# ASEAN GUIDE FOR SUSTAINABLE DATA CENTRE DEVELOPMENT

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## EXECUTIVE SUMMARY

ASEAN Guide for Sustainable Data Centre Development is a strategic document designed for policymakers and regulators to navigate the rapid growth of digital infrastructure in Southeast Asia while ensuring economic competitiveness and climate resilience. The region's digital economy is expanding rapidly, projected to exceed USD 1 trillion by 2030, serving sectors like AI, e-commerce and fintech. This growth has made ASEAN a major hub, accounting for over half of the Asia-Pacific's data centre pipeline. However, this expansion creates mounting pressure: per-rack energy use is escalating, expected to jump from about 8 kW in 2021 to as high as 50 kW by 2027, intensifying the strain on electricity grids and cooling systems. With strong efficiency measures and access to renewable energy, ASEAN Member States (AMS) will be well-positioned to stay on track to achieve their national climate targets by adopting this Guide.

This tension is captured in the Digital Infrastructure Trilemma, which policymakers must balance to prevent locking in unbalanced growth patterns that could create operational risks and resource conflicts. The Trilemma centres on three interconnected dimensions below:

- **Digital Expansion** (scaling capacity for AI and cloud services)
- **Environmental Sustainability** (reducing carbon, water and waste footprints)
- **Resilience and Resource Security** (safeguarding essential resources like electricity grids and urban water supply chains)

To implement and manage sustainable development, the Guide proposes a strategic framework built upon Four Elements of Sustainable Data Centre Development. The four elements are:

1. **Element 1: Energy & Renewable Integration**, which promotes measuring efficiency using Power Usage Effectiveness (PUE) and establishing predictable pathways for clean power procurement (e.g., corporate Power Purchase Agreements or green tariffs)

2. **Element 2: GHG Emissions & Operational Efficiency**, which requires transparent reporting of emissions (Scope 1, 2 and eventually Scope 3) and measuring performance using metrics like Carbon Usage Effectiveness (CUE) and Whole-Life Carbon (WLC)

3. **Element 3: Water Management & Cooling Innovation**, which mandates measuring Water Usage Effectiveness (WUE) and aligning siting decisions and technology choices with local water-stress classifications to minimise reliance on potable water.

4. **Element 4: Waste & Circular Economy**, which integrates principles like reuse and recycling for construction materials and equipment, promoting Extended Producer Responsibility (EPR) schemes and measuring Circularity Performance (CP)

Successful implementation relies heavily on Cross-Cutting Policy Integration & Planning to overcome the common obstacle of fragmented governance across energy, water, ICT and land-use ministries. Key implementation pathways include establishing national cross-sector taskforces to harmonise standards, building regional transparency by creating an ASEAN-level registry for key performance indicators (like PUE, WUE and renewable share). This can enable benchmarking and aligning tax incentives, grants and green finance eligibility with verified sustainable outcomes under frameworks like the ASEAN Taxonomy for Sustainable Finance. This coordinated approach ensures that digital expansion supports both economic development and ASEAN sustainability aspiration.

# 1 INTRODUCTION

## 1.1 ASEAN's Digital Economy and Strategic Importance of Data Centres

The digital economy in Southeast Asia is growing at an exceptional speed (Figure 1). By 2030, it is projected to exceed USD 1 trillion, as data centres power AI, fintech, e-commerce, smart-city platforms and public-sector digitalisation. This growth is accelerating regional demand for digital infrastructure, with per-rack energy use having risen from around 8 kW in 2021 to as high as 50 kW expected by 2027, intensifying the strain on grids and cooling systems. ASEAN now accounts for over half of Asia-Pacific's total data centre pipeline, combining cost competitiveness with mounting environmental pressures.

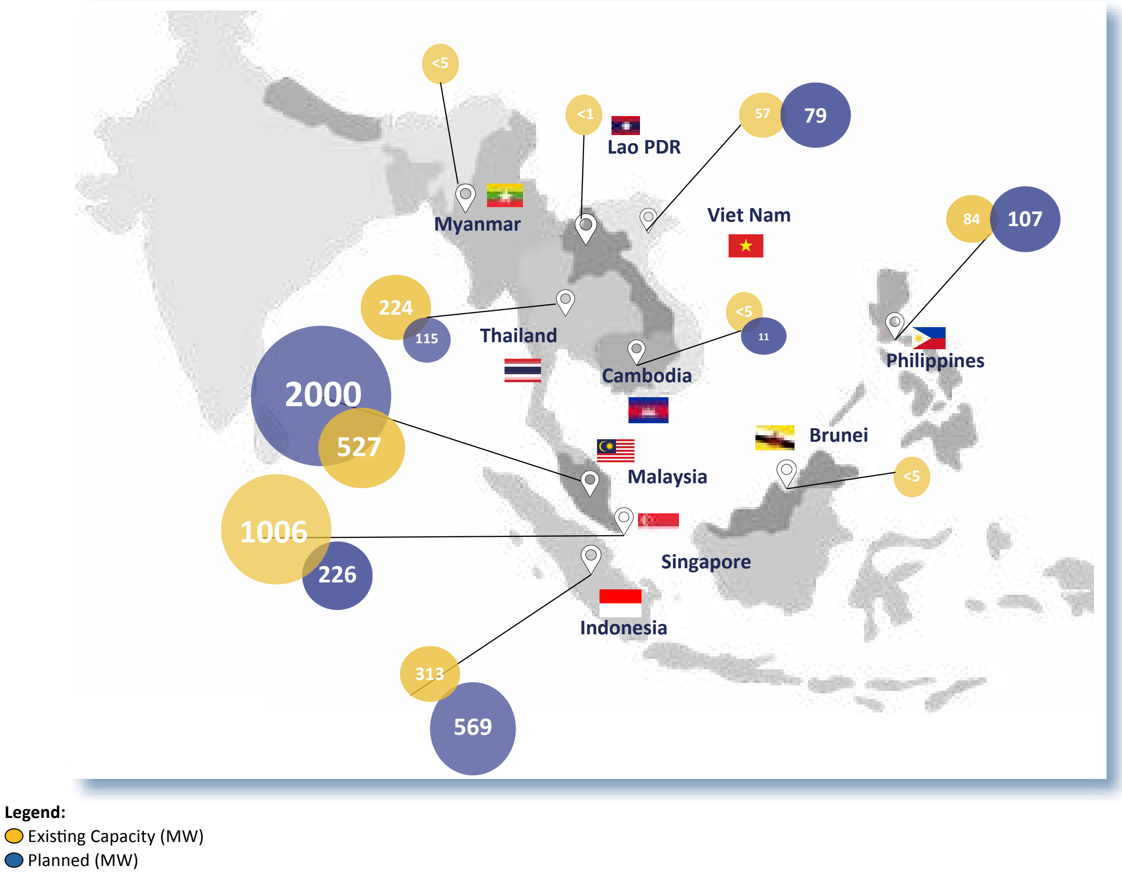



*Figure 1: ASEAN's Data Centre Development and Pipeline, 2025 Ember Report*

Data centres are among the most energy-intensive assets in the modern economy, with global operations consuming roughly 1.5 percent of total electricity consumption (approximately 415 TWh in 2024) and are projected to more than double to about 945 TWh by 2030, or nearly 3 percent of global demand. This underscores why data centre sustainability is not a niche topic but a central issue for national climate and infrastructure planning. Across ASEAN, electricity demand from data centre is expected to rise sharply. Without strong energy efficiency measures and renewable energy access, the emissions from this growth could make it difficult for ASEAN Member States (AMS) to meet their climate targets. Global ESG reporting and recent surveys show that while energy usage is rising, emissions intensity is gradually decreasing due to greater adoption of renewables.

Water is another emerging challenge. Southeast Asia's tropical climate, coupled with rapid urbanisation, increases cooling demands for data centre, many of which now operate 24/7. Closed-loop water reuse systems remain limited, and many facilities still depend on large volumes of potable water for cooling. The Asian Development Bank (ADB) Southeast Asia Development Solutions (SEADS) project notes that a mid-size data centre can use over one million liters of water per day and highlights the urgent need for better water efficiency planning.

At the same time, waste, circularity and emissions disclosure are moving to the forefront of sustainability governance. Stakeholders are increasingly scrutinising Scope 2 (purchased electricity) and Scope 3 (supply chain) emissions. For example, a hyperscaler reported in 2025 that Scope 3 emissions now represent over 70% of its total footprint and have grown 22% year-on-year, largely due to upstream supply chains. Globally, ESG reports from data centre operators indicate that water usage and waste management reporting (e-waste, hardware lifecycle) are among the weakest areas of environmental disclosure.

By embedding sustainable metrics such as energy efficiency, water use effectiveness, waste circularity and robust emissions disclosure into data centre planning, ASEAN can ensure that its digital expansion is both economically competitive and climate resilient. These issues are foundational to the policy pathways laid out later in this report and frame the subsequent sections on gaps, best practices and recommendations.

## 1.2 Purpose and Role of the Guide

This ASEAN Guide for Sustainable Data Centre Development is designed for policymakers, regulators and stakeholders seeking to make data centre expansion sustainable.

Rather than prescribing technical designs, the Guide:

**01** Presents a policy framework aligned with ASEAN's institutional roadmaps (ASEAN Digital Masterplan 2025, ASEAN Green Agenda, ASEAN Plan of Action for Energy Cooperation (APAEC) and the ASEAN Taxonomy v4 2025/26).

**02** Offers a three-step maturity progression level so each AMS can adopt measures suited to its readiness and infrastructure context.

**03** Illustrates real-world best practices from regional and global examples to show what works, when and how.

This balance between aspiration and realism was strongly echoed during the stakeholder consultations. Both AMS and industry players all emphasised flexibility, outcome-based policies and supportive market mechanisms over uniform mandates.

A defining feature of this process has been the direct engagement of AMS. Feedback gathered through a structured questionnaire allowed AMS to highlight existing policies, identify gaps and share national perspectives on key sustainability topics.

Incorporating this feedback ensures that the recommendations in this Guide are grounded in technical analysis, practicality and reflect local realities and national priorities. By weaving together diagnostic research, AMS perspectives and industry insights, this Guide aims to provide regulators and policymakers with a practical, regionally tailored framework.

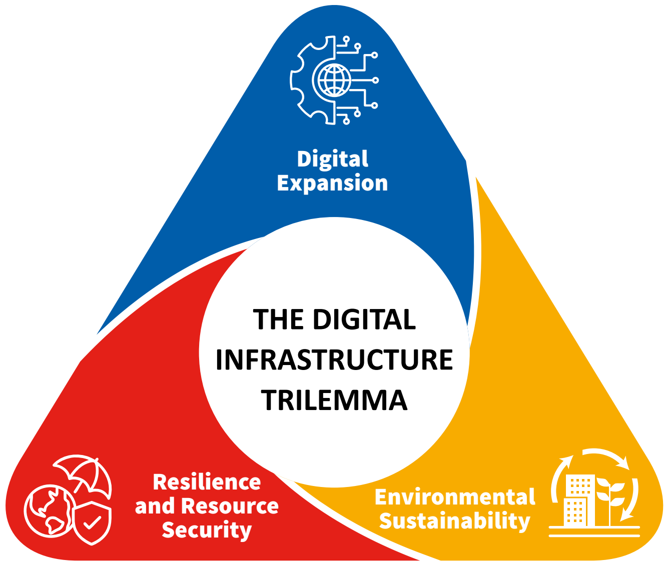



*Figure 2: The Digital Infrastructure Trilemma*

**The Digital Infrastructure Trilemma**

These dimensions are not competing goals. The Digital Infrastructure Trilemma highlights how gaps in one area often have cascading effects on others and underscores the need for integrated, future-focused governance.

This framing aligns with ASEAN's ambition to become a digital powerhouse while honouring Net-Zero targets and resource constraints. This will be explored further in Section 3.

The **Digital Infrastructure Trilemma** refers to the complex policy and planning challenge faced by governments and regulators in balancing three interdependent goals for digital infrastructure, particularly data centres:

**01 Digital Expansion:**
Scaling data centre capacity to support economic growth, cloud adoption, AI and digital services

**02 Environmental Sustainability:**
Reducing the carbon, water and waste footprint of data infrastructure to align with climate goals and ESG standards

**03 Resilience and Resource Security:**
Safeguarding national electricity grids, urban water systems and critical material supply chains from long-term stress or overuse

These goals are interlinked: aggressive digital growth can compromise sustainability; strict environmental rules may be seen to limit short-term investment; and poor resource planning can create economic and geopolitical vulnerabilities.

Navigating this trilemma requires forward-looking governance, harmonised standards and smart public-private collaboration to ensure that the digital backbone is both resilient and responsible.

## 1.3 Intended Audience

This Guide is designed for:

- Policymakers and regulators in AMS seeking actionable frameworks
- Regional and national planners responsible for aligning digital infrastructure with energy and environmental systems
- Investors and developers, especially hyperscalers and cloud infrastructure providers, who require policy clarity and performance incentives
- ASEAN Secretariat bodies, including those overseeing ASEAN Digital Masterplan, Green Agenda and APAEC, who can facilitate regional coherence and alignment.

## 1.4 AMS Engagement Development Approach

This Guide evolved from the Interim Guide and has been refined via consultative session dialogues, questionnaires and feedback sessions with:

- All 10 AMS
- Data Centre industry leaders and ESG Subject Matter Experts (SME)
- Malaysian government stakeholders
- Regional stakeholders such as the ASEAN Centre for Energy (ACE), ASEAN Secretariat and Dialogue Partners

Feedback centred on four recurring themes:

- The need for flexible policies that adapt to grid and water realities.
- Avoiding one-size-fits-all thresholds, instead allowing progressive standards.
- Emphasising coordination across ministries (energy, water, ICT, planning).
- Incentivising sustainability through licensing, fiscal tools and clear metrics, not just mandates.

# 2 ASEAN DIGITAL INFRASTRUCTURE CONTEXT

This section assesses the regional context for sustainable data centre development, highlighting the economic drivers, cost structures, competitive dynamics and emerging opportunities. Together, these factors frame both the promise and the risks of ASEAN's rapid build-out, setting the stage for Section 3's deeper analysis of sustainability and resilience challenges.

## 2.1 Economic Drivers

Three key forces are propelling ASEAN's position as one of the most dynamic digital infrastructure markets worldwide:

**Artificial Intelligence (AI) and Cloud Computing**

Demand for AI is reshaping the energy profile of data centres. AI workloads and sovereign-cloud strategies are reshaping the region's data centre profile, pushing rack power densities from 8–12 kW to as high as 50 kW by 2027.

**Consumer Digitalisation**

The region's booming fintech, e-commerce and social media sectors require reliable, low-latency digital infrastructure. ASEAN's digital economy is projected to grow by more than USD 300 billion in GMV between 2023 and 2030, driven by mobile-first adoption and a young, digitally active population. This is accelerating demand for edge data centres in secondary cities, complementing hyperscale hubs in Singapore, Johor, Jakarta, Ho Chi Minh City and Metro Manila.

**Government Policy**

National digital economy blueprints are prioritising data centre expansion as part of industrial upgrading. Examples include Indonesia's Making Indonesia 4.0 roadmap (Gov of Indonesia), Viet Nam's National Digital Transformation Program (Gov of Viet Nam) and Thailand 4.0 (Thailand BOI). Malaysia has integrated data centres into its New Industrial Master Plan 2030 (MITI), while Singapore is positioning itself as a green digital hub through its Green Data Centre Roadmap (IMDA).

Together, these economic drivers underpin ASEAN's status as both a cost-competitive and strategically vital location for digital infrastructure. However, they also intensify pressures on grids, land and water, with the sustainability and resilience challenges explored in Section 3.

