://tapchicongthuong.vn/hieu-qua-quan-ly-luoi-truyen-tai-tu-ung-dung-uav-va-cong-nghe-lidar-129807.htm
[220] https://baochinhphu.vn/ung-dung-tri-tue-nhan-tao-vao-he-thong-camera-quan-sat-tren-duong-day-102300928.htm
[221] https://en.evn.com.vn/d6/news/EVN-is-on-the-road-to-becoming-the-leading-digital-enterprise-in-the-region-66-163-1437.aspx
[222] https://en.evn.com.vn/d/en-US/news/Artificial-intelligence-application-become-driving-force-for-comprehensive-innovation-in-EVNs-operations-60-205-500717
[223] https://en.evn.com.vn/d/en-US/news/EVNHCMC-automates-smart-power-grids-60-204-500496
[224] https://en.evn.com.vn/d/en-US/news/EVNHCMC-automates-smart-power-grids-60-204-500496
[225] https://evn.com.vn/d6/news/EVNHCMC-lien-tiep-dat-2-giai-thuong-quoc-te-cho-Luoi-dien-thong-minh-Smart-Grid-0-12-126319.aspx

Real-world examples	• Duke Energy applies ML to monitor transformer networks and anticipate climate-driven risks, reducing outage rates by ~20 %[226]. • FNET-GridEye's wide-area measurement network uses AI for event localization and situational awareness in the U.S. transmission system[227].
Expected benefits	• Real-time detection and localization of grid disturbances. • Automated self-healing isolates faults and reduces average outage restoration time. • Early anomaly detection ensures continuity and minimizes disruption impacts.
Indicative duration per sub-activity	• Scoping & data-gap analysis: 2 months • Sensor & edge-node deployment: 3 months • Model development & validation: 3 months • Pilot integration & testing: 2 months • Evaluation & calibration: 2 months • Scale-up framework design: 1 month
Lead entity	EVNNPT in partnership with EVN GENCOs and EVN dispatch centers, under MoIT oversight.
Key stakeholders	MoIT; ERAV; EVN subsidiaries; development partners
Data requirements & sources	• High-frequency PMU/SCADA telemetry (50–120 Hz) • UAV/drone imagery for asset inspection • Historical outage & maintenance logs • Weather and load forecasts
Estimated investment & funding	Potential financing: AFD, ADB, GIZ
Top 3 risks & mitigations	1. **Data integrity failures** → implement rigorous QA/QC pipelines and anomaly-label validation. 2. **Model overfitting** → employ cross-domain training, regular retraining, and interpretability checks. 3. **Cybersecurity vulnerabilities** → use encrypted edge-to-cloud communications and anomaly-triggered lockdown protocols.
Key performance indicators (KPIs)	• Anomaly detection precision/recall • Mean time to detect (MTTD)

226 https://sccms.eei.org/en/delivering-the-future/articles/duke-energy-floridas-smart-automation-technology-limits-power-outages

227 https://ietresearch.onlinelibrary.wiley.com/doi/10.1049/hve2.12157

	• Mean time to isolate (MTTI) • Outage frequency & duration • False-alarm rate
Monitoring & reporting	• Real-time dashboards with geo-tagged alerts • Automated incident reports • Monthly resilience scorecards • Annual regulatory compliance filings
Capacity-building needs	• Edge-AI and anomaly-detection workshops for grid operators • Digital-twin simulation training • Cybersecurity for OT (operational technology) certifications
Ethical & data-governance	• Privacy-preserving analytics (federated learning where applicable) • Encryption at rest and in transit • Compliance with Vietnam Cybersecurity framework • Transparent AI audit trails
Regulatory prerequisites	• Amend grid code to formalize AI-driven anomaly detection and self-healing procedures • Issue MoIT circular on AI data-sharing protocols • Align with national cybersecurity and data-privacy regulations

Table 20. Activity T-8. Distribution Grid Automation & Loss Reduction

Field	Details
Title	Distribution Grid Automation and Loss Reduction
Short description	Deploy an Advanced Distribution Management System (ADMS), combining SCADA, DMS, OMS, FLISR and Volt/VAR optimization, with remote-controlled reclosers and sectionalizers to enable rapid fault isolation, dynamic feeder reconfiguration and real-time loss detection.
Technical approach	Integrate SCADA telemetry and GIS/CIM network model into an ADMS platform, deploy FLISR logic for automated sectionalizing/restoration, implement Volt/VAR control algorithms and analytics for pinpointing technical/non-technical losses. Communicate via IEC 61850/DNP3 to edge devices.
Current status in Vietnam	• National power-loss rate fell from 12.23 % in 2003 to 6.25 % in 2022[228].

[228] https://pecc1.com/d4/news/Challenges-in-reducing-power-loss-on-the-Vietnamese-grid-8-2147.aspx

	• EVNHANOI's distribution-network PLR dropped from 5.71 % in 2015 to 3.55 % in 2021[229]. • EVNHCMC's DAS project automating its 22 kV feeders with Survalent's FLISR solution has markedly improved SAIDI/SAIFI and won POWER's 2024 Smart Grid Award[230].
Real-world examples	• Da Nang Power Company: fully automated feeders expected to present 43% decrease in SAIFI and a 16% reduction in SAIDI once FLISR is fully deployed[231]. • Tata Power-DDL (India): implemented GE-T&D ADMS integrating SCADA, GIS and DMS for self-healing distribution in North Delhi[232].
Expected benefits	• System Performance Loss Rate (PLR) improvement. • FLISR cuts SAIDI/SAIFI, minimizes customer impact and avoids regulatory penalties.
Indicative duration per sub-activity	• Scoping & design: 2 months • Procurement & comms planning: 3 months • Hardware & field-device rollout: 4 months • ADMS integration & testing: 4 months • FLISR/Volt-VAR commissioning: 4 months • Pilot evaluation & calibration: 3 months • Scale-up planning: 2 months
Lead entity	EVN distribution subsidiaries (EVNHCMC, EVNHANOI) coordinated by EVN's DMS Implementation Unit and EVNNPT oversight.
Key stakeholders	MoIT/ERAV; EVN subsidiaries; provincial DSMUs; Industrial technology providers, World Bank, GIZ.
Data requirements & sources	• SCADA feeder telemetry (1-min currents/voltages) • AMI interval data (15-min) • GIS/CIM network model • FLISR switchgear status • weather/temperature feeds
Estimated investment & funding	• Avg. cost ~ US$ 1 M per feeder for automation. Total pilot budget depends on feeder

229 https://en.evn.com.vn/d6/news/EVNHANOI-Reducing-power-loss-thanks-to-grid-modernization-and-leadership-accountability-66-163-3629.aspx

230 https://www.powermag.com/vietnamese-distribution-grid-automation-system-a-winning-project/

231 https://www.survalent.com/casestudy/da-nang-company-case-study/

232 https://www.tdworld.com/smart-utility/article/20971370/advanced-distribution-management-system-for-delhis-electric-grid

	count[233]. • Potential financing via ADB, World Bank, JETP.
Top 3 risks & mitigations	1. **Data-quality gaps** → enforce sensor QA/QC and validation rules. 2. **Vendor lock-in/interoperability** → mandate open standards (IEC 61850, DNP3). 3. **Cybersecurity threats** → apply end-to-end encryption and ISO 27001/IEC 62443 controls.
Key performance indicators (KPIs)	• % feeders automated • PLR reduction • SAIDI/SAIFI improvements • FLISR events executed • mean restoration time • system availability
Monitoring & reporting	• Real-time ADMS dashboards • monthly loss-and-reliability reports • quarterly stakeholder reviews • automated alerts for anomaly thresholds (> 10 %)
Capacity-building needs	• ADMS operation & maintenance training for EVN engineers • vendor-led FLISR/Volt-VAR workshops • cybersecurity and human-machine interface (HMI) training • regulatory briefings
Ethical & data-governance	• Customer-data anonymization protocols • Consent management • Transparent algorithmic logs • Compliance with Vietnam Cybersecurity Law.
Regulatory prerequisites	• Amend grid code to formalize FLISR and ADMS functions • Establish data-sharing agreements among EVN, ERAV and NLDC • Recognize automated restoration outcomes in regulatory reporting

Table 21. Activity T-9. AI for Grid Stability & Transmission System Optimization

[233] https://www.energy.gov/sites/prod/files/2016/11/f34/Distribution%20Automation%20Summary%20Report_09-29-16.pdf

Field	Details
Title	AI for Grid Stability & Transmission System Optimization
Short description	Implement AI-driven real-time monitoring (PMU/SCADA synchrophasor analytics), dynamic line rating (DLR), digital-twin simulations, and machine-learning-based optimal power-flow adjustments in the transmission network to enhance capacity utilization, reduce congestion, and improve voltage and frequency stability.
Technical approach	Integrate high-resolution PMU and weather-sensor streams into reinforcement-learning and graph-neural-network models, coupled with digital-twin platforms for topology control, anomaly detection, and dynamic-line-rating, feeding AI-driven dispatch signals back into the EMS/NMS for real-time optimization.
Current status in Vietnam	• EVNNPT has deployed AI-assisted UAV flight inspections and equipment-anomaly detection since 2024 (EVNNPT's Power Transmission Company 3 (PTC3) has deployed DJI Matrice 300 RTK UAVs with LiDAR since February 2023, autonomously scanning 220–500 kV lines across challenging terrain. AI processes the scan data to build 3D grid models and automatically identify technical anomalies—enhancing stability by reducing human error and improving fault prediction)[234]. • In 2025, AFD signed a €76.48 M financing agreement to modernize 500 kV substations and enhance grid stability with digital tools[235]. • PTC3 and Dak Nong, Phu Yen power transmission units have installed AI-enhanced image-capture cameras at substations and along lines. These systems detect thermal hotspots, insulator defects, and right-of-way encroachments. Integration with PMIS enables early interventions, reducing outage risk and occupational hazards [236] • EVNHCMC has automated 80% of its medium-voltage grid via Mini-SCADA and integrated AI in grid oversight—automated fault detection/reset and substation operation—restoring power to unreached sections within minutes [237] • The NSMO leverages Big Data and AI for load forecasting, hydropower inflow prediction, battery-renewables integration, and Automatic Generation Control (AGC). These tools contribute directly to grid stability and efficiency [238][239][240] • In May 2025, EVN announced AI across its operations, notably at Son La Hydropower plant where AI robots and image-analytics monitor environmental conditions and

[234] https://en.evn.com.vn/d/en-US/news/UAV-and-AI-technology-applications-Breakthrough-in-transmission-grid-operation-management-60-205-500334

[235] https://www.tdworld.com/distributed-energy-resources/news/55294974/evnnpt-and-frances-afd-sign-7648-million-financing-agreement-to-expand-and-modernize-power-transmission-network-in-vietnam

[236] https://en.evn.com.vn/d/en-US/news/Application-of-advanced-technology-to-ensure-safe-power-transmission-60-205-4110

[237] https://en.evn.com.vn/d6/news/EVN-is-on-the-road-to-becoming-the-leading-digital-enterprise-in-the-region-66-163-1437.aspx

[238] https://en.evn.com.vn/d6/news/EVN-is-on-the-road-to-becoming-the-leading-digital-enterprise-in-the-region-66-163-1437.aspx

[239] https://en.evn.com.vn/d6/news/Automating-the-distribution-grid-to-best-supply-power-to-customers-66-163-3360.aspx

[240] https://en.evn.com.vn/d/en-US/news/EVNHCMC-automates-smart-power-grids-60-204-500496

	electrical cabinets to prevent failures [241]
Real-world examples	• Gridraven's DLR solution can increase transmission capacity by up to 30 % in U.S. networks[242]. • VIE Technologies' sensor-based AI forecasts prevent transformer failures, markedly reducing unplanned outages[243]. • Duke Energy's hybrid AI system flags high-risk equipment, improving vulnerability identification and maintenance planning[244].
Expected benefits	• Transmission capacity increase up to 30 % via DLR. • Storm-induced outages decreased with AI-driven risk mapping. • Reduced congestion costs and enhanced voltage-stability margins, facilitating higher renewable integration.
Indicative duration per sub-activity	• Scoping & design: 1 month • Sensor procurement & integration: 3 months • Data-pipeline & digital-twin development: 6 months • Model development & validation: 3 months • Pilot deployment & testing: 3 months • Evaluation & calibration: 3 months • Scale-up planning: 2 months
Lead entity	Vietnam National Power Transmission Corporation (EVNNPT), in coordination with MoIT and ERAV.
Key stakeholders	MoIT; ERAV; EVN GENCOs; provincial DSMUs; international partners; equipment vendors.
Data requirements & sources	• PMU/SCADA telemetry streams (50–120 Hz) • Weather-station & LiDAR line-rating sensors • Historical dispatch and outage logs • Network-model data

[241] https://en.evn.com.vn/d/en-US/news/Artificial-intelligence-application-become-driving-force-for-comprehensive-innovation-in-EVNs-operations-60-205-500717

[242] https://www.gridraven.com/news/power-mag-op-ed-software-and-dlrs-key-to-unlocking-power-grids-potential

[243] https://www.vietechnologies.com/technology

[244] https://www.tdworld.com/digital-innovations/article/21262976/duke-energys-hybrid-approach-to-ai

Estimated investment & funding	• Pilot CAPEX ≈ €2 million (sensors, digital-twin platform, analytics) (propulsiontechjournal.com)[245] • Potential co-financing: AFD, World Bank, ADB.
Top 3 risks & mitigations	1. **Data quality & availability** → enforce QA/QC protocols and sensor calibration (businessinsider.com). 2. **Regulatory bottlenecks** → collaborate with MoIT/ERAV to formalize DLR and AI dispatch in grid codes. 3. **Cybersecurity threats** → apply end-to-end encryption and adhere to NERC CIP/IEC 62443 standards.
Key performance indicators (KPIs)	• % increase in line capacity • Number of congestion events avoided • Voltage-stability margin (MVA) • Model-forecast error (RMSE/MAE) • Mean time to restore (MTTR)
Monitoring & reporting	• Real-time EMS/NMS dashboards • monthly performance summaries • quarterly stakeholder reviews • automated alerts for threshold breaches (> 10 %).
Capacity-building needs	• Workshops on PMU and digital-twin operations • ML-model tuning training • change-management sessions for TSO engineers and regulators.
Ethical & data-governance	• Compliance with Vietnam Cybersecurity Law • anonymization protocols • transparent AI audit trails
Regulatory prerequisites	• Amend grid code to recognize DLR and AI-driven dispatch signals • Establish data-sharing agreements between EVNNPT, MoIT, and ERAV • Update dispatch procedures to integrate AI-based optimal-flow adjustments

Table 22. Activity T-10. Consumer-Side Intelligence

[245] https://www.propulsiontechjournal.com/index.php/journal/article/download/8506/5315/14443