## 2.2 Cost Structure and Value Chains

Data centres are among the most capital-intensive forms of digital infrastructure, requiring upfront investments of USD 7–10 million per MW of IT load in Southeast Asia, depending on land, power and cooling costs. While ASEAN remains cost-competitive compared to North Asia or Europe, the apparent advantage masks significant hidden system costs borne by governments and utilities.

**Capital Expenditure (CapEx) and Operational Expenditure (OpEx) dynamics:**

**CapEx:**

Major components include land acquisition, grid interconnection, cooling infrastructure and backup power systems. In Johor, Malaysia land costs are significantly lower than in Singapore, but grid upgrade costs fall on the public utility, shifting part of the burden to the state (ISEAS).

**OpEx:**

Electricity typically accounts for 60–70% of ongoing operating costs, followed by maintenance and staffing (IEA). Rising AI workloads may increase this share further, particularly in AMS reliant on fossil-heavy grids.

### Hidden costs and externalities:

**Grid upgrades:**
In many jurisdictions, the cost of new substations, transmission upgrades and generation capacity needed to serve large data centre clusters is borne by public utilities and recovered through general electricity tariffs. This means the expense is shared across all consumers rather than fully paid by the operator, effectively socialising grid-upgrade costs and creating a subsidy effect for data centre developments. Policymakers could mitigate these costs through progressive connection-charge models or capacity-allocation frameworks that assign upgrade expenses proportionally to large new loads.

**Water stress:**
Cooling systems depend on reliable water supply, but most AMS lack cost-reflective pricing for industrial users, effectively under-pricing resource impacts.

**Environmental impacts:**
Without circularity frameworks, e-waste disposal costs are externalised to informal recycling sectors, creating pollution and resource loss.

### Value chains and industrial linkages:

Data centres are not only consumers of resources but also anchors of wider industrial value chains:

**Upstream:**
Construction, power equipment and ICT hardware supply.

**Downstream:**
Cloud services, AI development, fintech, e-commerce and digital government applications.

**Industrial symbiosis:**
Where properly planned, data centres may supply heat, wastewater and hardware to adjacent industries, creating circular economy opportunities.

While ASEAN's cost competitiveness is a driver of investment, the true economic footprint is shaped by who bears the hidden costs of grid, water and environmental pressures. Ensuring that these are addressed through standards, incentives and integrated planning (Section 4) will be critical to securing both investment and long-term sustainability.

## 2.3 Regional Competition and Risks

ASEAN is increasingly seen as a competitive hub for data centre investment, benefiting from lower land and power costs than North Asia or Europe and from its proximity to fast-growing digital economies. ASEAN has become a priority destination for hyperscale and colocation investments, benefiting from competitive costs and proximity to high-growth digital markets across Asia.

### Risks from uneven maturity

Data centres are not only consumers of resources but also anchors of wider industrial value chains:

**Regulatory arbitrage:**
Operators may site facilities in jurisdictions with weaker environmental safeguards, undermining regional sustainability (a risk already noted by industry feedback).

**Infrastructure bottlenecks:**
Markets with rapid pipelines but underprepared grids (Malaysia, Viet Nam, Philippines) face risks of curtailment, stranded assets or delayed operations.

**Investment perception risk:**
If AMS are perceived as lagging on renewable integration, emissions disclosure or water management, they risk losing investment to markets that align more closely with global ESG expectations.

ASEAN's diversity in maturity can also be a strength. Countries with policy frameworks and roadmaps already in place (e.g. Singapore) can set regional benchmarks, while fast-growth markets can demonstrate scale and innovation if properly aligned with sustainability. Coordinated regional action through harmonised standards, renewable trading and shared monitoring would enable ASEAN to position itself not only as a cost hub, but also as a sustainable digital innovation hub that combines competitiveness with environmental resilience.

## 2.4 Opportunities for ASEAN

ASEAN's position as one of the fastest-growing digital infrastructure markets globally presents a unique window of opportunity. Unlike Europe or North America, where data centres were often built before sustainability frameworks were in place, many AMS are still in the formative stages of large-scale deployment. This creates the chance to embed sustainability into the sector's growth trajectory from the outset.

**Leapfrogging through integrated planning**

By drawing on global best practices and adapting them to local contexts, ASEAN can avoid the costly retrofits faced elsewhere. Industrial symbiosis models, such as locating data centres in industrial parks with shared utilities and heat reuse, could be adopted early, reducing long-term resource pressures.

**Unlocking renewable investment**

Demand from hyperscalers for renewable power is already strong, with global corporate Power Purchase Agreements (PPA) exceeding 46 GW in 2023. If AMS provide clear procurement pathways through PPAs, green tariffs, or cross-border trading they can attract billions in renewable energy investment, research and development of alternative clean energy alongside data centre growth, accelerating progress toward APAEC and national climate goals.

**Building circular value chains**

Data centres can anchor new industries in e-waste recycling, water reuse and modular construction, creating green jobs and reducing import dependency for critical minerals. Singapore's EPR scheme for ICT equipment and pilot projects in closed-loop water cooling provide replicable models for other AMS.

**Strengthening ASEAN's global competitiveness**

By setting regional baselines for energy, water and emissions disclosure, ASEAN can position itself as a trusted digital hub aligned with global ESG expectations. This would not only reduce reputational risks but also improve access to sustainable finance, lowering the cost of capital for both industry players and governments.

**Strategic positioning**

How ASEAN's projected USD 1 trillion digital economy by 2030 is built will determine whether growth reinforces or undermines the region's resilience. With coordinated action, ASEAN can leverage its latecomer advantage to deliver digital expansion that is both sustainable and resource-secure, balancing the three dimensions of the Digital Infrastructure Trilemma introduced in this guide. These opportunities illustrate that ASEAN's challenge is systemic and not technological, ensuring that digital expansion, environmental sustainability and resource security advance together, a balance explored in the next section.

# 3 NAVIGATING THE DIGITAL INFRASTRUCTURE TRILEMMA

ASEAN data centre sector is expanding at a speed and scale unmatched in most other regions. This growth brings enormous opportunity for economic development, digital innovation and investment attraction. Yet it also exposes a fundamental challenge - how to expand digital infrastructure without overshooting environmental limits or straining essential resources.

This tension is captured by the **Digital Infrastructure Trilemma** which frames the three interconnected dimensions that ASEAN must balance:

**01 Digital Expansion:**
Delivering the computational capacity needed for AI, cloud, e-commerce and sovereign digital strategies

**02 Environmental Sustainability:**
Reducing the energy, water, waste and carbon impacts of a resource-intensive industry

**03 Resilience and Resource Security:**
Ensuring that electricity, water and land systems can support growth without undermining wider societal needs

These dimensions cannot be pursued in isolation. Decisions that privilege expansion without efficiency risk grid instability and water scarcity. Overemphasis on sustainability without enabling clean energy access could limit competitiveness. Weak governance of resource security may create stranded assets or public opposition. The trilemma lens highlights how gaps in one dimension create cascading risks in the others.

## 3.1 Digital Expansion

ASEAN is now one of the fastest-growing data centre markets globally. Indonesia, Malaysia, Philippines, Singapore, Thailand and Viet Nam are all experiencing rapid build-outs, while Cambodia, Lao PDR and Myanmar are seeing early-stage investments and planning activities that reflect growing digital ambitions. Collectively, the region's pipeline is projected to surpass 10 GW by the end of the decade, reflecting its strategic importance for hyperscalers.

### Country Highlights

**Brunei Darussalam:** The country is actively advancing digital-infrastructure programmes under its Digital Economy Masterplan 2025, with data-processing and commercial-cloud infrastructure singled out for priority investment.

**Cambodia:** The 2024 "Data Centres – The Cambodia Report" shows the sector is entering a phase of expansion with new facilities expected.

**Indonesia (Greater Jakarta):** With over 1 GW in the pipeline, Jakarta has become the largest single-city hub outside Singapore. Domestic cloud growth and sovereign digitalisation strategies are fueling sustained investment.

**Lao PDR:** Although direct data centre figures are limited, Lao PDR is noted as a country exploring clean-power and digital infrastructure potential, positioning it as an emerging hub.

**Malaysia (Johor and Klang Valley):** Johor alone has more than 5 GW of data centre projects in various stages of development, with live capacity already exceeding 500 MW. Its proximity to Singapore and lower land and energy costs make it the single most dynamic market in Southeast Asia.

**Myanmar:** The country's data centre sector remains at an early stage of development and is gradually expanding through private-sector and cross-border investments. Small-scale facilities are emerging in Yangon and Mandalay. Local telecom operators and regional firms are driving gradual expansion, supported by improving power reliability and digital-economy initiatives.

**Philippines (Metro Manila):** Attracted by strong demand for cloud and digital services, Metro Manila has a data centre pipeline of nearly 500 MW, with hyperscalers and colocation providers entering the market.

**Singapore:** It has ASEAN's largest capacity of data centres, with more than 1.4 GW of operational capacity, but given its limited natural resources such as land and renewable energy, there is a need to calibrate its expansion, with growth spilling to neighbouring markets such as Johor and Batam (Indonesia).

**Thailand (Bangkok and Eastern Economic Corridor):** Thailand is promoting data centres as part of its Thailand 4.0 strategy, with capacity expected to reach 400 MW by 2027. Investment is supported by a combination of colocation demand and government incentives.

**Viet Nam (Ho Chi Minh City and Hanoi):** Viet Nam is emerging as a preferred site for regional hyperscale expansion, supported by rising e-commerce penetration and government-backed digital economy initiatives. Its market is projected to grow at over 14% CAGR through 2030.

Yet this expansion is often outpacing infrastructure readiness and regulatory safeguards:

- **Grid constraints:** Malaysia's pipeline capacity could require nearly half of Johor's total electricity generation; some other AMS are experiencing curtailment risks and reliability issues.
- **Land-use competition:** Rapid clustering in peri-urban zones can compete with agriculture and housing where zoning and industrial planning do not explicitly account for data centres. Several AMS indicated interest in integrating data centres into industrial/utility zones to reduce conflict and enable symbiosis (e.g., heat reuse, reclaimed water).
- **Approvals and coordination:** AMS feedback indicates approvals are often administered by multiple agencies with limited cross-coordination across energy, water and land-use. Some of the AMS expressed support for single-window/multi-agency models to improve predictability and align siting with infrastructure readiness.

If unaddressed, ASEAN risks locking in unbalanced growth patterns, with clusters that attract investment in the short term but face long-term risks to operational viability, competitiveness and resource security. These pressures underscore the importance of addressing the Digital Infrastructure Trilemma head-on.

AMS noted that land-use planning for data centres is still at an early stage. Approval is often managed separately from broader industrial or spatial planning processes, which can create uncertainty and overlapping land demands. Several AMS expressed interest in integrating data centres more explicitly into industrial zoning and permitting frameworks and in linking approvals to sustainability criteria such as grid readiness, water availability, or opportunities for heat reuse. This reflects a wider recognition that better coordination between ICT, energy, environment and urban planning agencies can reduce conflicts and improve predictability for investors.

## 3.2 Environmental Sustainability

Rapid digital infrastructure growth in ASEAN is occurring while sustainability frameworks are still evolving in many markets. While some AMS have introduced efficiency targets or disclosure requirements, most lack binding rules on energy performance, water use, e-waste, or carbon reporting. The result is a patchwork of policies that do not yet match the scale or pace of investment.

### Energy efficiency and emissions

Data centres in ASEAN consume an estimated 2–3% of national electricity demand in Singapore, Malaysia and Indonesia, with shares rising quickly elsewhere. This highlights the need for policies that account for the demand on the grid.

AMS feedback confirmed that approaches vary: Singapore has set out a roadmap and guiding standards for the industry, Malaysia and Thailand provide voluntary guidance, while others are still considering suitable baselines. Many AMS noted the value of ASEAN-wide benchmarks to reduce fragmentation.

AMS highlighted that access to Power Purchase Agreements (PPAs), green tariffs and renewable certificates is uneven, with several schemes in pilot or capped phases. This constrains operators' ability to meet efficiency and emissions goals at scale and underscores the importance of expanding credible procurement pathways.

AMS noted inconsistent Scope 2 reporting and that Scope 3 accounting is at an early stage. Many expressed interests in ASEAN-aligned guidance to support investor expectations and access to sustainable finance. The current gap limits AMS' ability to align with international ESG reporting standards or green finance requirements.

### Water management

Cooling remains a major sustainability risk. A single 1 MW data centre can consume more than 25 million litres of water annually if reliant on evaporative cooling. AMS responses showed that water efficiency tracking is limited beyond Singapore and Malaysia, but interest in developing disclosure requirements and context-specific Water Usage Effectiveness (WUE) benchmarks is growing:

- Singapore has introduced WUE targets and requires large facilities to submit Water Efficiency Management Plans to Public Utilities Board (PUB).
- AMS feedback: Beyond Singapore and Malaysia, systematic WUE tracking is limited but under consideration; several AMS are exploring WUE disclosure and context-specific benchmarks appropriate to climate and infrastructure.
- Independent analyses highlight water-stress hotspots in parts of the region; integrating WUE reporting, reclaimed or non-potable water use and siting guidance for water-stressed basins can reduce conflict risk and improve resilience.

### Waste and circularity

E-waste is the fastest-growing waste stream globally, projected to reach 82 million tonnes by 2030. Data centres contribute significantly through frequent hardware refresh cycles.

- Singapore operates an Extended Producer Responsibility (EPR) scheme, requiring producers and operators to ensure formal collection and recycling.
- Thailand is drafting its first Waste Electrical and Electronic Equipment (WEEE)-specific legislation.

Several respondents indicated interest in regional guidance and reporting templates for data centre specific ICT streams (servers, networking gear, batteries, cooling equipment)

### Systems-level implications

These sustainability gaps reflect a deeper policy–practice misalignment. Investors and hyperscalers increasingly demand clean energy access, low-carbon construction and circular supply chains, but AMS frameworks are not yet designed to deliver. The absence of enforceable standards and transparent reporting creates reputational risks, deters green finance and may ultimately undermine ASEAN's competitiveness as a sustainable digital hub. AMS feedback consistently points to the value of harmonised baselines (PUE, WUE, emissions disclosure) as a foundation for investment confidence. These needs are addressed concretely in Section 4's Four Elements of Sustainable Data Centre Development.

## 3.3 Resilience and Resource Security

Alongside sustainability gaps, ASEAN faces major challenges in ensuring the resilience and security of resources needed to support data centre growth. Without stronger safeguards, the sector risks amplifying existing vulnerabilities in electricity grids, water systems and land-use planning.

### Grid reliability and capacity

Data centres are high-load, 24/7 facilities that require stable electricity supply. In several AMS, rapid development pipelines are colliding with constrained grid capacity. AMS feedback noted that pipeline growth in some markets may place pressure on existing grid capacity, underscoring the importance of aligning project approvals with infrastructure readiness. For example, in some regions electricity supply agreements linked to data centre projects could require nearly half of a region's total generation, raising challenges for supply. In other instances, grid instability and power outages create reliability risks, with developers flagging delays in interconnection approvals. Furthermore, rising curtailments of renewable power highlight the stress of adding large new loads to a constrained grid. AMS noted that pipeline growth in some markets may exceed near-term grid headroom, reinforcing the need to align approvals with infrastructure readiness and demand-management plans developed with utilities.

### Water security

Feedback from AMS showed that systematic tracking of water use is limited: only Singapore and Malaysia currently require large facilities to report water usage or submit water efficiency management plans. Other AMS noted reliance on potable water for cooling and some interest in disclosure and alternative cooling technologies; frameworks for water efficiency are under development.

External analysis confirms that this is an area of growing risk. A Planet Tracker report finds that a majority of data centres in Asia are located in areas of "high water stress," which could affect long-term viability of operations. Another recent article, "The Water Crisis Behind Southeast Asia's Data Centre Boom", highlights that rapid digital infrastructure expansion is increasingly colliding with climate constraints and resource limits, including water scarcity in certain basins.