Field	Details
Title	Consumer-Side Intelligence
Short description	Deploy AI-driven consumer platforms and home-energy-management portals that deliver personalized, disaggregated usage insights, behavioral recommendations, and automated alerts, empowering end users to optimize their consumption and participate in flexibility markets.
Technical approach	Machine-learning–based non-intrusive load-disaggregation to identify end-use patterns. Automated Home Energy Reports with behavioral-science nudges (e.g., peer comparisons, targeted tips). Mobile/web dashboards integrated via MDMS/AMI APIs and IoT gateways for real-time monitoring. Rule-based and ML-driven scheduling for thermostats, water heaters, and EV chargers via OCPP/OpenADR integration.
Current status in Vietnam	• EVNHANOI's "App EVNHANOI" enables Hanoi customers to search and monitor consumption data via smartphone since 2020[246]. • EVNCPC completed electronic-meter and telemetry installations for all customers in 2021, laying groundwork for consumer-facing data services[247]. • EVN's nationwide "Electricity Customer Care" application provides daily usage dashboards and billing alerts to registered users[248].
Real-world examples	• Opower (Oracle Utilities): 1.5–2.5 % average annual energy savings per household across > 150 utilities; > 24 TWh cumulative savings[249]. • Google Nest Learning Thermostat: independent studies show 10–12 % heating and 15 % cooling savings via automated scheduling and seasonal optimization [250].
Expected benefits	• Residential energy consumption decrease coupled with bill savings • Peak-load shaving via automated DR participation • Increased customer engagement and satisfaction • Foundation for future V2G and flexibility markets
Indicative duration per sub-activity	• Scoping & requirements: 2 months • Platform & API development: 4 months • ML-model training & validation: 3 months • Pilot deployment & user trials: 6 months

[246] https://en.evn.com.vn/d6/news/Customers-in-Hanoi-Capital-enabled-to-search-electricity-bill-on-smartphone-66-163-40.aspx

[247] https://en.evn.com.vn/d6/news/In-2021-EVNCPC-will-install-100-of-electronic-meters-and-telemetry-66-163-2309.aspx

[248] https://en.evn.com.vn/d/en-US/news/Proactively-monitor-and-control-daily-electricity-usage-with-Electricity-Customer-Care-application-60-204-500820

[249] https://www.oracle.com/a/ocom/docs/industries/utilities/utilities-opower-energy-efficiency-cs.pdf

[250] https://store.google.com/intl/en/ideas/articles/nest-thermostat-savings/

	• Evaluation & iteration: 3 months • Scale-up planning: 2 months
Lead entity	EVN's Customer Care Division in partnership with provincial Power Corporations (e.g., EVNHANOI, EVNCPC)
Key stakeholders	MoIT; ERAV; EVN subsidiaries; telecom providers; smart-home vendors; consumer-rights groups; development partners
Data requirements & sources	• AMI/interval-meter data (15–60 min) • Meter Data Management System (MDMS) exports for billing & aggregation • Weather & temperature feeds for baseline modeling • Customer metadata (tariff class, demographics) • Device telemetry (thermostats, smart plugs)
Estimated investment & funding	Potential co-financing: World Bank, ADB, bilateral grants
Top 3 risks & mitigations	1. **Low user adoption** → gamification, incentives, seamless UX 2. **Data privacy concerns** → strict consent management, anonymization frameworks under PDPD Decree 13/2023/ND-CP 3. **Integration challenges** → standardized AMI/MDMS APIs and modular middleware
Key performance indicators (KPIs)	• % of registered users vs. total customer base • Average bill reduction (%) per user • Peak-load reduction per event (kW) • Engagement metrics (active sessions, alerts responded) • Customer satisfaction/NPS
Monitoring & reporting	• Real-time consumer-dashboard analytics • Monthly program-evaluation reports • Quarterly stakeholder reviews • Automated alerts for data gaps or opt-out rates > 10 %
Capacity-building needs	• Training for EVN customer-care and IT teams on platform administration • Workshops on behavioral-science design and data analytics • Consumer education campaigns (online tutorials, call-centre scripts)

Ethical & data-governance	• Compliance with Vietnam's Personal Data Protection Decree 13/2023/ND-CP and Law on Cybersecurity (Decree 53/2022) • Clear consent flows and data-access audits • Transparent algorithms and explanation protocols
Regulatory prerequisites	• Update MOIT Circulars to recognize digital consumption services in retail licensing • Align with Decree 13/2023/ND-CP on Personal Data Protection for user-data handling

Table 23. Activity T-11. Smart Electric Vehicle (EV) Charging Management

Field	Details
Title	Smart Electric Vehicle (EV) Charging Management
Short description	Deploy smart charging management platforms that dynamically control EV charging processes i.e., peak shaving, priority-based charging, and emergency-stop functions, across sites to minimize energy procurement costs and stabilize grid load.
Technical approach	Integrate charging-station backends via OCPP/OpenADR with utility EMS/MDMS. Develop API and ML algorithms for real-time load forecasting, dynamic scheduling, and V2G bidirectional control. Use user-behavior prediction to optimize charging order and reduce peaks.
Current status in Vietnam	• Vietnam currently has just over 150 000 EV charging ports, mostly operated by VinFast[251]. • V-GREEN targets 1 million charging ports by 2028[252]. • Draft national technical regulations stipulate safety requirements for EV charging equipment (rated up to 1 000 V AC/1 500 V DC)[253]. • MOIT proposed a draft retail electricity-pricing scheme for charging stations (Dec 2023)[254]. • Absence of unified guidelines on siting, safety, and pricing remains a barrier[255].

[251] https://www.reuters.com/world/asia-pacific/vietnam-plans-electricity-subsidies-ev-charging-stations-2024-08-12/
[252] https://www.ainvest.com/news/vinfast-charging-port-operator-aims-1-million-ports-vietnam-years-2507/
[253] https://igarr.com/2025/03/15/vietnam-national-technical-regulation-on-electric-vehicle-charging-equipment/
[254] https://www.reccessary.com/en/news/moit-presents-draft-electricity-pricing-for-charging-station
[255] https://vietnamlawmagazine.vn/vietnams-ev-charging-infrastructure-key-to-green-transition-74018.html

Real-world examples	• Audi AG Ingolstadt pilot (Germany): 6-month smart-charging system saved up to €12 million in energy procurement via peak shaving and emergency-stop functions[256]. • Essonne, France: A study for 2040 showed that smart charging reduced peak load by 6 % and avoided 25 % of annual network reinforcement costs[257]. • South Australia: The modelling exercise in the roadmap development exercise V2G operation can also contribute to reduced distribution network costs by reducing local peak demand. The study estimated network cost savings of up to \$1.5 bn [258].
Expected benefits	• Peak load reduction of up tp 5 % (smart) and further decreased with V2G. • Avoids annual network reinforcement costs. • Energy procurement cost savings.
Indicative duration per sub-activity	• Scoping & design: 1 month • Requirements & architecture definition: 1 month • Algorithm & API development: 3 months • Hardware integration & testing: 2 month • Pilot deployment & testing: 6-12 months • Evaluation & calibration: 2 months • Scale-up planning: 2 months
Lead entity	EVN’s EV Charging Management Division
Key stakeholders	MoIT; ERAV; EVN; charging-station operators; telecom providers; DSOs.
Data requirements & sources	• Charger-level telemetry & usage logs • Dynamic tariff & demand signals via openadr • EMS/MDMS grid-load profiles • Weather forecasts for predictive scheduling