Together, these insights suggest ASEAN has a strategic opportunity: since AMS are already considering water efficiency and disclosure, aligning policy now with external evidence will help safeguard both environmental resilience and investor confidence. Embedding metrics such as WUE, siting guidance for water-stress zones and requirements for reclaimed or non-potable water use will reduce risk and improve sustainability.

### Land-use conflicts

The siting of large-scale facilities without integrated planning is creating pressure on land availability:

- Evolving zoning: ASEAN studies show rapid expansion of built-up areas in several industrial/ peri-urban districts across ASEAN, increasing competition for land.
    - AMS feedback: Highlighted interest in explicitly integrating data centres into zoning/ industrial-park planning and linking approvals to site-level sustainability criteria (e.g. heat-reuse feasibility, water availability, grid access). This supports balanced spatial development and reduces siting contention.

These resilience challenges highlight that while digital infrastructure is booming, the essential physical systems of power, water and land are constrained. If left unresolved, this imbalance may lead to stranded assets, strained local resources and community pushback.

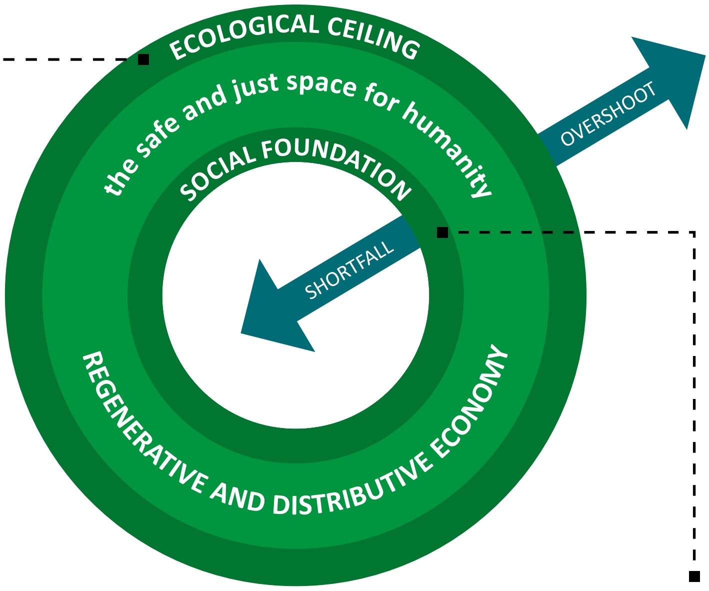
These resilience considerations point to a common conclusion from AMS engagement that integrated planning (cross-agency approvals, infrastructure-ready sites and industrial clustering) reduces the risk of stranded assets, local resource strain and community concern, while improving predictability for investors.

## 3.4 A Doughnut Economics Perspective

The Digital Infrastructure Trilemma highlights the immediate challenge of balancing digital expansion, environmental sustainability and resource resilience. Yet these three dimensions sit within a broader set of societal and ecological boundaries. To capture this wider context, the Doughnut Economics framework provides a useful perspective.

At its core, the Doughnut defines a safe and just operating space between the ecological ceiling (planetary boundaries we must not overshoot) and the social or governance foundation (minimum conditions societies must meet to remain resilient and inclusive). For data centres, this means expansion can only be sustainable if it both respects environmental thresholds carbon emissions, water stress, land conversion and e-waste and strengthens governance foundations such as integrated planning, disclosure and regulatory capacity.

*Figure 3: The Doughnut Model*




## Ecological Ceiling

Based on the concept of planetary boundaries, this sets the limits humanity must not exceed to preserve Earth's life-supporting systems. These include critical thresholds for climate change, biodiversity loss, freshwater use, land conversion, ocean acidification and other environmental pressures. Crossing these boundaries risks irreversible environmental degradation and systemic harm.

## Social/Governance Foundation

Representing the essential elements every person need for a dignified life. This includes access to clean water, energy, healthcare, education, income, political voice, gender equality and social equity. Falling below this foundation leads to deprivation, exclusion and weakened societal resilience.

**How the Doughnut Relates to the ASEAN Context:**

- **Carbon emissions:** Without clean energy access, ASEAN's data centre electricity demand risks locking in coal and gas-based emissions. The AI-driven surge in demand is forecast to add up to 80 TWh annually by 2030 across the region if left unmanaged.
- **Water use:** Heavy reliance on evaporative cooling means facilities could add to already stressed basins. As noted earlier, 63% of Asian data centres are located in water-stressed areas.
- **E-waste:** Hardware/digital devices refresh cycles generate growing volumes of ICT waste; without effective Extended Producer Responsibility, these materials contribute to pollution and lost resource value.

- **Fragmented planning:** Multiple ministries oversee ICT, power, water and land use, but process currently uncoordinated in most AMS.
- **Missing baselines:** There are minimal binding regional standards for PUE, WUE or emissions disclosure..
- **Limited enforcement capacity:** Even where guidelines exist, enforcement is often inconsistent due to resource or institutional constraints.

### Implications for ASEAN

Linking this to the Digital Infrastructure Trilemma, Doughnut Economics shows that:

**01** **Digital Expansion** must stay within the ecological ceiling otherwise growth risks overshooting emissions and water boundaries.

**02** **Environmental Sustainability** provides the corrective force, ensuring energy, water and waste systems remain inside safe operating limits.

**03** **Resilience and Resource Security** overlaps with the governance foundation without coordinated institutions, monitoring and disclosure, ASEAN risks falling below the "floor" of societal safeguards.

This perspective reinforces that incremental fixes are not enough. Addressing only one part of the Trilemma (e.g., improving efficiency) without tackling others (e.g., renewable access, water stewardship, circularity) risks shifting pressure elsewhere. Instead, AMS need integrated approaches to align data centre growth with clean energy strategies, embedding water and waste safeguards into planning and strengthening regulatory capacity so that expansion supports both economic and societal goals.

By situating the Digital Infrastructure Trilemma within the Doughnut Economics framework, ASEAN policymakers can see clearly that sustainable data centre growth is not only a matter of balancing three industry dimensions, but of ensuring digital infrastructure contributes to a safe, just and resilient development pathway for the region.

These insights form the bridge to the next stage of the Guide. Section 4 translates the Trilemma and Doughnut-Economics framing into four actionable elements: Energy & Renewable Integration, GHG Emissions & Operational Efficiency, Water Management & Cooling Innovation and Waste & Circular Economy, providing ASEAN with practical levers to align growth, sustainability and resilience.

# 4 POLICY PATHWAYS AND ASEAN ALIGNMENT

This Guide sets out Four Elements of Sustainable Data Centre Development in ASEAN. These elements respond directly to the challenges highlighted in the Digital Infrastructure Trilemma and reflect feedback from AMS, industry perspectives and global best practices.

*Figure 4: The Four Elements of Sustainable Data Centre Development*


These are the elements that most strongly influence data centre sustainability outcomes in ASEAN while aligning with current regional frameworks and market practice.

Stakeholder feedback across AMS and industry players repeatedly emphasised the following recommendations:

- Use outcome-based (not technology-specific) policy conditions;
- Create credible procurement channels for clean energy and water-smart cooling; and
- Adopt consistent disclosure so performance can be tracked and financed.

Equally important, these elements are closely linked to existing ASEAN frameworks, including the ASEAN Digital Masterplan 2025, the ASEAN Green Agenda and the ASEAN Plan of Action for Energy Cooperation (APAEC). Anchoring recommendations in these frameworks ensures coherence, avoids duplication and strengthens ASEAN's credibility in international climate and investment dialogues.

Figure 4 identifies four elements that collectively address the sustainability performance of data centres. Cross-Cutting Policy Integration & Planning is the enabling layer connecting these four elements, ensuring coherence across energy, emissions, water and circular-economy policies.

**How to Read This Section**

The Four Elements translate the Digital Infrastructure Trilemma into actionable policy pathways for AMS. Each element presents:

- An overview of its policy relevance and regional context;
- A concise set of internationally recognised measurement standards and indicators drawn from existing global frameworks (ISO/IEC 30134, EN 50600-4, GHG Protocol, EN 15978 etc.);
- Illustrative regional performance ranges that reflect emerging industry practice across ASEAN; and
- Policy guidance and a maturity progression table outlining how AMS can move from foundational disclosure to advanced, outcome-based regulation.

These metrics are not prescriptive mandates but voluntary reference points. They provide a common language that enables policymakers, regulators and data centre industry players to track progress consistently, compare performance and adapt targets to national conditions such as grid mix, climate and resource availability.

Together, these elements form a coherent framework that links measurement with implementation, ensuring that data centre growth across ASEAN remains efficient, low-carbon and resource-secure.

## 4.1 Element 1 – Energy & Renewable Integration

In the ASEAN region, electricity demand from data centre is projected to nearly double by 2030 compared to 2024. Analysis suggests that solar and wind could supply up to 30% of ASEAN data centre electricity demand by 2030 without requiring large battery storage. Reliable access to clean power and sufficient grid capacity are among the main constraints for sustainable data centre expansion across ASEAN.

Governments across ASEAN have highlighted the need to maintain grid stability as demand rises, while the industry consistently emphasises three priorities:

**01** Predictable routes to contract renewables (corporate PPAs, green tariffs, cross-border imports);

**02** Outcome-based approval criteria linked to carbon intensity rather than fixed design values; and

**03** Transparent reporting of efficiency metrics to attract sustainable finance.

Balancing these objectives requires clear, consistent metrics that allow regulators, utilities and operators to measure progress on a comparable basis.

The following section therefore sets out internationally recognised standards for monitoring energy performance and renewable integration in data centres. These are voluntary reference points intended to guide AMS in calibrating national targets to their grid mix, renewable availability and market maturity.

**Measurement & Definitions**

| Indicator / KPI | Definition & Standard Reference | Unit / Boundary / Notes |
|---|---|---|
| **Power Usage Effectiveness (PUE)** | ISO/IEC 30134-2 - ratio of total facility power to IT equipment power. Annualised PUE is the global KPI for facility energy efficiency. | • Ratio (time based i.e months or/and measured at ≥ 50 % IT utilisation). Applicable to new data centres (commencing construction on or after 1 January 2027) and existing data centres (before that date).<br>• Values shall be determined using time-based measurements covering a minimum of 15 months of operation at ≥50% IT utilisation.<br>• Climate bands follow the Köppen classification: A = tropical, C = temperate.<br>• All reporting should specify both climate band and IT-load utilisation when stating PUE. (ISO Catalogue 30134-2) |
| **Clean-Energy Coverage (%)** | Share of electricity sourced from renewable or carbon-free generation as defined by RE100. | % of total annual electricity consumed. Recognise on-site RE, off-site PPAs, utility green tariffs and regional imports consistent with international voluntary reporting frameworks such as RE100 Technical Criteria. |
| **Carbon Intensity of Operations** | kg $CO_2e$ per kWh IT load (Scope 2 basis). Optional derived indicator linking efficiency to grid mix. | kg $CO_2e$ / kWh IT (load-adjusted). Useful for licensing conditions and taxonomy eligibility. |

**Key definitions**

- *New data centres* = construction commencing on or after 1 January 2027.
- *Existing data centres* = construction before 1 January 2027.
- *Annualised PUE =* total energy for the entire year divided by IT-equipment energy, reported only once the site achieves ≥ 50 % IT utilisation and steady operations (≥ 15 months).
- *Climate bands* refer to Köppen A (tropical) and C (temperate) zones to reflect cooling-system variability.

**Illustrative Regional Performance Ranges**

*(for voluntary adoption or national calibration by AMS)*

| Facility Type / Climate Band | Indicative Target | Rationale / Context |
|---|---|---|
| **New data centres (≥ 2027)** | Regional average annualised PUE = 1.4 at ≥ 50 % IT utilisation (Köppen A/C climates). | Reflects the voluntary target agreed by industry colocation operators and aligned with emerging regional practice Asia-Pacific Data Centre Association (APDCA, 2025). This represents co-location facilities, typically the least efficient operator class. Therefore, appropriate as a conservative regional guideline. |
| **Existing data centres (≤ 2026)** | By 2035: Average annualised PUE ≤ 1.45 for tropical (A) and ≤ 1.35 for temperate (C) climates at ≥ 50 % IT utilisation. | Applies to all facilities constructed prior to 2027, with progressive retrofits to reach the stated PUE levels by 2035. This schedule allows for technology refresh cycles and infrastructure upgrades, acknowledges climatic variation and load profiles across ASEAN, while maintaining alignment with regional industry consensus. |
| **Clean-Energy Coverage (%)** | Data centres follow a progressive pathway toward increasing access to carbon-free electricity through to 2030. This includes renewable and other recognised carbon-free sources such as solar, wind, hydro, nuclear, and geothermal energy, as well as renewable energy procured directly by operators or customers through market-based mechanisms. Progress can be demonstrated through annual matching that aligns with the RE100 Technical Criteria, with the option to move toward hourly matching approaches promoted by the 24/7 Carbon-Free Coalition as power systems and market structures continue to develop. | Progress toward higher shares of carbon-free electricity will depend on broader developments within national and regional power systems. These include greater availability of renewable energy, improvements in cross-border electricity trade, and regulatory frameworks that recognise high-quality market-based instruments such as Renewable Energy Certificates (RECs) or equivalent local certificates. As these elements mature, data centres will have more options to procure carbon-free electricity in ways that are transparent, credible, and aligned with evolving international best practice.<br><br>To support meaningful progress, clean electricity procurement should prioritise contributions to new renewable generation wherever possible, rather than relying solely on existing projects. Transparent systems that prevent double-counting of certificates across jurisdictions are also important. As markets mature, the ability to track electricity use on an hourly basis will enable more advanced approaches aligned with 24/7 Carbon-Free Coalition, offering an increasingly accurate picture of carbon-free electricity consumption. |
| **Operational Carbon Intensity** | Encourage disclosure of kg $CO_2$e per kWh IT load and annual reduction trend in line with national decarbonisation pathways. | Enables comparison and taxonomy eligibility for green finance instruments. |

While PUE remains the global benchmark for data centre efficiency, it could be treated as a reporting and benchmarking indicator. The indicative PUE values are provided for reference and policy calibration, not for regulatory enforcement. AMS may adapt or phase targets according to national grid mix, renewable availability and policy maturity. All metrics should be reported with supporting context data (IT load, utilisation rate, climate band, and energy-source breakdown).

## Policy Guidance and Implementation Considerations

### Approvals and Monitoring Mechanism

- Link new data centre approvals to sustainability requirements such as verified clean-electricity procurement, operational carbon intensity (e.g., kg CO.e / kWh IT) and/or PUE targets.
- Require submission of annual PUE data together with renewable or carbon-free electricity procurement records at licence renewal or during environmental reporting.
- Encourage a progressive pathway toward 100 % renewable electricity in alignment with RE100 Technical Criteria, recognising procurements using energy attribute certificates (EACs), power purchase agreements (PPAs) or on-site generation that meet RE100's eligibility rules.
- Recognise renewable procurement via PPAs, green tariffs or I-RECS/RECS, provided they are additional and auditable in line with the key principles under international voluntary reporting frameworks such as RE100 and GHG Protocol 2015.

### Planning and Infrastructure

- Coordinate grid-capacity studies and renewable-corridor planning with data centre approvals to avoid overloading local systems.
- Encourage co-location with renewable projects or within industrial parks that support private wire connections or microgrids.
- Integrate data centre loads into national power-system development plans to align growth with supply.

### Disclosure and Reporting

- Recommend annual PUE, clean-energy coverage and carbon-intensity disclosure using templates aligned with ISO and GHG Protocol formats.
- Apply dual-metric guardrails (PUE and WUE) to avoid optimising one metric at the expense of another
- Encourage participation in voluntary programmes such as RE100 or CDP renewable reporting for transparency and market credibility.

### Incentives, Market Mechanisms and Capability Development

- Raise industry capabilities through the development of standards to establish best practices and benchmark performance.
- Provide tax allowances, accelerated depreciation or support grants for ISO50001-certified operators, or verified efficiency retrofits.
- Use grant or rebate schemes to co-finance demand-response participation or grid-support technologies.
- Recognise PPAs and green tariff participation as qualifying criteria for green-finance access under national taxonomy frameworks.

### Trade-off Management

- Develop analysis and optimisation plan where there are trade-offs between achieving different aspects of sustainability (e.g. energy efficiency vs water efficiency).

## Energy & Renewable Integration Maturity Progression Table

| Level | Policy Focus | Institutional / Regulatory Outcome | Illustrative Policy Actions |
|---|---|---|---|
| **1. Foundational** | Establish national visibility and baselines | • National inventory of data centre electricity demand and efficiency performance.<br>• Standardised PUE / clean-energy disclosure templates endorsed by ICT and energy ministries. | • Require PUE and electricity-use disclosure at licensing stage using ISO 30134 definitions.<br>• Develop central registry of data centre locations, connected capacity and load forecasts.<br>• Publish grid-capacity maps for designated DC zones.<br>• Pilot streamlined approvals for ≤ 1 MW on-site solar or other RE systems. |
| **2. Developing** | Enable market access to low-carbon electricity | • Legal and procedural frameworks for corporate PPAs, grid interconnections through submarine power cables and green tariffs.<br>• Functioning renewable-attribute registry (I-REC or national equivalent). | • Enact regulation allowing large users to contract RE through direct PPAs or utility-facilitated tariffs.<br>• Define certification process for renewable-attribute tracking and reporting.<br>• Standardise interconnection and wheeling rules for RE projects.<br>• Offer fiscal incentives for ISO 50001 certification or energy-efficiency retrofits. |
| **3. Advanced** | Integrate efficiency and clean energy into approvals and grid planning | • Outcome-based licensing criteria linked to carbon intensity (kg $CO_2e$ / kWh IT).<br>• Joint ICT–energy planning for grid stability and RE integration. | • Embed verified clean-energy share or carbon-intensity thresholds into new-site licensing.<br>• Require DC participation in demand-response or flexible-load programmes.<br>• Review and tighten indicative PUE and carbon-intensity ranges every 3–5 years as grids decarbonise.<br>• Establish public reporting dashboards to track national progress.<br>• Embed outcome-based licence conditions that require facilities to meet verified carbon-intensity performance thresholds and demonstrate progress toward 100 percent carbon free electricity by 2030, using hourly-matched carbon-free energy procurement consistent with the 24/7 Carbon-Free Energy Technical Criteria. |

### ASEAN Alignment

**Element 1: Energy & Renewable Integration supports the following:**

a. Regional digital-infrastructure agenda under the ASEAN Digital Masterplan 2025 (Goal 4: Digital Infrastructure);

b. ASEAN Plan of Action for Energy Cooperation (APAEC) Renewable Energy and Energy Intensity Reduction targets;

c. Multilateral trading initiatives such as the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP) and the realisation of the ASEAN Power Grid; and

d. ASEAN Green Agenda Pillar 2 – Low-Carbon Growth, through enhanced renewable procurement pathways, strengthened grid coordination and the development of an ASEAN Regional REC Framework to support REC access across the region once established.

The ASEAN Plan of Action for Energy Cooperation (2026–2030) is elevating renewable targets and efficiency, strengthening the case for national PPA frameworks and cross-border trade to support Data Centres growth.

## 4.2 Element 2 – GHG Emissions & Operational Efficiency

As ASEAN's data centre footprint expands, energy use and associated greenhouse-gas (GHG) emissions are rising rapidly. Even with gains in efficiency, overall emissions continue to grow because of higher compute densities, legacy infrastructure and grids with heavy reliance on fossil fuels. A recent analysis reports that data centres are among the few sectors projected to experience the largest growth in both direct and indirect emissions through 2030.

As governments across ASEAN commit to net-zero or carbon-neutral pathways under their Nationally Determined Contributions (NDCs), aligning the region's digital-infrastructure growth with these commitments demands policies that move beyond narrow energy metrics and address a whole-emissions perspective, covering both operations and embodied life-cycle impacts.

Industry feedback emphasises three priorities:

**01** Transparent, comparable reporting of both operational and embodied carbon to satisfy investors and ESG standards;

**02** Use of internationally recognised accounting and disclosure standards to avoid fragmented and incomparable metrics; and

**03** Incentives for verified efficiency upgrades, renewable-energy procurement and use of low-carbon materials.

The section that follows sets out internationally recognised standards and indicators for monitoring and managing GHG emissions and operational efficiency across the full life-cycle of data centres. These are voluntary reference points intended to guide AMS in establishing baselines, promoting efficiency and preparing for lifecycle-carbon frameworks.

In addition to physical infrastructure, the digital carbon footprint of data centres is increasingly significant. High-intensity software workloads, including AI models, unoptimised databases and inefficient code drive higher compute demand and operational emissions. Cloud service providers can contribute to emission reductions by adopting Green Software Principles such as:

- Energy-efficient coding
- Scalable architectures
- Workload scheduling
- Data minimization

Extending this approach through Extended Producer Responsibility (EPR) encourages organisations to take accountability for the full lifecycle impacts of digital services, from infrastructure and hardware to software and data, supporting a comprehensive and sustainable digital ecosystem.

### Measurement & Definitions

| Indicator / KPI | Definition & Standard Reference | Unit / Boundary / Notes |
|---|---|---|
| **Carbon Usage Effectiveness (CUE)** | ISO/IEC 30134-3 – KPI for carbon usage effectiveness in data centres. | kg $CO_2e$ / kWh IT (load-adjusted, annualised) which reflects operational emissions intensity. |
| **Operational Carbon Intensity** | Based on GHG Protocol (2015) standards for Scope 1 + Scope 2 emissions. | kg $CO_2e$ / kWh IT-load. Useful for licensing thresholds or performance disclosures. |
| **Embodied or Whole-Life Carbon (WLC)** | EN 15978:2011 "Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method". | kg $CO_2e$ / $m^2$ gross-floor-area or kg $CO_2e$ / kW capacity. Reported at design and as-built stages. |
| **Energy Reuse Effectiveness (ERE)** | ISO/IEC 30134-6:2021 – defines energy reuse from the facility. | Unitless ratio (0-1). Lower means more effective reuse of waste heat or other streams. |

**Key definitions**

- *Operational emissions* = Scope 1 + Scope 2 (purchased electricity) of the facility.
- *Embodied emissions* = Scope 3 upstream (construction, manufacturing) + downstream (end-of-life) emissions.
- *New data centres* = construction commencing on or after 1 January 2027.
- *Existing data centres* = construction before 1 January 2027.
- *Low-carbon materials* = products with verified Environmental Product Declarations (EPDs) under ISO 14040/44.
- All operational metrics apply at ≥ 50% IT utilisation; climate adjustments, where relevant, follow Köppen A (tropical) and C (temperate).

**Illustrative Regional Performance Ranges**

*(for voluntary adoption or national calibration by AMS)*

| Emission Category | Indicative Target / Benchmark | Rationale / Context |
|---|---|---|
| **Operational Carbon Intensity (Scope 1 + 2)** | ≤ 0.35 kg $CO_2e$/kWh IT by 2030 (new data centres) at ≥ 50 % IT utilisation. | Aligns with industry pathways toward net-zero Scope 2 emissions and national NDCs. Represents the combined effect of efficiency and renewable-energy adoption. (GHG Protocol 2015; ISO 14064-1:2018) |
| **CUE (Carbon Usage Effectiveness)** | Target CUE ≈ 0.30–0.35 kg $CO_2e$ /kWh IT (tropical) and ≤ 0.25 kg $CO_2e$ /kWh IT (temperate) by 2030 at ≥ 50 % IT utilisation | Illustrative industry practice at ≥50 % IT utilisation; adjust for national grid emission factors. |
| **Embodied / Whole-Life Carbon (WLC)** | ≤ 500 kg $CO_2e/m^2$ gross-floor-area (new facilities by 2030) | Based on large-scale building benchmarks using EN 15978-based LCA tools and emerging APAC practice. |
| **Energy Reuse Effectiveness (ERE)** | ≤ 0.8 by 2030 for new facilities integrating heat-reuse systems | Encourages integration of waste-heat reuse in industrial or district-energy settings. |

These ranges are voluntary regional averages drawn from current ASEAN industry practice and global benchmarks. AMS could explore complying based on national grid decarbonisation, renewable-availability and market maturity. Embodied-carbon reporting should be submitted via recognised LCA tools using EN 15978 boundaries.

## Policy Guidance and Implementation Considerations

### Approvals and Monitoring Mechanisms

- Require disclosure of Scope 1 and Scope 2 operational emissions and CUE for facilities above a material threshold (e.g., ≥ 500 kW IT load).
- Link new data centre approvals to sustainability requirements such as verified clean-electricity procurement, operational carbon intensity (e.g., kg CO.e / kWh IT) and/or PUE targets.
- Pilot embodied-carbon reporting for new facilities ≥ 5 MW IT load, using EN 15978 or ISO 14067 frameworks.

### Planning and Infrastructure

- Incorporate emissions-intensity benchmarks into environmental-impact assessments (EIAs) for large data centre developments.
- Coordinate with energy and industrial-policy bodies to enable waste-heat reuse through district-energy or industrial symbiosis networks.
- Promote low-carbon materials through national green-procurement policies that require verified EPDs or LCAs.

### Disclosure and Reporting

- Emphasize annual reporting of operational emissions (Scope 1 + 2) and encourage disclosure of upstream supply-chain (Scope 3) emissions where feasible.
- Align operator disclosures with national GHG-inventory systems to support NDC tracking.
- Require publication of verified CUE and embodied-carbon values as part of sustainability reports or licence renewal provisions.

### Incentives and Market Mechanisms

- Offer tax allowances or rebates for facilities achieving verified reductions in carbon intensity or certified ISO 50001 energy-management systems.
- Recognise embodied-carbon reduction achievements via green-building certification or bonus zoning allowances.
- Enable access to green-finance or taxonomy-aligned funding for projects meeting verified life-cycle carbon performance and heat-reuse integration.

### Trade-off Management

- Efficiency upgrades can increase upfront embodied carbon, for example when installing new cooling infrastructure. This could trigger a requirement for a carbon pay-back assessment that shows the upgrade will deliver a net emissions benefit within a defined timeframe.
- Encourage modular and prefabricated construction strategies to reduce material waste, enable future reconfiguration and lower whole-life emissions.

## GHG Emissions & Operational Efficiency: Maturity Progression Table

| Level | Policy Focus | Institutional / Regulatory Outcome | Illustrative Policy Actions |
|---|---|---|---|
| **1. Foundational** | Establish visibility and baseline for carbon performance | • National inventory of data centre GHG emissions (Scope 1 & 2).<br>• Standardised reporting templates aligned with GHG Protocol and ISO 14064. | • Require voluntary disclosure of CUE and operational carbon intensity for all licensed facilities.<br>• Launch capacity-building programmes on energy and emissions management (ISO 50001 readiness). |
| **2. Developing** | Transition to standardised operational carbon reporting and incentive alignment | • Require operational-emissions reporting for facilities ≥ 500 kW IT.<br>• Verification and public dashboard summarising performance metrics. | • Integrate CUE and operational carbon intensity into licence frameworks.<br>• Offer fiscal incentives for ISO 50001 certification and verified efficiency retrofits.<br>• Publish national benchmark ranges for carbon intensity to guide investors. |
| **3. Advanced** | Integrate whole-life carbon into planning and procurement | • Outcome-based licences linked to operational carbon-intensity targets and embodied-carbon disclosure.<br>• Lifecycle-carbon reporting framework for new and major redevelopments. | • Voluntary embodied-carbon disclosure for data centre projects > 5 MW IT and publish verified values in public registry.<br>• Establish annual emissions-intensity reduction trajectories aligned with national NDCs.<br>• Align green-finance eligibility and tax incentives to verified whole-life carbon performance and heat-reuse integration.<br>• Develop guidance for embodied-carbon assessment using EN 15978. |

### ASEAN Alignment

**This element 2 – GHG Emissions & Operational Efficiency aligns with:**

a. **ASEAN Green Agenda**, through consistent emissions disclosure and performance standards;

b. **ASEAN Taxonomy for Sustainable Finance**, by defining eligible digital-infrastructure activities based on carbon-intensity and lifecycle performance;

c. **APAEC**, through integration of efficiency criteria in the region's energy-intensive industries; and

d. **ASEAN Digital Masterplan 2025**, by linking digital-infrastructure build-out with regional climate objectives.

## 4.3 Element 3 – Water Management & Cooling Innovation

Water is a critical resource for data centre operations in ASEAN and yet its availability, quality and cost vary widely across the region. Cooling systems, often the dominant source of operational water use, are influenced by climate, geography, grid mix and local infrastructure. In many destinations, water use is expected to rise alongside compute growth, as cooling loads increase and more facilities move into less mature markets. For example, recent research projects suggest that freshwater abstraction by data centres and related infrastructure in high growth markets may increase by over 60% between 2024 and 2030.

However, the picture is far from uniform. Some ASEAN Member States have abundant access to freshwater and can choose water-intensive cooling systems with relatively lower energy penalty, while others face high or very high water-stress categories (per World Resources Institute (WRI) Aqueduct) and must prioritise low-water or water-reuse technologies, even if that means higher energy consumption (higher PUE) or more complex infrastructure.

This variation means that one size does not fit all. Water-use targets and technology choices must be adapted by country, and even by site, depending on water-stress classification, cooling technology, grid conditions and resource availability. Some operators in low-stress zones may accept higher water use to drive energy (and PUE) gains, while in water-scarce areas the optimum may be lower freshwater abstraction even at a higher PUE.

Industry feedback emphasises three priorities:

**01** Use of water-stress classification in site-selection and permitting to identify risk and required mitigation (e.g. WRI Aqueduct high/very-high);

**02** Transparent metrics that capture both direct freshwater use and indirect water use associated with electricity generation and cooling; and

**03** Deployment of low-water cooling technologies, closed-loop systems, or heat-reuse pathways that minimise net water abstraction.

There are also important consequences and trade-offs to be aware of when designing policy responses:

- Over-incentivising evaporative cooling systems to achieve lower PUE targets can significantly increase WUE, placing additional pressure on municipal water supplies during dry seasons.
- Mandating non-potable water use in every location may be infeasible where reclaimed-water networks are unavailable; therefore, the guidance links conditions to basin stress levels and existing infrastructure readiness.
- Public and regulatory scrutiny of data centre water use is increasing globally, particularly as AI workloads expand, creating reputational and compliance risks in markets where water-use transparency remains low

Accordingly, this element sets out internationally recognised metrics, illustrative regional performance ranges based on industry consultation, and policy guidance that AMS can calibrate to climate, hydrology and technology.