Estimated investment & funding	• Hardware costs[259]:
	  ○ Level 2 chargers \$600–\$12 700 (equipment only excluding installation)
	  ○ Level 3 DC fast chargers \$30 000–\$150 000+ (equipment only excluding installation)

[256] https://www.hubject.com/case-study/design-and-development-of-a-smart-charging-management-pilot-system-for-the-plant-in-ingolstadt

[257] https://theicct.org/wp-content/uploads/2025/03/RAP-ICCT-Hildermeier-Jahn-Schmidt-Bernard-Ragon-Basma-Savings-from-smart-charging-electric-cars-and-trucks-in-Europe-March-2025.pdf

[258] https://arena.gov.au/assets/2025/02/Bidirectional-Bidi-ROADMAP-2025-01-15-1.pdf

[259] https://www.greenlancer.com/post/guide-commercial-electric-vehicle-charging-stations

	• Smart-charging software development costs $40,000 – $250,000/yr[260] • Potential financing: ADB green-loan facility for EV charging stations[261].
Top 3 risks & mitigations	1. **Investment risk (uncertain demand, high CAPEX)** → phased rollout, demand forecasting, concessional financing. 2. **Regulatory uncertainty (no unified standards)** → fast-track technical regulations with MS&T & Construction Ministries. 3. **Cybersecurity & interoperability** → secure OCPP/OpenADR protocols; pilot interoperability tests.
Key performance indicators (KPIs)	• Peak load reduction (%) • Network reinforcement cost avoided ($) • Energy procurement cost savings (€) • Managed charging events/day • User participation rate (%) • System uptime (%) & response latency (s)
Monitoring & reporting	• Real-time dashboards • Monthly performance & savings reports • Automated peak-event alerts • Quarterly stakeholder reviews
Capacity-building needs	• Operator workshops on E2E smart-charging operations • Regulator seminars on EV-charging business models • Consumer engagement campaigns
Ethical & data-governance	• End-to-end encryption • Consent-based data usage • Anonymization per vietnam cybersecurity law
Regulatory prerequisites	• Finalize & enforce national technical regulations for EV charging station safety • Adopt MOIT retail pricing scheme for charging stations • Issue unified siting, safety & interoperability standards (OCPP/OpenADR)

[260] https://appinventiv.com/blog/cost-to-build-ev-charging-management-software/
[261] https://www.adb.org/projects/54268-001/main

Table 24. Activity T-12. AI-driven Ancillary-Service Dispatch Optimization

Field	Content
Title	AI-Driven Ancillary-Service Dispatch Optimization
Short description	Combine machine-learning forecasts of load and variable renewables with a mixed-integer optimization engine to perform real-time, security-constrained reserve and ancillary-service dispatch, reducing reliance on manual scheduling and enabling sub-5-minute automatic re-procurement.
Technical approach	Leverage a hybrid control-optimization pipeline: • LSTM-based short-term load and VRE forecasting • Mixed-integer linear programming solver for economic-dispatch and reserve procurement • Closed-loop integration with EMS/SCADA via RESTful APIs for continuous re-optimization • Human-in-the-loop dashboard for "what-if" adjustments
Current status in Vietnam	Preliminary forecasting modules were piloted under the Smart Grid Development Roadmap (PM Decision 1670/QĐ-TTg, 2012) and are now under review in Proposal No. 6068 to extend digital-dispatch trials in NLDC and regional dispatch centres
Real-world examples	• Camus Energy orchestration software: A comprehensive data fabric, AI-driven insights, and powerful applications to accelerate interconnections, streamline engineering analyses, and enable flexible operation in large US DSOs[262] • ML-Assisted SCUC: Security-constrained UC solve times cut by ~50 % on IEEE test systems with no loss of optimality[263]
Expected benefits	• Lower reserve-procurement costs • Tighter renewable integration margins • Decreased automated re-dispatch latency • Reduced human errors and faster contingency response
Indicative duration per sub-activity	• Model development & training: 4 months • Solver integration & API development: 3 months • Pilot testing & validation: 6 months • Operator training & commissioning: 3 months
Lead entity	Electricity Authority of Vietnam (EAV) / NLDC dispatch centre

[262] https://www.camus.energy/technology

[263] https://arxiv.org/pdf/2111.09824

Key stakeholders	MOIT/EAV; EVN dispatch centres; provincial DSMUs; SCADA/EMS vendors; academic partners (HUST, VNU-HCM); development partners
Data requirements & sources	Historical SCADA/EMS snapshots; AMI 5-min interval load data; VMGD meteorological forecasts; existing market-bid archives; network model (PSS/E or PowerFactory)
Estimated investment & funding	USD 1.0 – 1.5 million for software development, cloud infrastructure, pilot hardware and workshops
Top 3 risks & mitigations	1. **Data-quality issues** → establish centralized data-governance protocols and automated cleansing routines 2. **Model drift** → implement continuous retraining and hybrid ML-physical safeguards 3. **IT/OT integration delays** → adopt modular, API-first architecture and run parallel SIT/UAT streams
Key performance indicators (KPIs)	• Reserve-procurement cost reduction (%) • Renewable-curtailment events per month
Monitoring & reporting	• Real-time performance dashboards in EMS • Monthly KPI scorecards • Quarterly steering-committee reviews with MOIT/EAV
Capacity-building needs	• Workshops on ML model maintenance and solver parameter tuning for dispatch engineers • Training on API-driven integration for IT teams • Joint exercises with academic partners on advanced optimization methods
Ethical & data-governance	• Comply with Law 86/2015/QH13 on critical infrastructure data privacy • Enforce role-based access controls • Maintain explainability logs for all automated dispatch decisions
Regulatory prerequisites	• Amend dispatch-code Circulars to permit AI-informed unit-commitment and reserve procurement • Formalize data-sharing agreements between NLDC and DSOs • Define oversight framework for algorithmic decision-making

9.3. Policy / Regulatory Activities

This section presents "Activity Cards" for each of the policy / regulatory activities.

Table 25. Activity P-1. Introduce Time-of-Use Pricing building upon existing Demand Response Regulations

Field	Content
Title	Introduce Time-of-Use Pricing building upon existing Demand Response Regulations
Type	**Policy**
Short description	Develop and deploy a nationwide time-of-use (ToU) tariff framework, leveraging the legal foundation of Vietnam's Demand Response regulations to incent load-shifting, flatten peaks and integrate distributed flexibility resources.
Objectives	• Align retail price signals with wholesale cost variations to drive consumer demand-shifting toward off-peak periods • Enhance overall system efficiency by reducing peak load and deferring capacity additions • Strengthen the market for Demand Response aggregators and virtual power plants • Lay a data-driven foundation for advanced dynamic-pricing schemes in future phases
Legal/Regulatory Basis in Vietnam	• Decision No. 1670/QĐ-TTg (2012) promotes smart metering and time-based pricing to optimize load management. • Decision on Demand Response Framework (e.g. Decision 41/QĐ-ĐTĐL 2020) mandates AMI, Direct Load Control and Response Automation to support DR programmes • Circular 05/2025/TT-BCT sets metering and data-management standards required for hourly billing • Circular 06/2025/TT-BCT requires integration of SCADA/EMS platforms for real-time data exchange—core to ToU settlement systems
Real-world examples	• Singapore EMA DR Expansion: its 2022–24 pilot rewarded industrial participants up to S$4 500/MWh for peak-period reductions, achieving over S$700 million in buyer savings by mid-2024[264] • IRENA ToU Innovation Brief: ToU tariffs in OECD markets have enabled peak-load reductions of 5–10% and consumer bill savings of 3–7%, demonstrating reliability in implicit DR programmes[265]