### Measurement & Definitions

| Indicator / KPI | Definition & Standard Reference | Unit / Boundary / Notes |
|---|---|---|
| **Water Usage Effectiveness (WUE)** | ISO/IEC 30134-9 – KPI for water usage effectiveness in data centres; ratio of annual total water consumption, e.g: (freshwater, potable water, recycled water, whichever is applicable). consumed to IT energy (kWh). | L/kWh IT. Include cooling abstraction, make-up and evaporation; exclude reclaimed or seawater where there is no net freshwater loss. |
| **Water-Stress Category** | WRI Aqueduct baseline water-stress classification with explicit thresholds: Low <10%, Low-Medium 10–20%, Medium-High 20–40%, High 40–80%, Extremely High >80% (ratio of total withdrawals to renewable supply). | Categorical. Disclose site-level status at licensing and annually; use latest Aqueduct layer available for national calibration. |
| **Indirect Water Use** | Electricity-embedded water abstraction calculated from local power-sector water intensity (IEA Water-Energy interactions 2024). | L/kWh IT (or annual litres). Disclose data sources and method; update when grid mix or plant fleet changes materially. |
| **Cooling Source Mix** | Annual share of potable, non-potable/reclaimed, and seawater used for cooling, including any pre-treatment. | % of total cooling volume with notes on quality/treatment; disclose any switch-over logic for seasonal operations. |

**Key definitions**

- Total water consumption in WUE excludes reclaimed or saline sources where there is no net freshwater loss (ISO/IEC 30134-9).
- "New data centres" = construction commencing on or after 1 January 2027
- "Existing data centres" = before 1 January 2027.
- Closed-loop/air-cooled systems minimise net water abstraction but can increase PUE; report both WUE and PUE to evidence trade-offs (WRI Aqueduct).

**Illustrative Regional Performance Ranges**

*(for voluntary adoption or national calibration by AMS)*

| Facility Context | Indicative Target | Rationale / Context |
|---|---|---|
| **Regional WUE (total water consumption) – new and existing facilities** | Regional average annualised WUE of 1.8–2.0 by 1 January 2030, with commitments to improve where conditions allow. *(Applies to sites where the operator has operational control and access to consistent data.)* | Reflects voluntary industry feedback for an achievable regional average, while allowing AMS/site calibration based on climate and technology (ISO/IEC 30134-9). |
| **Water-stressed areas (WRI: High / Extremely High)** | Assess local water stress; implement site water-management plans; seek alternatives to potable water where feasible; and implement water-reduction measures. | Aligns siting and operations to basin stress and infrastructure readiness (WRI Aqueduct) |
| **Disclosure scope (all facilities)** | Report WUE (total water consumption), water-stress category, cooling source mix, and indirect water use annually with third-party verification. | Ensures completeness and enables policy comparability across AMS and climates; supports public confidence (ISO/IEC 30134-9). |

**Important application notes**

- Report both total facility water and IT energy consistently; disclose cooling type and water-source mix.
- WUE for new sites may be fully representative only after ~12–15 months of stable operation (ISO/IEC 30134-9).

These ranges represent voluntary regional averages based on recent industry practice. AMS may adjust targets for climate, hydrology, and cooling technology. Dual-metric reporting of PUE and WUE is recommended to document trade-offs between energy and water efficiency.

## Policy Guidance and Implementation Considerations

### Approvals and Monitoring Mechanism

- Require WUE (total water consumption), water-stress category, cooling source mix, and indirect water use disclosure at licence application and annually thereafter.
- In High/Extremely High stress basins, condition permits on non-potable/reclaimed water use where feasible and submission of a multi-year water-management plan (WRI)
- Maintain a dual-metric requirement: require disclosure of PUE whenever cooling changes materially affect WUE (ISO/IEC 30134-2 PUE explainer).

### Planning and Infrastructure

- Align DC zoning with national water-resource plans; avoid high-stress aquifers unless alternative cooling or reclaimed networks are viable (WRI Aqueduct).
- Enable district energy / heat-reuse where climate and urban form permit to reduce cooling loads (general method reference: ISO/IEC 30134-6 Energy Reuse metrics).
- Incentivise co-location with wastewater treatment for reclaimed-water supply (ADB reclaimed-water guidance).

### Disclosure and Reporting

- Specify annual reporting of direct and indirect water use, WUE cooling type, water-source mix, and stress category, with third-party verification (IEA water-energy interactions).
- Where gains in WUE come with losses in PUE, or the opposite, this could trigger a requirement for a brief trade-off statement and an optimisation plan across energy and water performance, consistent with ISO/IEC 30134-9 & ISO/IEC 30134-2.
- Publish aggregate national dashboards for DC water use and stress-zone distribution to build public confidence (WRI Aqueduct).

### Incentives and Market Mechanisms

- Offer priority permitting or fiscal incentives for facilities that (i) achieve the regional WUE average early, or (ii) use ≥ 80% non-potable/reclaimed water for cooling (ISO/IEC 30134-9).
- Tie green-building / DC certification to documented reductions in water abstraction and heat-reuse integration (ISO/IEC 30134-6).
- Explore water-offset schemes to fund municipal reuse or watershed restoration in stressed basins (ADB recycled-water).

### Trade-off Management

- If shifting to evaporative cooling (lower PUE) raises WUE, document basin stress, seasonality and mitigation (e.g. non-potable sources, blow-down optimisation) (ISO/IEC 30134-9).
- If moving away from evaporative cooling raises PUE, quantify energy and carbon impacts and show the net water-carbon outcome using both WUE and PUE (ISO/IEC 30134-2).

## Water Management & Cooling Innovation: Maturity Progression Table

| Level | Policy Focus | Institutional / Regulatory Outcome | Illustrative Policy Actions |
|---|---|---|---|
| **1. Foundational** | Establish visibility of water use and risk | National inventory of DC water use; WRI stress maps overlaid with DC clusters; standard WUE template (ISO/IEC 30134-9). | Require WUE (total water consumption), water-stress, cooling source mix, and indirect water disclosure at licensing; publish an annual national snapshot (ISO/IEC 30134-9; WRI). |
| **2. Developing** | Integrate water risk into siting and incentives | Water-impact assessment required in High/Extremely High stress zones; incentives for reclaimed/ closed-loop cooling. | Link permits/tax benefits to non-potable/reclaimed use and documented WUE improvement; grants for closed-loop or heat-reuse systems. (ISO/IEC 30134-6). |
| **3. Advanced** | Link water performance to licensing and finance | Outcome-based licence conditions: meet/report regional WUE average and basin-specific mitigation; public dashboard. | Mandate third-party verification of WUE and stress status for renewal; establish water-offset mechanisms and publish basin-level progress (ADB recycled-water). |

### ASEAN Alignment

a. **ASEAN Water Security Strategy –** integrating large new water users into basin planning and risk mitigation;

b. **ASEAN Digital Masterplan 2025 –** ensuring digital growth is resource-secure and publicly accountable;

c. **ASEAN Circular Economy –** closed-loop water and heat-reuse reduce resource pressure and local impacts.

## 4.4 Element 4 – Waste & Circular Economy

As ASEAN's data centre capacity expands, so too does the volume of material use, construction waste and end-of-life (EoL) equipment flows. A typical hyperscale facility uses thousands of tonnes of steel, concrete and aluminium, while servers and cooling systems require frequent component replacement. Globally, the IT sector generates more than 50 million tonnes of e-waste each year, with volumes projected to grow by around 30 % by 2030. Circular-economy approaches such as refurbishment, reuse, recycling and component recovery offer both resource-efficiency gains and cost benefits.

While e-waste represents the most material and regulated stream for data centres, broader waste types (such as packaging, construction materials and cooling-system consumables) also fall within emerging circular-economy frameworks. ASEAN's circular-economy agenda is progressing, with 2024–2025 updates emphasising implementation at scale and alignment with taxonomy-based finance. This makes Extended Producer Responsibility (EPR) schemes, decommissioning plans and licensed recovery important next steps for managing both e-waste and related material flows. Yet adoption remains limited due to data-security concerns, lack of secondary-materials markets and inconsistent policy incentives.

AMS and Data Centre Industry player feedback revealed:

- Data Centre industry players want clear, secure take-back pathways (including certified data erasure) to expand reuse/refurbish without reliability or data-security concerns.
- Integrating waste-heat recovery, material recovery and circular design into national data centre standards.
- Policymakers requested regionally coherent definitions and documentation to reduce friction for cross-border recovery, consistent with Basel Convention obligations while supporting ASEAN-level harmonisation.

Some consequences and trade-offs to be aware of:

- Without formal EPR and decommissioning plans, valuable components leak to informal sectors, increasing pollution and foregone material value.
- Setting rigid "new-only" procurement rules can undercut circularity; the guidance therefore enables verified refurbished components where reliability standards are met.

Accordingly, this element sets out internationally recognised metrics, illustrative regional performance ranges based on industry consultation, and policy guidance that AMS can calibrate to climate, hydrology and technology.

### Measurement & Definitions

| Indicator / KPI | Definition & Standard Reference | Unit / Boundary / Notes |
|---|---|---|
| **Circularity Performance (CP)** | Measured according to ISO 59020: 2024 Circular Economy – Measurement of Circularity, which quantifies how effectively resources are circulated across material, component, and product levels within an organisation or system. | Index / score per ISO 59020; report annually for both construction (Capex) and operations (Opex) scopes. Results are normalised 0–100 %, where higher values indicate greater circularity. |
| **Embodied / Whole-Life Carbon (WLC)** | Life-cycle GHG of materials and construction using EN 15978:2011 and ISO 14067 (Product Carbon Footprint). | kg $CO_2e$ per $m^2$ (GFA) or per kW (IT); report at design and as-built. |
| **Electronic Waste Recovery Rate** | Share of EoL ICT equipment collected and recycled through licensed facilities per EU WEEE Directive 2012/19/EU | % by mass per year; exclude exports without verified treatment; track batteries separately. |
| **Energy Reuse Factor (ERF)** | ISO/IEC 30134-6:2021 – proportion of data centre waste heat reused externally. | 0–1 (dimensionless). Higher ERF = greater external energy reuse. |

**Key definitions**

- *Circularity* = maximising reuse, repair and recycling of components and materials while minimising waste generation.
- *EoL waste* = equipment, batteries and materials removed from service after replacement or decommissioning.
- *Reused equipment* = IT or mechanical systems redeployed for equivalent or lower workloads with warranty or verified reliability.

**Illustrative Regional Performance Ranges**

*(for voluntary adoption or national calibration by AMS)*

| Category | Indicative Target / Benchmark | Rationale / Context |
|---|---|---|
| **Electronic Waste Recovery Rate – new & existing** | ≥ 85 % by 2030 (mass-based, licensed facilities, batteries tracked separately). | Reflects voluntary industry ambition and aligns with UN Global E-waste Monitor targets for OECD markets |
| **Circularity Performance (ISO 59020)** | ≥ 60 (index or %) by 2030 across build and operations. | Provides auditable metric for circular progress and green-finance alignment (ISO 59020) |
| **Embodied / Whole-Life Carbon (WLC)** | ≤ 500 kg $CO_2e$ per $m^2$ (GFA) for new builds by 2030; report as-built variance. | Aligns with industry whole-life-carbon benchmarks and voluntary corporate targets (WorldGBC 2024) |
| **Energy Reuse Factor (ERF)** | ERF ≥ 0.2 for new urban sites by 2030 with district / industrial offtake. | Encourages planning of heat-recovery and district-energy links in suitable urban areas (IEA Data Centres) |

These ranges represent voluntary regional averages discussed with industry and reflect current achievable practice across ASEAN. AMS could tailor them to national material markets, urban density and energy infrastructure. For example, heat-reuse opportunities may be highest in dense urban clusters, while smaller regional facilities may focus on equipment reuse and recycling targets.

## Policy Guidance and Implementation Considerations

### Approvals and Monitoring Mechanism

- Require EoL & Decommissioning Plans covering data erasure, certified logistics and licensed treatment (EU WEEE 2012/19/EU).
- For new builds ≥ 5 MW IT, encourage design-stage and as-built WLC (EN 15978 / ISO 14067).
- In urban zones, request ERF feasibility study for district / industrial offtake (ISO/IEC 30134-6).

### Planning and Infrastructure

- Embed EoL infrastructure zones for safe treatment and recycling of data centre equipment within industrial parks.
- Encourage co-location of data centres with district heating/cooling grids to maximise heat-recovery potential.
- Facilitate public-private platforms for component reuse and reverse logistics across ASEAN.

### Disclosure and Reporting

- Specify annual disclosure of E-waste volumes, recovery percentages, reuse rates and final destinations.
- Report Circularity Performance (ISO 59020) for capex and opex scopes.

### Incentives and Market Mechanisms

- Provide tax incentives for verified WLC reductions, ≥ 85 % E-waste recovery and reuse expansion.
- Recognise EPR and take-back schemes as eligibility criteria for green-finance programmes.

### Trade-off Management

- If reuse extends life but reduces efficiency, require Life Cycle Assessment (LCA) showing carbon payback ≤ 5 years (EN 15978).
- If heat reuse raises auxiliary load, report ERF with CUE to show net impact (ISO/IEC 30134-6 & 30134-3).

## Waste & Circular Economy: Maturity Progression Table

| Level | Policy Focus | Institutional / Regulatory Outcome | Illustrative Policy Actions |
|---|---|---|---|
| **1. Foundational** | Establish visibility of material flows and EoL management | National inventory of data centre materials and licensed recyclers. | Require EoL plans and annual E-waste reporting by stream.<br>Publish secure data-erasure guidelines. |
| **2. Developing** | Build reuse / recycling markets and circular procurement | EPR or take-back schemes for ICT and batteries; verified LCA framework. | Legislate EPR for ICT equipment.<br>Offer tax credits for reuse and EPD-verified materials. |
| **3. Advanced** | Integrate circularity into licensing and green finance | Outcome-based licences with CP (ISO 59020) and E-waste KPIs; public dashboard. | Target WLC for ≥ 5 MW projects.<br>Tie incentives to ≥ 85 % recovery, reuse growth and ERF feasibility. |

### ASEAN Alignment

Element 4 – Waste & Circular Economy supports:

a. **ASEAN Circular Economy Framework 2024,** by mainstreaming resource efficiency and reuse in infrastructure projects;

b. **ASEAN Digital Masterplan 2025 (Goal 4 – Digital Infrastructure),** by integrating waste and materials standards into digital-infrastructure planning; and

c. **ASEAN Taxonomy for Sustainable Finance (v4 2025/26)**, by linking green-finance eligibility to verified embodied-carbon and circularity performance.

Together, these four Elements represent the operational foundation of sustainable data centres. The following section addresses how institutional coordination and planning can bring them together in practice.

## Cross-Cutting Policy Integration & Planning

One of the major obstacles to sustainable data centre growth in ASEAN is fragmented governance. Energy, land, water, environment and ICT ministries act independently, leading to slow approvals and misaligned incentives. Integrated land-use, energy-and-water system planning can reduce permitting delays and enable more sustainable infrastructure roll-out (for example co-location of data centres, renewables, cooling networks in Industrial Clusters). Regional transparency moves, like the EU's DC reporting database, show how common data fields can improve comparability.

Consequences and trade-offs to be aware of:

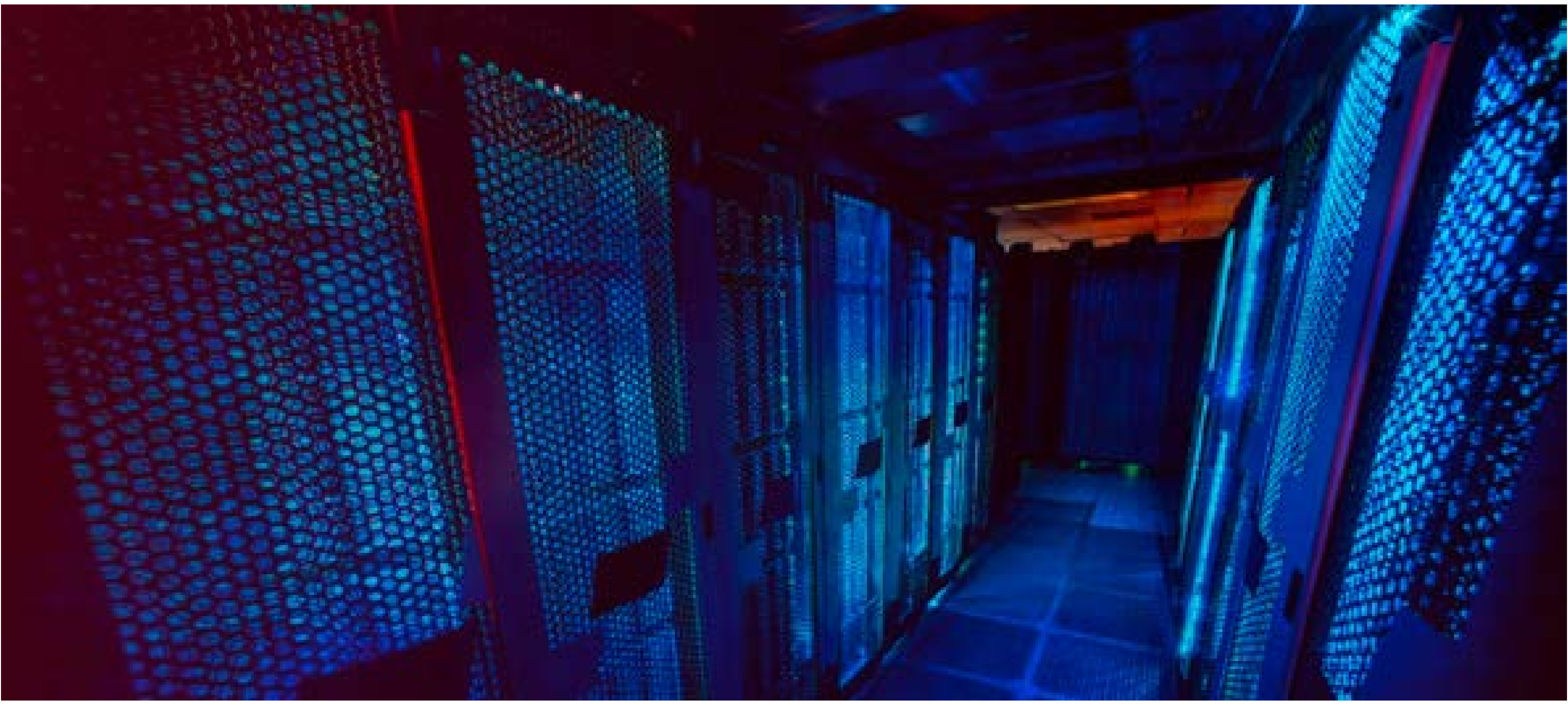
- Over-centralising approvals without resourcing the one-stop entity can increase delays; mandates should be paired with clear SLAs and staffing.
- Publishing indicative timelines and required studies improves predictability and reduces speculative applications that clog the pipeline.

### Cross-Cutting Policy Integration & Planning: Maturity Progression Table

| Level | Focus | Illustrative Policy Actions |
|---|---|---|
| **1. Foundational** | Get the right actors at one table | Establish a national Data Centre taskforce bringing together ICT, energy, environment, water, land and finance agencies, plus utilities.<br>Create a basic DC registry capturing location, IT load, energy source, PUE, WUE and e-waste arrangements to inform planning. |
| **2. Developing** | Predictable, sustainability-aware approvals | Set up one-stop permitting with a published checklist covering land, grid, water and environmental requirements.<br>Establish zones for Data Centre clusters inside industrial parks where shared utilities, reclaimed water and heat-reuse opportunities exist.<br>Publish typical timelines and required studies to improve certainty for investors and communities. |
| **3. Advanced** | Reward verified outcomes | Link tax incentives or grants to verified outcomes such as renewable electricity share, water reuse or certified recovery of e-waste.<br>Align green-finance eligibility with ASEAN Taxonomy developments to ease access to capital for projects meeting higher performance. |

### ASEAN Alignment

This Cross-Cutting Policy Integration & Planning section supports the broader regional digital-infrastructure agenda and the coordinated policy frameworks of the ASEAN Secretariat and AMS ministries. Together, the four elements outlined above — Energy & Renewable Integration, GHG Emissions & Efficiency, Water Management & Cooling and Waste & Circular Economy — form the foundation for sustainable data centre policy. This cross-cutting section outlines how institutional coordination and planning can integrate these elements into cohesive national frameworks.



# 5 GLOBAL BEST PRACTICES AND ASEAN ADAPTATION PATHWAYS

ASEAN's data centre sector is at a pivotal stage of development. As regional demand accelerates, policymakers now could integrate sustainability from the outset rather than retrofit solutions later. Chapter 5 builds on the policy foundations established in Section 4 and turns to global experience to show how other regions have addressed similar challenges under the Digital Infrastructure Trilemma of expansion, sustainability and resilience.

This chapter compiles global best practices and emerging models that can inform ASEAN's own adaptation pathways. It identifies practical lessons on how efficiency standards, renewable-energy integration, carbon disclosure, water management, waste circularity, and coordinated planning have been successfully implemented in mature markets such as the European Union, the United States, Japan, and Korea. These insights are contextualised for ASEAN to support Member States in shaping fit-for-purpose policies that align with national readiness and regional frameworks.

Examples in this chapter are structured around the Four Elements of Sustainable Data Centre Development—Energy & Renewable Integration, GHG Emissions & Operational Efficiency, Water Management & Cooling Innovation and Waste & Circular Economy—illustrating how governments and industry in other regions have applied measurable standards and coordinated implementation approaches. Selected case studies also highlight how cross-cutting policy integration and planning have been embedded in practice, showing the value of inter-ministerial coordination, shared data and spatial or industrial planning frameworks that enable resource efficiency across sectors.

The chapter further examines technology and innovation pathways, exploring how emerging solutions such as advanced cooling technologies, circular-design materials, digital-twin optimisation and next-generation clean-energy sources such as advanced nuclear systems, can support long-term decarbonisation and energy resilience in ASEAN's data centre ecosystem. Together, these best-practice examples demonstrate how ASEAN can translate the Four Elements into coordinated action through integrated policy frameworks and technology deployment.

***Global Best-Practice Snapshots for ASEAN Adaptation***

| Element | Policy / Example | Policy Lever / Mechanism | Outcome Achieved | Key ASEAN Takeaway | Relevant ASEAN Initiatives |
|---|---|---|---|---|---|
| **Energy & Renewable Integration** | Germany – Energy Efficiency Act (2023) | Mandates renewable-electricity share, PUE ≤ 1.2 for new builds and waste-heat recovery plans. | Created binding national standards aligning DC licensing with energy and decarbonisation goals. | Combine efficiency and clean-power conditions in new-build licensing; phase thresholds as the grid decarbonises. | APAEC (2026–2030) – Regional cooperation on efficiency & renewables |
| | Viet Nam – Direct PPA Decree (2024) | Enables direct renewable procurement between generators and large consumers. | Opened bankable channel for Data Centre players to buy RE directly; accelerated private-sector clean-power investment. | Establish credible renewable-procurement pathways (PPAs, green tariffs, imports) for data centre operators. | ASEAN Power Grid (LTMS-PIP) – Cross-border clean-power trade |
| | Malaysia – Guideline for Sustainable Development of Data Centres (2024) | Introduces mandatory declaration of PUE, CUE and WUE metrics for all new and existing data centres; aligns measurement and reporting with ISO/IEC 30134 standards | Established a national benchmarking framework for energy, water and carbon efficiency in data centre operations; encouraged integration of renewable energy and circular-water use; advanced transparency in environmental performance reporting. | Harmonise GHG and efficiency reporting metrics (PUE/CUE/WUE) across ASEAN; link fiscal or licensing incentives to operational-performance disclosure; support digital-sector decarbonisation aligned with national net-zero targets. | ASEAN Green Agenda Pillar 2 – Low-Carbon Transition; ASEAN Taxonomy for Sustainable Finance (v4 2025/26) |
| **GHG Emissions & Operational Efficiency** | EU – Energy Efficiency Directive (Recast 2023) | Requires Data Centres ≥ 500 kW to report PUE, WUE, renewable share & heat reuse into an EU database. | Delivered transparent benchmarking across 27 Member States; enabled finance and compliance tracking. | Introduce harmonised reporting templates and public dashboards across ASEAN to track performance. | ASEAN Green Agenda Pillar 2 – Low-Carbon Transition |
| | France – Décret n° 2023-259 (Digital Sustainability) sect | Links data centre operational efficiency and emissions reporting to national climate objectives; requires annual disclosure of energy and environmental performance. | Created a binding framework for energy and carbon transparency in the digital sector, supporting national emissions targets. | Embed efficiency and carbon-intensity reporting requirements in licensing to align data centre growth with AMS NDCs. | ASEAN Taxonomy for Sustainable Finance |

***Global Best-Practice Snapshots for ASEAN Adaptation***

| Element | Policy / Example | Policy Lever / Mechanism | Outcome Achieved | Key ASEAN Takeaway | Relevant ASEAN Initiatives |
|---|---|---|---|---|---|
| **Water Management & Cooling Innovation** | Singapore – Green DC Roadmap (2024) | Sets staged WUE trajectory (≤ 2.0 $m^3$/MWh over the next 10 years) and promotes non-potable and recycled water use. | Embedded water-efficiency and reuse in national planning; accelerated adoption of hybrid cooling. | Develop WUE baselines and non-potable-water targets in licensing and cluster planning. | Framework for Circular Economy for the ASEAN Economic Community |
| | California (USA) – Recycled Water Regulations | Permits recycled water for industrial cooling and sets treatment standards. | Enabled large-scale substitution of potable with reclaimed water in high-tech clusters. | Issue clear guidelines and quality standards for safe industrial reuse in ASEAN urban hubs. | Advancing Water Security across Asia and the Pacific |
| **Waste & Circular Economy** | South Korea – EPR System (2003) | Legally requires manufacturers and importers to meet annual recycling targets for electronics, batteries and packaging, enforced through Korea Environment Corporation KECO's compliance system. | Delivered high recovery rates for ICT and electronic waste, supported by digital tracking and producer-financed infrastructure. | Apply mandatory EPR frameworks for ICT and data centre equipment with clear quotas and digital reporting. | ASEAN Circular Economy Framework (2024) |
| | European Union – WEEE Directive (2012/19/EU) | Harmonised producer responsibility for collection and treatment of ICT and electrical equipment, with 65 %/85 % recovery targets and transparent national registers. | Created consistent EPR systems across 27 countries, boosting formal recycling capacity for servers and ICT. | Adopt regionally harmonised EPR definitions and reporting to support cross-border reuse and recycling of data centre components. | ASEAN Circular Economy Framework (2024) |

## 5.1 Energy & Renewable Integration

Energy is one of the most material sustainability challenge for data centres. Globally, electricity use accounts for more than 60–70% of a facility's operating costs and over 80% of its direct environmental footprint when connected to fossil-heavy grids. In ASEAN, where fossil fuels remain the dominant source of electricity, addressing energy use is critical to balancing the Digital Infrastructure Trilemma.

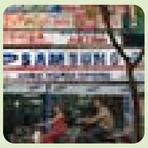
AMS can act on two fronts: first, by setting efficiency standards to reduce energy demand at the facility level; and second, by enabling renewable energy procurement to clean the electricity supply. Together, these measures form the foundation of sustainable energy strategies for data centre growth.

Level 1

**Foundational:**
**Make demand visible, map options**

**Transparency on performance & planning (EU):**
Under the recast Energy Efficiency Directive, data centres ≥500 kW must report to an EU database on energy, water, cooling effectiveness and heat reuse. This creates comparable baselines for planning and policy.

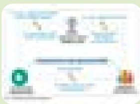
**Delegated Regulation details (EU):**
The implementing delegated act sets the indicators, reporting dates and the database interface. This is useful as a ready template for AMS disclosure schemes.



**Direct PPAs (Viet Nam):**
The 2024 DPPA Decree allows large consumers to buy renewable electricity directly (physical/virtual), creating a bankable route to decarbonise large loads.

Level 2

**Developing:**
**Open clean-power procurement channels**



**Corporate Green Power (Malaysia):**
The CGPP launched with an 800 MW quota for virtual PPAs, fully subscribed by Nov 2023, signalling strong demand and a replicable model for AMS.

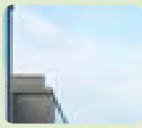
**Regional imports (Singapore):**
Renewable imports and certificates are being developed alongside domestic efficiency standards to enable low-carbon growth in a land-constrained hub.

CLIMATE GROUP RE100

**Corporate Renewable Commitments (RE100):**
More than 400 global companies, including major cloud and data centre operators, have joined RE100, committing to 100% renewable electricity and publishing transparent sourcing data. Member actions are driving corporate PPA markets in emerging economies, offering AMS a ready framework to attract investment and standardise reporting.

Level 3

**Advanced:**
**Link clean power approvals & system services**



**Binding efficiency & renewable use (Germany):**
The Energy Efficiency Act (EnEfG) ties new Data Centre to ≤1.2 PUE from 2026, phases thresholds for existing sites and mandates renewable use and heat reuse, an example of integrating licensing and system outcomes.

**24/7 carbon-free energy pilots (C40 Cities):**
C40 cities are applying hourly-matched carbon-free energy procurement to align electricity use with local clean-generation every hour of the year, demonstrating how large consumers can support system-level decarbonisation through verified 24/7 clean supply and flexible demand practices.

## KEY MESSAGES FOR ASEAN

**Diversify clean-energy procurement channels**
ASEAN could create transparent pathways for data centre operators to source renewable electricity through corporate PPAs, green tariffs or regional imports, reducing reliance on fossil-heavy grids and supporting energy-market liberalisation.

**Integrate energy efficiency into licensing**
Linking facility approvals to verified efficiency or carbon-intensity performance ensures that new capacity expands within national climate targets rather than adding unmitigated load to the grid.

**Grid planning and capacity coordination are essential**
Close coordination between ICT, energy and utility regulators will allow planned substations, interconnections and renewable corridors to align with digital-infrastructure zoning, minimising stranded assets and hidden subsidy effects.

**Regional data transparency builds investor confidence**
Developing a shared ASEAN registry of energy, renewable share and efficiency indicators will attract green finance and demonstrate alignment with APAEC and the ASEAN Power Grid.

**Align incentives with system benefits**
Fiscal incentives should reward verified outcomes, such as renewable-energy use, grid-support services or heat reuse, to balance data centre profitability with power-system resilience.

**Utilise voluntary initiatives**
Voluntary initiatives such as RE100 and the 24/7 Carbon-Free Coalition can complement national policy, enhancing transparency and acceleration clean energy uptake.

## 5.2 GHG Emissions & Operational Efficiency

As data centre deployments scale in the ASEAN region, the challenge is shifting from simply reducing energy overheads to managing overall carbon emissions, enhancing operational efficiency and aligning with grid decarbonisation trajectories. Recent research demonstrates that while many facilities have achieved early efficiency gains, newer high-density compute environments and legacy infrastructure impose fresh ceilings on further improvements.

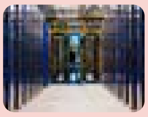
For ASEAN policymakers, this means linking energy-management efforts with emissions disclosure, renewable procurement, lifecycle carbon accounting and equipment refresh strategies, rather than relying solely on a single metric like PUE. One global insight is that without a carbon-intensity lens (kg $CO_2$e/kWh IT), efficiency gains may not translate into meaningful climate outcomes.

ASEAN Member States can progress from voluntary efficiency initiatives to standardised performance frameworks that link operational improvements to measurable carbon outcomes.

Level 1

### Foundational:

**Establish baselines and transparency**

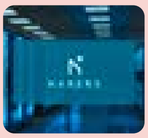


**Mandatory reporting (European Union):**

Under the EU Energy Efficiency Directive (Recast 2023), all data centres ≥ 500 kW must disclose performance data, including PUE, WUE, renewable share and heat reuse, to an EU database, establishing a consistent evidence base for policy design.

**Public benchmarking (United States):**

The U.S. Environmental Protection Agency's ENERGY STAR for Data Centres programme publishes annual benchmarks and best-practice guidance, enabling operators to compare performance and plan retrofits.