[264] https://www.ema.gov.sg/news-events/news/media-releases/2024/new-initiatives-to-harness-demand-flexibility-potential-in-sg

[265] https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Feb/IRENA_Innovation_ToU_tariffs_2019.pdf

Expected benefits	• Reduction in national peak demand • Increased household bill savings through load-shifting incentives • Deferral of new generation/transmission capacity over five years • New revenue streams for dr aggregators and enhanced system resilience
Indicative duration per sub-activity	• Tariff design & modelling: 5 months • Stakeholder consultation & legal drafting: 3 months • System integration & pilot implementation: 6 months • Full rollout & monitoring: 12 months
Lead entity	Ministry of Industry & Trade (MOIT); Electricity Authority of Vietnam (EAV)
Key stakeholders	EVN & Distribution Companies; commercial and industrial consumer associations; DR aggregators; meter vendors; development partners
Dependencies & Prerequisites	• Smart-meter (AMI) coverage with interval-data capability • SCADA/EMS platforms integrated with retail-billing systems • Consumer-protection rules for tariff transparency and hardship support • Accredited third-party settlement and auditing frameworks
Estimated cost & funding sources	USD 0.3–0.5 million for tariff modelling tools, stakeholder workshops and IT upgrades
Top 3 risks & mitigations	1. **Low consumer engagement** → deploy targeted communications campaigns and pilot consumer apps with bill-impact forecasts 2. **Technical integration delays** → procure modular, API-driven AMI-billing interfaces and run parallel testing 3. **Regulatory resistance** → stage phased tariff bands with grandfathering clauses and cross-ministerial "fast-track" working group
Capacity-building needs	• Training for EAV and utilities on ToU settlement and tariff analytics • Workshops for consumer groups on load-shifting strategies • Technical sessions for meter vendors and IT integrators on IEC 61968/61970 and OpenADR standards
Enabling Technical Activities	• Demand Response Programs via Digital Platforms • Advanced Metering Infrastructure & Data Analytics • Virtual Power Plants & DER Aggregation • AI-Enhanced Load & Renewable Energy Forecasting

Table 26. Activity P-2. Build Institutional Capacity & Skills for Digitalization

Field	Content
Title	Build Institutional Capacity & Skills for Digitalization
Type	Policy
Short description	Launch a structured, multi-tiered capacity-building programme, covering regulators, utility staff, municipals and technical consultants, to master digital-grid architectures, data-analytics platforms, AI/ML toolkits, and agile regulatory methodologies.
Objectives	• Equip policy-makers and technical staff with hands-on expertise in AI-driven forecasting, AMI analytics, VPP orchestration and cybersecurity standards • Strengthen institutional agility for iterative rule-making and data-driven oversight • Foster a community of practice linking public, private and academic actors
Legal/Regulatory Basis in Vietnam	• National AI Strategy (Decision No. 127/QĐ-TTg, Jan 26 2021): mandates R&D, talent pipelines and cross-agency coordination for AI to 2030 • MOIT Digital Transformation Plan for the energy sector (PDP 8 annex): calls for regulator and utility upskilling in digital modalities
Real-world examples	**GIZ SGREEE (2017–22):** Provided technical-assistance and tailored-curriculum development for ERAV staff in AMI, data governance and smart-meter analytics[266]
Expected benefits	• Faster regulatory review cycles for digital-pilot approvals • Reduction in post-pilot implementation errors through improved QA/QC • Stronger cross-agency data sharing and joint-task-force readiness
Indicative duration per sub-activity	• Curriculum & materials development: 4 months • Regional & in-house workshops: 6 months • Mentorship and on-the-job coaching: 12 months
Lead entity	Ministry of Science & Technology (MoST), in coordination with MOIT's Electricity Authority of Vietnam (EAV)
Key stakeholders	EVN (and subsidiaries); Provincial DOITs; Electricity Regulatory Authority of Vietnam; Universities & research institutes (HUST, VAST-ISTEE); development partners; private technology vendors
Dependencies & Prerequisites	• Completion of baseline skills assessment across agencies • Procurement of training platforms (LMS, sandbox environments) • Engagement of accredited training providers or academic partners

[266] https://www.giz.de/en/downloads_els/Smart%20Grids_ENG_25-6.pdf

Estimated cost & funding sources	• USD 300 000–500 000 for programme design, delivery and mentorship
Top 3 risks & mitigations	1. **Low participation** → mandate minimum training quotas in staff KPIs 2. **Curriculum misalignment** → co-design modules with utilities and regulator via kick-off workshops 3. **High turnover** → incorporate "train-the-trainer" model to cascade skills internally
Capacity-building needs	• Deep-dive modules on AI-based forecasting and predictive maintenance • Hands-on labs for AMI/data-lake management and DER integration • Regulatory sandbox simulations and agile rule-drafting exercises
Enabling Technical Activities	• AI-Enhanced Load & Renewable Energy Forecasting • Advanced Metering Infrastructure & Data Analytics • Virtual Power Plants & DER Aggregation • Demand Response Programs via Digital Platforms

Table 27. Activity P-3. Strengthen Cybersecurity & Grid Resilience Regulations

Field	Content
Title	Strengthen Cybersecurity and Grid Resilience Regulations
Activity Type	**Regulation**
Short description	Revise and expand Vietnam's electricity-sector regulations to impose mandatory cybersecurity and resilience requirements on all grid assets and operators, including continuous patching, AI-driven threat detection, incident reporting, and periodic resilience audits, to safeguard digital and physical infrastructure against evolving threats.
Objectives	• Mandate baseline and advanced security controls (e.g. IEC 62443, network segmentation) across generation, transmission and distribution assets • Enforce real-time anomaly detection and mandatory incident-reporting protocols • Increase minimum resilience benchmarks (e.g. N-1 contingency, DER ride-through) to ensure rapid recovery from cyber or physical disruptions • Foster a unified national CERT and clear escalation pathways
Legal/Regulatory Basis in Vietnam	• Decree 85/2016/NĐ-CP (Network Information Security): mandates data-privacy and system-integrity norms for essential services • Law on Cyberinformation Security No. 24/2018/QH14 : Requires critical information infrastructure operators, including the electricity sector, to implement measures to ensure cybersecurity • Decision No. 749/QĐ-TTg (2020) establishes cybersecurity and safety as foundational requirements for digital transformation across all sectors, including energy

Real-world examples	• Singapore Cybersecurity Act (2018): requires owners of Critical Information Infrastructure—including energy utilities—to implement risk-management measures, report major incidents within 24 hrs, and undergo regular CSA audits[267] • NERC CIP (US): mandates Critical Infrastructure Protection standards for Bulk Electric System operators, covering asset identification, access control, incident response and periodic compliance audits[268] • EU NIS2 Directive: extends mandatory risk-management and incident-reporting obligations to a broad set of essential entities, including energy, with strict enforcement and cross-border cooperation[269]
Expected benefits	• Reduction in successful intrusion events • Faster containment and recovery from incidents via standardized response protocols • Increased investor and consumer confidence through transparent compliance reporting • Harmonization with ASEAN and OECD partners, opening access to regional resilience funds
Indicative duration per sub-activity	• Regulation drafting & stakeholder review: 4 months • Public consultation & legal vetting: 3 months • Issuance of technical guidelines & standards: 2 months • Compliance-monitoring framework setup: 6 months
Lead entity	Ministry of Industry & Trade / Electricity Authority of Vietnam, in coordination with Ministry of Public Security and Vietnam Information Security Authority
Key stakeholders	EVN & regional DSOs; National Cybersecurity Centre (A05); Ministry of Science & Technology; private DER & SCADA vendors; development partners
Dependencies & Prerequisites	• Existing AMI/SCADA deployments with open-API capability • Accredited national CERT and accredited incident-response teams • Baseline IT and OT security audits completed by all utilities • Legal mandate for mandatory reporting (e.g. amendments to Law 86/2015)
Estimated cost & funding sources	Potential financing: bilateral grants (e.g., GIZ ICT Security Programme, USAID Cybersecurity Partnerships); possible GCF/GEF resilience grants