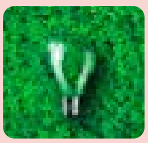
**Voluntary disclosure (Australia):**

The NABERS Energy for Data Centres scheme rates facilities based on measured energy performance, providing a transparent national benchmark for energy and emissions intensity.

Level 2

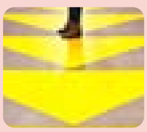
### Developing:

**Open clean-power procurement channels**



**Energy-management systems (Japan):**

Japan' Top Runner Programme and Energy Conservation Act incentivise continuous efficiency improvements through mandatory reporting and certification, driving technology upgrades across ICT sectors.



**Fiscal incentives (Germany):**

Germany's Energy Efficiency Act (2023) ties financial support and fast-track permitting to verified efficiency measures and renewable-energy sourcing within data centres.

**Operational benchmarking (Sweden):**

National guidelines developed under the Swedish Energy Agency integrate PUE and carbon-intensity metrics into voluntary certification, supporting public-sector procurement of low-carbon digital services.

Level 3

**Advanced:**
**Link clean power approvals & system services**

**Carbon-intensity thresholds (France):**

France's Décret n° 2023-259 on digital sustainability sets carbon-intensity and energy-efficiency disclosure requirements for data centre operators, linking operational metrics to national climate objectives.

**Lifecycle reporting (European Union):**

The EU's Corporate Sustainability Reporting Directive (CSRD) now requires large ICT operators to report Scope 1–3 emissions, including embodied carbon in construction and hardware.

**Performance-based allocation of capacity (Singapore):**
New DC developments are assessed on energy-efficiency and other key outcomes before receiving support for capacity allocations.


## ★ KEY MESSAGES FOR ASEAN

**Move from voluntary to outcome-based regulation**
Integrating operational-efficiency standards and carbon-intensity thresholds into licensing will ensure that data centre expansion supports national climate commitments.

**Standardised reporting enables comparability and finance**
Establishing a regional template for PUE, renewable-share and GHG-intensity data, similar to the EU database, will attract sustainable-finance opportunities and reduce investor uncertainty.

**Lifecycle emissions are the next frontier**
ASEAN can pilot embodied-carbon disclosure for new data centre construction and equipment procurement, preparing for future lifecycle standards.

**Capacity building and verification are essential**
Training regulators and auditors to interpret energy and emissions data will improve policy credibility and enable effective enforcement.

**Alignment with ASEAN frameworks drives consistency**
Coordinating through the ASEAN Green Agenda Pillar 2 (Low-Carbon Growth) and the ASEAN Taxonomy for Sustainable Finance will create region-wide coherence and position ASEAN as a trusted hub for sustainable digital infrastructure.

## 5.3 Water Management & Cooling Innovation

Water is a critical yet often overlooked policy aspect of sustainable data centre expansion. Cooling systems, particularly in hyper-scale facilities, can consume up to 1.5 million litres of water per day, placing significant strain on local municipal or ecological systems in drought-prone regions. As the AI-driven growth of digital infrastructure accelerates, water demand is projected to surge dramatically, forecasted to reach upwards of 6.6 billion cubic meters globally by 2027, raising serious concerns for regions already facing scarcity.

Without water-efficient policy frameworks, data centres risk becoming competing stakeholders in regions where water is finite, potentially displacing agricultural, industrial, or community water needs.

Level 1

**Foundational:**
Monitor, baseline, disclose

**Mandatory water planning (Singapore):**
Since 2015, Singapore's PUB has required major water users (≥ 60,000 $m^3$/year) to submit Water Efficiency Management Plans. The Green Data Centre Roadmap aims for all data centres in Singapore to achieve Water Usage Effectiveness (WUE) of < 2.0m3 per MWh over the next 10 years.

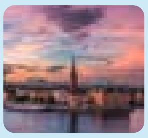
**Sectoral benchmarks (Singapore):**
PUB develops sectoral water-efficiency benchmarks (including data centres), which AMS can mirror to contextualise WUE by climate and technology.

Level 2

**Developing:**
Reuse & optimise cooling; shift to non-potable sources

**Recycled water for cooling (California, USA):**
State and local frameworks permit and supervise recycled water for cooling towers and industrial use, showing how non-potable supplies can be integrated safely.

**Local implementation (Santa Clara, USA):**
City-level rules require plan reviews for on-site recycled systems and operate a reclaimed-water utility with advanced treatment. This is useful for AMS cities exploring industrial reuse.



**District thermal integration (Stockholm):**
Policy-enabled heat recovery converts a data centre externality into a city-scale resource, reducing primary energy and emissions for buildings.

Level 3

**Advanced:**
Link clean power approvals & system services

**WUE trajectory via national roadmap (Singapore):**
Regulators are working with operators to reach WUE ≤ 2.0 $m^3$/MWh over ~10 years, focusing on cooling-tower optimisation and recycled blowdown, an example of performance-based targets instead of tech mandates.

## ★ KEY MESSAGES FOR ASEAN

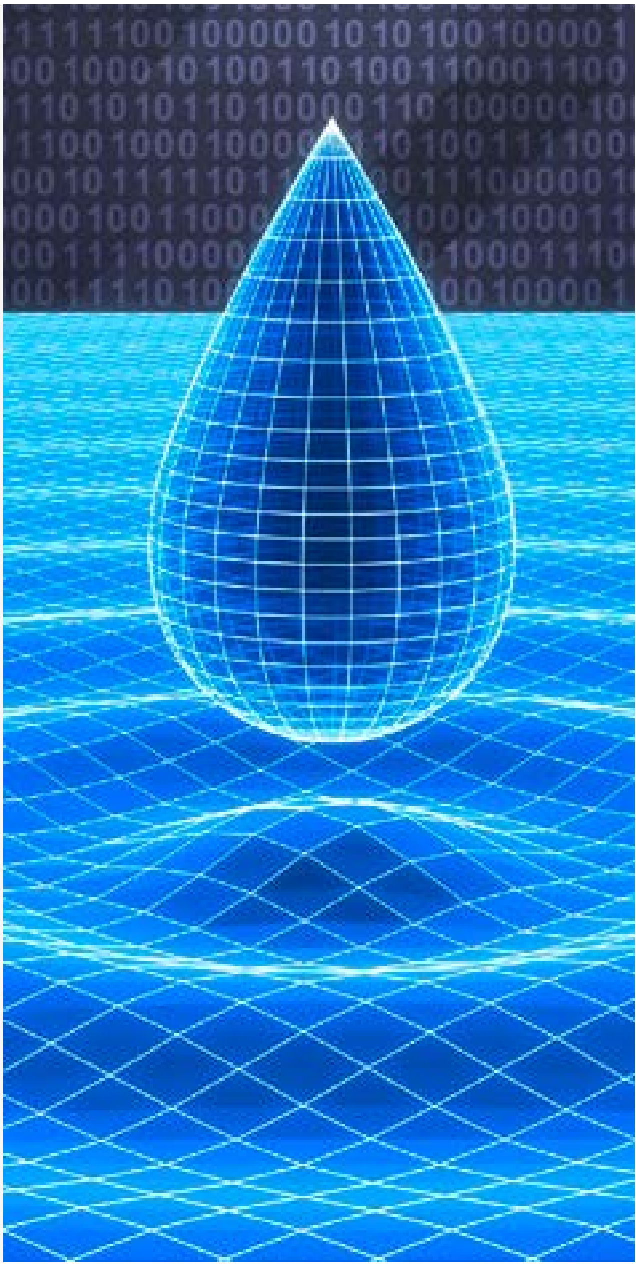
**Balance energy and water performance**
Policies must recognise the trade-off between low-energy and low-water cooling designs. Requiring both PUE and WUE disclosure ensures that efficiency in one area does not create excess demand in another.

**Encourage non-potable and reclaimed-water use**
Setting clear standards for reclaimed or seawater quality and permitting allows data centres to tap alternative sources safely, reducing competition with municipal supply.

**Encourage water-risk mapping and reporting**
Encouraging operators to work with governments on sustainable siting and providing relevant information to inform national water-security strategies.

**Enable cooling innovation through pilot zones**
Creating sandboxes for advanced liquid or hybrid-cooling trials in tropical climates can de-risk emerging technologies and provide regional performance benchmarks.

**Integrate water efficiency into permitting**
Including WUE and reuse conditions in development approvals, similar to energy-performance licensing, will lock water stewardship into long-term operations.



## 5.4 Waste & Circular Economy

Data centres are significant contributors to the growing global e-waste stream, which reached over 62 million tonnes in 2022 and is projected to rise by 30% by 2030 (UNEP). Within data centres, short hardware refresh cycles (every 3–5 years) generate large volumes of discarded servers, networking gear and storage devices containing critical minerals like rare earths, cobalt and gold. Without proper regulation, these materials are often processed informally, leading to toxic waste leakage and lost economic value.

Policy frameworks such as Extended Producer Responsibility (EPR) and mandatory e-waste reporting have proven effective in managing these risks. For ASEAN, where most Member States lack binding data centre e-waste regulation, embedding circular economy principles now can transform waste liabilities into new industrial opportunities.

Level 1

### Foundational:

Make flows visible; set secure pathways

**Basel e-waste controls:**

From 2025, transboundary movements of e-waste are subject to prior informed consent, raising compliance needs for cross-border refurbish/recycling chains.

**EU WEEE baseline:**

The EU sets a 65% collection target of EEE placed on the market (or 85% of WEEE generated) and defines recovery/recycling requirements. Tiered benchmarks could be incorporated for AMS targets.

**South Korea – EPR System:**

South Korea's EPR scheme legally requires manufacturers and importers to meet annual recycling targets for electronics, packaging and batteries. The Korea Environment Corporation (KECO) manages compliance data and imposes recycling fees if targets are missed. This approach drives quantified targets, enforcement capacity and producer-financed infrastructure, offering a strong model for AMS where enforcement remains a challenge.

Level 2

### Developing:

EPR & decommissioning

**Operationalisation (Singapore):**

The National Environment Agency details roles under the EPR system, including licensed scheme operators and obligations for regulated products.

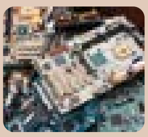
**EU WEEE performance framing:**

Guidance and studies reiterate 65%/85% targets and encourage harmonised reporting that AMS could emulate to ease cross-border trade in refurbished parts and recovered materials.

Level 3

### Advanced:

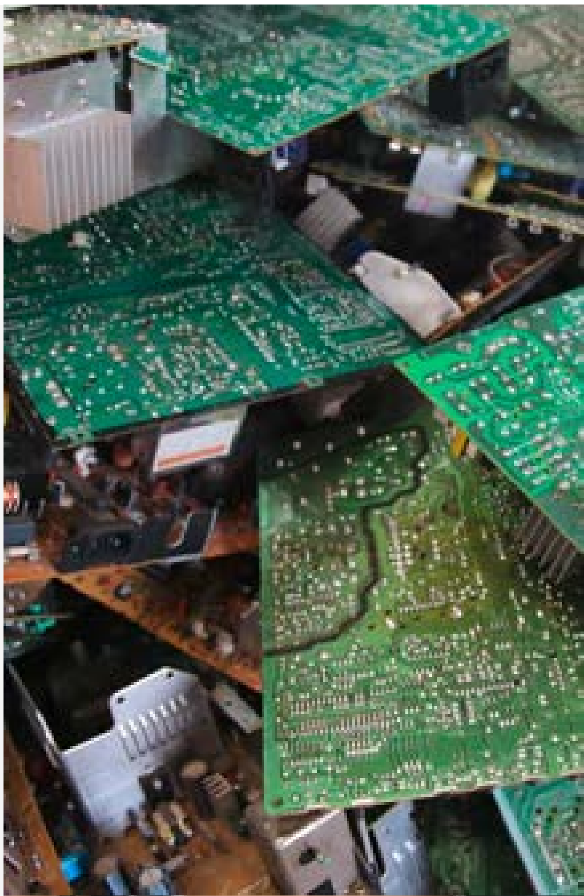
Regional circular networks



**Basel clarifications for shipments:**

COP decisions and FAQs clarify which waste streams require PIC and how to manage shipments, supporting compliant regional recovery markets.

## ★ KEY MESSAGES FOR ASEAN



**Turn e-waste from risk to resource**
Recovered components and critical minerals from data centre hardware can strengthen regional supply chains, reduce import dependence and create new recycling industries, transforming an environmental liability into an economic opportunity.

**Establish Extended Producer Responsibility (EPR) frameworks**
AMS can adopt EPR legislation that requires ICT and data centre operators to manage end-of-life collection, recycling and reporting, ensuring accountability throughout the equipment lifecycle.

**Develop licensed refurbishment and recycling hubs**
Designating industrial parks or free-trade zones as authorised e-waste processing clusters can enable economies of scale, promote traceable recycling and attract private investment into formal recovery networks.

**Promote circular procurement and modular design**
Public-sector and large private operators can drive demand for refurbished or modular components, reducing embodied carbon and extending product life within data centre ecosystems.

**Integrate circularity into approval and reporting frameworks**
Linking new data centre licences to verified e-waste management plans and periodic reporting will embed circular economy performance into long-term operational compliance.

**Align national policies with regional and global frameworks**
Harmonising definitions and reporting standards under the ASEAN Circular Economy Framework (2024) and the Basel Convention e-waste amendments (2025) will support compliant cross-border trade in refurbished components and recovered materials.

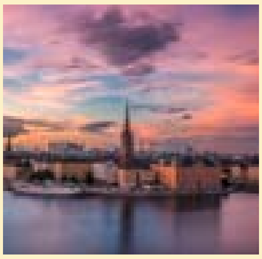
## 5.5 Cross-Cutting Policy Integration & Planning

One of ASEAN's greatest opportunities lies in adopting integrated planning approaches that co-locate data centres with other industries and infrastructure. When supported by clear zoning, inter-agency approvals and industrial symbiosis frameworks, data centres can evolve from resource-intensive facilities into anchors of sustainable industrial ecosystems.

### Global examples of integrated planning

**Industrial Clusters, World Economic Forum:** An emerging best practice is described in the World Economic Forum's 2024 report "Unleashing the Full Potential of Industrial Clusters: Infrastructure Solutions for Clean Energies." The report highlights how industrial clusters where energy-intensive facilities share heat, water and infrastructure can accelerate decarbonisation, lower system costs and attract co-investment in clean energy. It emphasises the importance of planning co-location from the outset so that utilities, manufacturers and data centre operators can exchange heat, water and circular resources within a single master-planned zone.

For ASEAN, this model offers immediate relevance. Data centres can be positioned as anchor loads within eco-industrial clusters, supplying waste heat to downstream industries such as beverage processing, food and cleaning-product manufacturing, or to water-reuse schemes. Coordinated zoning and early infrastructure planning would allow thermal loops and reclaimed-water pipelines to be designed from the start, turning what is now an energy-intensive asset into a resource hub for surrounding industries.



**District energy + heat reuse (Stockholm):** The city's Open District Heating concept lets large facilities feed waste heat into a 3,000 km district heating grid and a 300 km cooling network, moving toward heat from fully renewable or recovered sources by 2030. Enabled by municipal policy and energy utility agreements, operators channel waste heat from data centres into Stockholm's district heating network, warming tens of thousands of homes. This was made possible by early planning, zoning and infrastructure alignment between the city and utility.

**Amsterdam, Netherlands:** Following a 2019 pause on new data centre permits, the city introduced minimum standards for energy efficiency, water use and spatial planning. Development resumed under clearer guidelines, ensuring new projects aligned with grid capacity and environmental limits. This example shows that policy intervention can help shift growth from unplanned expansion to better planned and resource-balanced development.