[267] https://sso.agc.gov.sg/Acts-Supp/9-2018

[268] https://www.techtarget.com/searchsecurity/definition/North-American-Electric-Reliability-Corporation-Critical-Infrastructure-Protection-NERC-CIP

[269] https://digital-strategy.ec.europa.eu/en/policies/nis2-directive

Top 3 risks & mitigations	1. **Under-reporting of incidents** → impose escalating penalties and anonymized "safe-harbor" reporting channels 2. **Regulatory inertia** → establish a high-level inter-ministerial "fast-track" committee with clear goals 3. **Operator capacity gaps** → phase in requirements, paired with mandatory certification for security officers
Capacity-building needs	• IEC 62443 & NIST CSF training for utility cyber teams • Incident-response simulation exercises (table-top and live drills) • Workshops on AI-driven threat-detection and ICS/OT security best practices
Enabling Technical Activities	• AI-Powered Grid Resilience & Anomaly Detection • Advanced Metering Infrastructure & Data Analytics • SCADA/EMS & Data Concentrator Upgrades • Knowledge-Based DER Management Systems

Table 28. Activity P-4. Implement Regulatory Sandboxes for Energy Innovation

Field	Content
Title	Implement Regulatory Sandboxes for Energy Innovation
Type	Regulation
Short description	Establish a time-limited, outcome-based regulatory sandbox mechanism that permits energy innovators (utilities, technology vendors, start-ups) to trial novel digital and AI-driven business models (e.g. peer-to-peer trading, VPP aggregation, AI forecasting) under relaxed compliance rules, in order to generate real-world performance data and inform subsequent permanent rulemaking.
Objectives	• Accelerate market entry of high-impact digital/AI pilots by lowering upfront regulatory barriers • Generate empirical evidence on technology performance and consumer impacts • Build regulator capacity for agile rule-making and iterative licensing • Inform the design of permanent, outcome-based regulations in Vietnam
Legal/Regulatory Basis in Vietnam	• Resolution No. 55-NQ/TW (2020) encourages innovation and piloting new technologies and market model**s** in the energy sector • Law on Electricity 61/2024/QH15 mandates innovation in grid management • Revised Power Development Plan 8 targets "digital-ready" networks (PDP 8) • Decision 1670/QĐ-TTg outlines smart-grid standards and calls for pilot schemes

Real-world examples	• Singapore EMA sandbox: Open to innovations like P2P energy-trading pilots using blockchain smart contracts and AI load-forecasting, with outcomes informing national market code revisions[270] • Thailand ERC sandbox: Open to innovations like trading platforms, smart grids, innovative forms of PPAs (Virtual PPA, Sleeved PPA), Green Innovation and Green Regulation[271]. • UK Ofgem Regulatory Sandbox: Able to be utilized for many innovations like Demand-flexibility pilots, testing dynamic-pricing and VPP aggregation under outcome-based waivers[272]
Expected benefits	• Shortened approval cycles for pilots • Robust, context-specific evidence on tech performance and consumer acceptance • Lowered risk for investors and utilities through controlled experimentation • Enhanced regulator confidence in scaling successful models
Indicative duration per sub-activity	• Framework drafting: 6 months • Stakeholder consultation & legal review: 3 months • Pilot approvals & monitoring: 12 months
Lead entity	Ministry of Industry & Trade (MOIT), Electricity Regulatory Authority of Vietnam
Key stakeholders	EVN; municipal energy offices; private technology vendors; consumer associations; development partners
Dependencies & Prerequisites	• Baseline smart-meter/AMI coverage and SCADA modernization • Data-privacy and cybersecurity regulations in place • Legal mandate for outcome-based licensing (e.g. amendments to Electricity Law) • Regulator and operator readiness for agile governance
Estimated cost & funding sources	• USD 0.5–1 million for secretariat, legal drafting, stakeholder workshops, monitoring systems • Technical assistance grants from e.g., GIZ Energy Support Programme, JETP technical facility etc.
Top 3 risks & mitigations	1. Regulatory pushback → host early joint workshops, share international precedents 2. Market-player under-participation → introduce modest stipend or data-access incentives for pilot participants

[270] https://www.ema.gov.sg/regulations-licences/regulations/policies-frameworks/regulatory-sandbox

[271] https://chandler.morihamada.com/sites/default/files/newsletters/pdf/ERC%20Sandbox%20Thailand%20Pilot%20Virtual%20PPA%20and%20How%20RECs%20and%20Virtual%20PPAs%20Can%20Further%20Its%20Decarbonization%20Goals%2011%20March%202025.pdf

[272] https://www.ofgem.gov.uk/energy-regulation-sandbox

	3. Legal drafting delays → run parallel fast-track amendments and engage legal advisors from project outset
Capacity-building needs	• Agile-regulation training for MOIT/VREB staff • Technical upskilling on monitoring KPIs for digital/AI pilots • Living-lab exchanges with ASEAN sandbox hosts (Singapore, Thailand)
Enabling Technical Activities	• AI-Enhanced Load & Renewable Forecasting • Advanced Metering Infrastructure & Data Analytics • Demand Response Programs via Digital Platforms • Virtual Power Plants & DER Aggregation

Table 29. Activity P-5. Provide Financial Incentives & Support for Smart Grid Investments

Field	Content
Title	Provide Financial Incentives and Support for Smart Grid Investments
Type	**Policy**
Short description	Design and implement a suite of financial instruments e.g., grants, concessional loans, matching-fund mechanisms and tax incentives, to lower the cost of capital for utilities & private investors undertaking AMI, distribution-automation, virtual power plants and grid-edge digitalization projects.
Objectives	• Mobilize public and private capital to accelerate smart-grid deployment • De-risk early-stage investments in AMI, DA, DER aggregation and resilience measures • Encourage co-financing by development partners and commercial financiers • Ensure equitable grid modernization across regions
Legal/Regulatory Basis in Vietnam	• Law on Investment 61/2020/QH14: enables public co-funding of infrastructure and concessional financing schemes • Law on Electricity 55/2024/QH15: authorizes Ministry of Industry & Trade to establish investment support mechanisms for grid modernization • Decision 32/2023/QĐ-TTg approving National Energy Development Strategy: calls for blended-finance vehicles to support digital-grid rollout

Real-world examples	• US SGIG Program: DOE co-invested USD 8 billion in 99 cost-shared smart-grid projects, yielding 16 million smart meters and 82 000 intelligent devices, with average project leverage of 2:1 in private co-funding[273] • EIB support in Germany: €70 million concessional finance for Stadtwerke Reutlingen's grid-automation and digital-control upgrades, leveraging additional commercial debt to modernize cables & substations[274] • EU BRIDGE Initiative: Horizon 2020/ Horizon Europe provided grants for smart-grid R&I projects, mobilizing €1.6 billion in total investment[275]
Expected benefits	• Increase in annual smart-grid capex over baseline • Reduction in weighted average cost of capital for grid-edge digital projects • Faster AMI rollout • Enhanced investor confidence via clear, transparent co-financing rules
Indicative duration per sub-activity	• Instrument design & legal drafting: 6 months • Budget appropriation & partner MOUs: 3 months • Disbursement & monitoring: 12–24 months
Lead entity	Ministry of Industry & Trade (MOIT) in coordination with Ministry of Finance (MOF)
Key stakeholders	EVN & regional DSOs; commercial banks; Development partners; Ministry of Finance; consumer associations; private technology vendors
Dependencies & Prerequisites	• Approved legal mandate for concessional financing (amendments to Investment Law) • Established credit-appraisal frameworks within MOIT/MPI • Baseline grid-modernization roadmap (from PDP 8) • Standardized technical eligibility criteria for funded projects
Estimated cost & funding sources	Depends on the tools decided to be implemented.
Top 3 risks & mitigations	1. **Low private uptake** → mitigate via risk-sharing guarantee and clear repayment terms 2. **Project selection bias** → establish independent appraisal board with external experts 3. **Fund misallocation** → implement digital tracking & quarterly audits

[273] https://www.energy.gov/oe/recovery-act-smart-grid-investment-grant-sgig-program

[274] https://www.eib.org/en/press/all/2025-006-eib-supports-expansion-of-electricity-and-district-heating-networks-in-reutlingen

[275] https://bridge-smart-grid-storage-systems-digital-projects.ec.europa.eu/about-us

Capacity-building needs	• Training for MOIT/MPI on project-finance appraisal and blended-finance models • Workshops for regional utilities on proposal development and financial reporting • Hands-on sessions with DFIs on credit-risk assessment for energy-digital projects
Enabling Technical Activities	• Advanced Metering Infrastructure & Data Analytics • Distribution Automation & Control Systems • Virtual Power Plants & DER Aggregation • Demand Response Platforms

Table 30. Activity P-6. Update Grid Codes & Technical Regulations for AI and DER Integration

Field	Content
Title	Update Grid Codes and Technical Regulations for AI and DER Integration
Activity Type	**Regulation**
Short description	Revise Vietnam's Planning, Connection and Operating Codes—as well as key Circulars and Decisions—to embed explicit requirements for: • AI-enabled forecasting and control (data interfaces, performance metrics) • DER voltage and frequency ride-through, reactive-power and fault-ride-through capabilities • Telemetry & open-API standards for AMI/SCADA • Cybersecurity, data-governance and interoperability protocols
Objectives	• Ensure safe, reliable interconnection of high DER volumes • Enable AI/ML forecasting and real-time control within code governance • Standardize data streams and open-data interfaces to unlock third-party analytics • Increase hosting capacity and minimize curtailment through technical envelopes
Legal/Regulatory Basis in Vietnam	All regulations pertaining the Grid Code
Real-world examples	• Singapore EMA "Future-Proof Grid": mandates real-time digital twins and AI engines for asset health monitoring, integrated via open APIs in its Grid Code roadmap[276] • Germany VDE-AR-N 4105/4110: national regulations requiring DER ride-through, reactive power and telemetered control at LV/MV, with explicit cybersecurity clauses[277] • UK National Grid DER Requirements: publishes a DER Technical Requirements document specifying functional, data and communication specs for embedded resources[278]
Expected benefits	• Improved hosting capacity for rooftop PV and battery systems • Reduction in DER-related curtailment events • Faster AI-enabled reserve procurement and dispatch • Clear compliance framework reduces interconnection disputes

[276] https://www.ema.gov.sg/news-events/news/media-releases/2024/sg-future-grid-capabilities-roadmap-to-pave-way-for-resilient-sustainable-energy-future

[277] https://www.vde-verlag.de/standards/0100735/vde-ar-n-4110-anwendungsregel-2023-09.html

[278] https://www.nationalgrid.com/sites/default/files/documents/DER_Technical_Requirements_v2.5.1.pdf

Indicative duration per sub-activity	• Draft code amendments: 9 months • Stakeholder consultation & revision: 3 months • Regulatory approval : 2 months
Lead entity	Ministry of Industry & Trade (MOIT) / Electricity Authority of Vietnam (EAV)
Key stakeholders	EVN & regional DSOs; private DER vendors; development partners
Dependencies & Prerequisites	• Baseline AMI & SCADA deployment with open-API capability • Data-governance and cybersecurity policy in place • Accredited test-laboratory for DER ride-through certification
Estimated cost & funding sources	USD 200 000–500 000 for legal drafting, workshops, pilot-testing rigs
Top 3 risks & mitigations	1. **Technical complexity** → form a multi-agency technical committee with DSO and vendor experts 2. **Stakeholder misalignment** → hold targeted peer-review sessions with utilities and prosumers 3. **Enforcement gaps** → integrate code checks into EVN's interconnection process and capacity-building for inspection teams
Capacity-building needs	• Training for MOIT/EAV on AI-forecasting KPIs and DER control benchmarks • Workshops on open-API and cybersecurity standards for grid-code officers • Accredited certification courses for DER vendors and testing labs
Enabling Technical Activities	• Online Power-Flow & Real-Time Control Optimization • DER-enhanced Volt/VAR Control & Optimization • SCADA/EMS & Data Concentrator Upgrades • Knowledge-Based DER Management Systems

Table 31. Activity P-7. Create Market Mechanisms for Grid Flexibility & New Services

Field	Content
Title	Create Market Mechanisms for Grid Flexibility and New Services
Type	**Regulation**
Short description	Establish and refine market platforms (auctions, ancillary-services tenders, flexibility markets) to remunerate fast-responding resources—DER aggregators, storage, demand-response and VPPs—for grid balancing, congestion relief and new system services.

Objectives	• Signal the value of flexibility and incentivize least-cost system balancing • Unlock participation of DERs, storage and demand-side assets • Embed services (inertia, fast frequency response, capacity guarantees) into market structures • Drive competition, innovation and downward pressure on balancing costs
Legal/Regulatory Basis in Vietnam	• Electricity Law 61/2024/QH15 mandates competitive market operation and data transparency • Decision 41/QĐ-ĐTĐL (2020) prescribes IT systems for market operation, bidding datasets and settlement processes • PDP VIII (768/QĐ-TTg, 2025) commits to renewable-friendly grids and ancillary-services frameworks
Real-world examples	• PJM (USA): Performance-based Frequency Regulation (pay-for-performance) auctions rewarding rapid, accurate regulation resources[279] • AEMO (Australia): Eight FCAS markets under its Market Ancillary Services Specification, procuring regulation, contingency and network-support services[280] • FERC Order 2222 (USA): Requires RTOs to admit DER aggregations on par with traditional resources[281]
Expected benefits	• Lower system balancing costs via competitive procurement • Greater renewable integration by monetizing fast services • Broader market access for new entrants • Enhanced grid resilience through resource diversification
Indicative duration per sub-activity	• Market design & consultation: 6 months • Regulatory drafting & approval: 3–9 months • IT platform development & testing: 6–12 months • Pilot auctions & trials: 6 months • Full commercial launch: 3 months
Lead entity	Electricity Regulatory Authority of Vietnam (MOIT)
Key stakeholders	EVN & DISCOMs; A0/A1 dispatch centres; DER aggregators; storage developers; DR providers; Ministry of Finance; Development partners

[279] https://www.pjm.com/-/media/DotCom/documents/manuals/m18.ashx

[280] https://aemo.com.au/-/media/files/electricity/nem/security_and_reliability/ancillary_services/guide-to-ancillary-services-in-the-national-electricity-market.pdf

[281] https://www.ferc.gov/ferc-order-no-2222-explainer-facilitating-participation-electricity-markets-distributed-energy

Dependencies & Prerequisites	• Real-time data from SCADA/EMS & AMI • Legal provisions for ancillary-services procurement • Market operator IT capability (per Decision 41/QĐ-ĐTĐL) • Technical standards for resource qualification
Estimated cost & funding sources	Depends on the services decided to be implemented.
Top 3 risks & mitigations	1. **Low participation** → outreach, simplified qualification, early-mover incentives 2. **Data gaps** → strengthen AMI/SCADA coverage, enforce accuracy standards 3. **Regulatory delays** → fixed timelines, interim pilot sandboxes
Capacity-building needs	• Auction-design and settlement training for ERAV • Workshops for DER aggregators on bidding and integration • Study tours for hands-on market operation
Enabling Technical Activities	• AMI & SCADA/EMS sub-hourly settlement data • Demand-response aggregation platforms • Storage and VPP automated dispatch pilots • Real-time market dispatch interfaces in control rooms

Table 32. Activity P-8. Promote Public-Private & International Partnerships for Digital Innovation

Field	Content
Title	Promote Public-Private and International Partnerships for Digital Innovation
Activity Type	**Policy**
Short description	Establish a formal framework for public-private partnerships (PPPs) and international consortia to co-invest in, co-design and co-implement AI-driven and digital-grid pilot projects, leveraging MOUs, joint-venture vehicles and innovation challenges to streamline deal-making, risk-sharing and knowledge exchange.
Objectives	• Mobilize private, multilateral and bilateral capital for digital-grid innovations • De-risk early-stage pilots via shared guarantees and blended-finance instruments • Accelerate knowledge transfer through joint R&D, secondments and regional accelerator programmes • Strengthen linkages between Vietnamese innovators, global tech firms and development partners

Legal/Regulatory Basis in Vietnam	• Resolution No. 55-NQ/TW (2020) promotes innovation in market mechanisms to support renewable integration and new services, including flexibility services. • Electricity Law 61/2024/QH15 now authorizes private investment in sub-220 kV grid assets and PPP models (BOT, concession) • Resolution 68-NQ/TW (2025) promotes private-sector leadership in digital transformation and streamlines approval processes via e-licensing
Real-world examples	• India's Smart Meter Programme (EESL BOOT): 250 million meters deployed under a build-own-operate-transfer PPP, financing capex via commercial debt and cost-recovery fees, with pilots validating an 8–10 year payment horizon[282] • Nigeria MAP Scheme: Certified Meter Asset Providers finance, install and maintain meters under regulated tariffs and installment plans, delivering millions of digital meters in under 2 years[283] • New Energy Nexus Vietnam: A public-private accelerator since 2019, has supported 200+ clean-tech startups in energy-management and battery analytics[284]
Expected benefits	• Increase in private-sector capex for digital pilots • Reduction in time-to-market via coordinated deal-structures • Enhanced scalability of successful proofs-of-concept through co-investment commitments • Strengthened ecosystem of local innovators linked to global technology partners
Indicative duration per sub-activity	Depends on the approaches decided to be implemented.
Lead entity	Ministry of Industry & Trade (MOIT), in coordination with Ministry of Finance (MOF)
Key stakeholders	EVN & DSOs; private technology vendors; Electricity Regulatory Authority of Vietnam; development partners; universities & research institutes; consumer associations
Dependencies & Prerequisites	• Legal mandate for PPPs under revised Electricity Law • Standardized PPP guidelines and taxonomies for digital-infrastructure projects • Baseline digital-infrastructure (AMI, SCADA) in place • Clear IP, data-sharing and revenue-sharing protocols
Estimated cost & funding sources	Depends on the approaches decided to be implemented.

[282] https://www.smart-energy.com/industry-sectors/smart-meters/indias-smart-meter-rollout-250-million-meters-by-2025/

[283] https://nerc.gov.ng/wp-content/uploads/2020/03/MAP%20FAQ%20Final.pdf

[284] https://www.newenergynexus.vn/

Top 3 risks & mitigations	1. **Misaligned incentives** → co-draft clear performance KPIs in MoUs 2. **Regulatory uncertainty** → embed fast-track e-licensing clauses under Resolution 68 3. **Coordination complexity** → appoint a joint steering committee with defined TOR
Capacity-building needs	• Training on PPP contract structuring and blended-finance models • Workshops on cross-border legal & tax considerations for international consortia • Secondments to regional accelerators (e.g. Singapore EMA, ASEAN Smart Cities Network)
Enabling Technical Activities	• AI-Enhanced Load & Renewable Energy Forecasting • Advanced Metering Infrastructure & Data Analytics • Demand Response Programs via Digital Platforms • Virtual Power Plants & DER Aggregation

ANNEX

Plan details on power generation capacity & the volume of transmission grid

Table A1. Power Generation Capacity Structure in Vietnam by 2030 & 2050

	Source Type / Transmission Grid Item	Phase 2030	Phase 2050
1	Total generation capacity (MW)	183,291 - 236,363	774,503 - 838,681
2	Onshore and nearshore wind power (MW)	26,066 - 38,029	84,696 - 91,400
3	Offshore wind power (MW)	6,000 - 17,032	113,503 - 139,097
4	Solar power (MW)	46,459 - 73,416	293,088 - 295,646
5	Biomass power (MW)	1,523 - 2,699	4,829 - 6,960
6	Power from waste (MW)	1,441 - 2,137	1,784 - 2,137
7	Geothermal and other new energy sources (MW)	~45	~464
8	Hydropower (MW)	33,294 - 34,667	40,624
9	Nuclear power (MW)	4,000 - 6,400	10,500 - 14,000
10	Energy storage capacity (MW)	10,000 - 16,300	95,983 - 96,120
11	Coal-fired power (MW)	31,055	0 (no coal-fired power)
12	Biomass/ammonia-fired thermal power (MW)	-	25,798
13	Domestic gas-fired thermal power (MW)	10,861 - 14,930	7,900
14	Gas-fired thermal power running on hydrogen (MW)	-	7,030
15	LNG gas-fired power with CCS (MW)	-	1,887 - 2,269
16	LNG gas-fired power co-fired with hydrogen (MW)	-	18,200 - 26,123
17	LNG gas-fired power running fully on hydrogen (MW)	-	8,576 - 11,325
18	Flexible power sources (MW)	2,000 - 3,000	21,333 - 38,641
19	Pumped storage hydropower (MW)	2,400 - 6,000	20,691 - 21,327
20	Electricity imports (MW)	9,360 - 12,100	14,688

Table A2. Transmission Grid Construction Volume by Phase

Period	Category	New Construction	Upgrading / Renovation
2025–2030	500 kV Substation (MVA)	102,900	23,250
	220 kV Substation (MVA)	105,565	17,509
2031–2035	HVDC Converter Station (MW)	26,000 – 36,000	–
	HVDC Transmission Line (km)	3,500 – 6,600	–
	500 kV Substation (MVA)	73,800	36,600
	220 kV Substation (MVA)	44,500	34,625
2036–2050	HVDC Converter Station (MW)	26,000 – 36,000	–
	HVDC Transmission Line (km)	3,600 – 6,700	–
	HVAC Converter Station >500 kV (MVA)	24,000	–
	HVAC Transmission Line >500 kV (km)	2,500	–

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