## ★ KEY MESSAGES FOR ASEAN

**Integrated planning is the foundation of sustainable growth**
Fragmented permitting across ICT, energy, environment, water and land agencies slows investment and leads to poorly sited data centre clusters. Establishing a national coordination platform or one-stop permitting process can cut approval times and ensure new projects align with grid and water readiness.

**Industrial symbiosis unlocks shared value**
ASEAN can use data centres as anchor loads within eco-industrial zones, supplying waste heat and treated water to nearby industries such as beverage production, food processing and cleaning-product manufacturing.

**Transparent data improves governance and finance access**
A regional data centre registry capturing key indicators (location, IT load, PUE, WUE, renewable share, e-waste pathways) would allow benchmarking, reduce regulatory arbitrage and attract sustainable finance by demonstrating credible disclosure.

**Fiscal incentives should reward verified sustainability outcomes**
Linking tax breaks or investment incentives to proven energy, water and waste performance turns sustainability from a reporting exercise into a measurable investment condition, aligning AMS schemes with the evolving ASEAN Taxonomy for Sustainable Finance.

**Regional harmonisation ensures competitiveness**
Aligning metrics and permitting approaches under the ASEAN Green City Development Framework and ASEAN Digital Masterplan 2025 can promote cross-border investment and consistent sustainability standards across the region.

## 5.6 Technology and Innovation Pathways

Data centre sustainability in ASEAN will be shaped by a portfolio of technologies that ASEAN Member States can adopt, pilot or plan for depending on national circumstances. These technologies represent different stages of readiness and impact.

- **Near-term options** such as AI-enabled optimisation, advanced cooling, modular builds and circularity can immediately reduce energy and water intensity.
- **Medium-term options** like microgrids and storage systems can strengthen grid resilience and decarbonisation.
- **Longer-term options** including emerging low-carbon sources such as advanced nuclear in some AMS, may support firm, low-carbon capacity between 2035 and 2050 if accompanied by robust governance and public trust.

This section provides a bridge between the policy pathways outlined in Chapter 4 and the best practices and adaptation strategies discussed earlier in this chapter.

While the Guide does not prescribe specific technologies, it recognises that addressing the Four Elements — Energy & Renewable Integration, GHG Emissions & Efficiency, Water Management, and Waste & Circularity — will depend on how effectively innovation is deployed to support policy outcomes.

The table below therefore serves as a non-prescriptive reference of technologies and innovations relevant to sustainable data centres. It illustrates how global and regional examples from AI optimisation to heat recovery, water reuse, modular construction, microgrids and circular material use, are already being trialled or deployed.

Rather than a checklist of requirements, this table is designed as a toolkit of ideas to help policymakers, regulators, and industry players identify what could be adapted, piloted, or incentivised in their own contexts. Each example links to one or more of the Four Elements and demonstrates how technology can translate policy intent into practical implementation.

| Technology | Resource / Case | What it shows | Relevance to ASEAN / Data Centres |
|---|---|---|---|
| **AI-enabled optimisation/ workload & cooling** | *Energy Efficiency Using AI for Sustainable Data Centres* | Describes how AI models analyse cooling systems and optimize energy consumption; shows real-world improvement in cooling efficiency. | Good example of operational efficiency levers; applicable to tropical/hot-humid markets common in ASEAN. |
| | *A Data Center Energy Efficiency Optimization Method Based* | Study showing optimized temperature control and active server management can reduce energy usage significantly. | Useful for AMS considering stricter temperature/ operational controls and standards. |
| **GHG Emissions & Operational Efficiency** | *Cold Plates & Immersion Cooling vs. Air Cooling Study* | The study quantifies that cold plates and immersion cooling reduce GHG emissions, energy demand and water consumption by significant percentages (15-52%) compared with air cooling. | Strong example for AMS to consider in tropical climates (high cooling loads); supports setting standards or incentives. |
| | *Sustainable Tropical Data Centre Testbed (TDCT)* | The testbed was established to develop advanced cooling solutions in tropical settings, including liquid cooling, enhanced indirect evaporative cooling etc. | Extremely relevant for AMS in tropical climates; demonstration effect of what testbeds can do. |
| | *Liquid Immersion Cooling, Denmark* | In Europe's first immersion-cooled facility, located in Denmark, power consumption for cooling fell by up to 90% compared with traditional cooling systems. The report states that liquid immersion can be up to 1,000 times more efficient than air cooling, with major gains in both energy and space efficiency. | Very relevant; shows potential for significant power consumption and energy demand. |

| Technology | Resource / Case | What it shows | Relevance to ASEAN / Data Centres |
|---|---|---|---|
| **Water-alternative cooling / water reuse / cooling with reclaimed water** | *How Data Centres in Asia are Embracing a Water-Resilient Future* | Covers various cases in SEA: reclaimed water, desalination, alternative cooling sources in water-scarce zones; coastal desalination, rainwater harvesting. | Directly relevant to AMS facing water stress; gives precedent for policy / incentive / regulation around alternative water sources. |
| **Modular / prefabricated construction** | *Modular Data Center Market Summary* | Finds modular DCs reduce construction time by up to 40%, improve cost predictability and enable phased expansion. | Useful for AMS with fast-growing demand but uncertain long-term load. Enables smaller initial builds, reducing risk of stranded assets. |
| | *Modular DC Solutions – Asian deployments* | Shows deployments in Asia using modular design to match rapid digital growth with limited land and constrained power. | Illustrates relevance for ASEAN, particularly where incremental deployment may be preferable. |

### Opportunity for ASEAN

**ASEAN governments can help bring these innovations into practice by:**

- Allowing pilot projects under flexible rules, so operators can test new cooling or energy systems before full approval.
- Offering funding or tax incentives for advanced cooling and low-carbon backup power.
- Accepting new forms of renewable energy tracking, such as hourly certificates, in sustainability reporting.
- Updating building codes and permits to encourage modular design and energy-efficient construction.

By adopting these measures, ASEAN can encourage faster use of technologies that make data centres cleaner, more efficient and more competitive.

### Advanced nuclear within industrial clusters and decentralised grids (long-term option)

For data centres, the relevance of nuclear lies not in immediate deployment but in its potential to serve as a stable, low-carbon baseload option for the 2035–2050 horizon. In particular, small modular reactors (SMRs) could be co-located within industrial clusters or decentralised microgrids, directly supplying energy-intensive facilities like data centres while reducing dependence on traditional centralised fossil plants. This concept aligns with industrial-cluster planning in which shared infrastructure and clean-energy integration lower system costs and improve efficiency across collocated industries.

### Current Status by ASEAN Member State:

**Brunei Darussalam:** – Focus is on renewables and efficiency (solar roadmap/30% RE capacity target by 2035). No government policy indicating nuclear power development; capacity-building on peaceful uses and governance continues.

**Cambodia:** Cooperation on peaceful uses (medicine/research); no current policy for nuclear power generation.

**Indonesia (Greater Jakarta):** Government is studying SMRs/advanced nuclear within long-term decarbonisation. Official profiles and widely reported planning updates indicate nuclear is under consideration alongside broader transition measures (details subject to future decisions, siting and regulation).

**Lao PDR:** Laos does not have a nuclear power programme. Engagement has been limited to IAEA-supported capacity building on peaceful uses of nuclear science (e.g., medicine and agriculture). No government policy indicates plans for nuclear power generation.

**Malaysia (Johor and Klang Valley):** National Energy Transition Roadmap (NETR) recognises nuclear as a long-term option (no deployment date); authorities continue readiness studies within overall net-zero planning.

**Myanmar** – Intergovernmental agreement (2025) on a 110 MW SMR project signed; implementation contingent on governance, safety and financing.

**Philippines (Metro Manila):** PDP 2023–2050 and EO 164 (2022) establish nuclear as an option and direct DOE to develop the programme; preparatory work continues with IAEA support.

**Singapore:** Government is studying the potential deployment of nuclear energy. This includes building up capabilities and commissioning studies on safety and technical feasibility of advanced nuclear energy technologies.

**Thailand (Bangkok and Eastern Economic Corridor):** Draft PDP 2024–2037 notes potential SMR capacity in the long term (policy decision pending).

**Viet Nam (Ho Chi Minh City and Hanoi):** National Power Development Plan PDP8 (2025) emphasises renewables and new energy; public documents/analyses reference post-2035 discussion space for nuclear, but no formal deployment commitment is published on MOIT's public English pages.

# 6 FROM PRINCIPLES TO PRACTICE: POLICY INTEGRATION AND IMPLEMENTATION PATHWAYS

The ASEAN Guide for Sustainable Data Centre Development provides a regional policy foundation for embedding sustainability into rapid digital expansion. It aligns with the goals of the ASEAN Digital Masterplan 2025 (ADM 2025), the ASEAN Plan of Action for Energy Cooperation, and the ASEAN Green Agenda to ensure that data centre growth advances economic integration while supporting environmental and social objectives.

This Guide can be applied as a living reference, a tool for policymakers, regulators and industry to translate regional ambition into national action. Implementation can proceed through the following complementary steps.

**01**

**Institutionalise coordination**

Establish national cross-sector taskforces that bring together ministries responsible for ICT, energy, water, environment and industry planning.

These taskforces could:

- Adapt the Guide’s Four Elements—Energy, GHG & Operational Efficiency, Water, and Circularity—to national conditions and existing frameworks.
- Integrate sustainability checks into digital-infrastructure masterplans and industrial-park zoning.
- Coordinate with regional bodies through the ASEAN Digital Senior Officials’ Meeting (ADGSOM) and Senior Official’s Meeting on Energy (SOME) to ensure alignment with APAEC and ADM 2025 targets.

**02**

**Build regional transparency**

Create an ASEAN-level sustainability registry for data centre that consolidates key metrics on energy use, renewable-energy share, water efficiency, emissions intensity and e-waste management.

This registry could:

- Enable benchmarking across Member States and support regional progress tracking under the ASEAN Green Agenda Pillar 2 (Low-Carbon Transition).
- Provide a verified data platform to attract sustainable-finance flows through the ASEAN Taxonomy for Sustainable Finance v4 and the ASEAN Capital Markets Forum.
- Facilitate voluntary corporate disclosure consistent with international initiatives such as the EU Energy Efficiency Directive (2023), RE100 and Task Force on Climate-Related Financial Disclosures (TCFD).

**03**

### Align finance and incentives

Integrate sustainable-data centre criteria into national incentive schemes and investment-promotion frameworks.

Key options include:

- Incorporating renewable-energy sourcing, water reuse and e-waste recovery metrics into eligibility for fiscal incentives and green-investment grants.
- Linking public-finance institutions and export-credit agencies to the ASEAN Taxonomy so that high-performance data centre projects qualify for concessional finance.
- Encouraging the adoption of ESG reporting standards and green-bond frameworks for data centre developers and operators.

**04**

### Advance Knowledge Sharing and Capacity Building

ASEAN can establish a regional platform for knowledge exchange on data centre sustainability, hosted under the ASEAN Centre for Energy (ACE) or the ASEAN Smart Cities Network (ASCN).

This platform could:

- Share case studies and best practices from early adopters
- Offer technical training on energy-efficiency standards, renewable-procurement design and circular-economy regulation.
- Support harmonisation of data-collection methodologies to strengthen regional comparability.

**05**

### Monitor Progress and Review

A biennial progress review coordinated by the ASEAN Secretariat and relevant sectoral bodies can measure progress against shared key indicators:

- Renewable-energy share (%) in data centre electricity supply.
- Average power-usage effectiveness (PUE) and water-usage effectiveness (WUE).
- Percentage of facilities with EPR-compliant waste management.
- Volume of verified green-finance mobilised.

Publishing results through the ASEAN Digital Integration Index and ASEAN Energy Cooperation Reports will enhance accountability and visibility of ASEAN's leadership in sustainable digital infrastructure.

# **APPENDIX A:** Stakeholder Input Survey - ASEAN Guide for Sustainable Data Centre Development

**STAKEHOLDER INPUT SURVEY – ASEAN GUIDE ON SUSTAINABLE DATA CENTRE DEVELOPMENT**

**SECTION 1 OF 8 – INTRODUCTION**

This survey supports the development of the ASEAN Guide on Sustainable Data Centre Development. It aims to gather input from ASEAN Member States to inform policy priorities, identify gaps, and shape a regionally relevant and sustainable approach to digital infrastructure.

Data centres are central to ASEAN's digital growth, but their rapid expansion poses environmental and resource challenges. This creates what we call the Digital Infrastructure Trilemma consisting of:

- Digital Expansion – Growing capacity for AI, cloud, and digital service
- Environmental Sustainability – Minimising emissions, water use, and waste
- Resilience & Resource Security – Safeguarding grids, water systems, and supply chains

Without coordinated action, progress in one area can undermine the others. This survey explores six key themes to support smart, sustainable development across the region. Your insights are critical to ensure the Guide reflects real needs and opportunities across ASEAN.

**SECTION 2 OF 8 – GENERAL INFORMATION**

*Fields marked with an asterisk (*) are mandatory.*

**Name*:** ____________________

**Organisation*:** ____________________

**Country*:** ____________________

**Sector*:**

- ☐ Government
- ☐ Regulator
- ☐ Private Sector
- ☐ Academia / Research
- ☐ Civil Society / NGO
- ☐ Other ____________________

**SECTION 3 OF 8 – ENERGY**

*Trilemma Link: Digital Expansion, Environmental Sustainability, Resilience & Resource Security*

**1. What are the current primary energy sources used by data centres in your country?**

- ☐ Grid Electricity (fossil-dominant)
- ☐ Grid Electricity (renewable mix)
- ☐ On-site solar/renewables
- ☐ Off-site renewables via Power Purchase Agreement (PPA)
- ☐ Diesel backup
- ☐ Other ______________________

**2. How does the current primary energy source align with national energy plans or decarbonisation pathways for data centres?**

**3. What is the typical or average Power Usage Effectiveness (PUE) for data centres in your country or region?**

**4. What PUE thresholds do you consider appropriate for data centres operating in your climate zone?**

**5. What off-site renewable energy procurement mechanisms are available or in use in your country?**

- ☐ Green tariffs
- ☐ Renewable Energy Certificates (RECs)
- ☐ Direct Power Purchase Agreements (PPAs)
- ☐ None ______________________

**6. What infrastructure or regulatory reforms are most needed to ensure stable, scalable, and low-carbon energy access for data centres?**

**7. To what infrastructure or regulatory reforms are most needed to ensure stable, scalable, and low-carbon energy access for data centres?**

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

(1 = Not at all, 5 = Fully mandated)

**SECTION 4 OF 8 – GREENHOUSE GAS EMISSIONS**

*Trilemma Link: Environmental Sustainability*

**1. Are national emissions inventories or carbon profiles available for the data centre sector in your country?**

- ☐ Yes
- ☐ No
- ☐ Not Sure

**2. Which emission scopes are most material in your country's data centre sector?**

- ☐ Scope 1 (e.g., diesel use, refrigerants)
- ☐ Scope 2 (purchased electricity)
- ☐ Scope 3 (upstream/downstream value chain)
- ☐ Not assessed / Unknown

**3. Which carbon accounting frameworks are adopted by the data centre sector in your country?**

- ☐ GHG Protocol
- ☐ ISO 14064
- ☐ National/Custom framework
- ☐ None currently used
- ☐ Other ______________________

**4. What policy tools or metrics would accelerate Scope 2 emissions disclosure and influence procurement or investment decisions?**

**5. Are data centre climate risks or emissions considered in your national digital infrastructure or investment promotion frameworks?**

- ☐ Yes
- ☐ No
- ☐ Not Sure

**6. How influential are national climate targets (e.g., NDCs, Net-Zero pledges) in shaping policy guidance or incentives for the data centre sector?**

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

(1 = Not at all, 5 = Highly Influential)

**SECTION 5 OF 8 – WATER MANAGEMENT**

*Trilemma Link: Resilience & Resource Security*

**1. Is Water Usage Effectiveness (WUE) tracked or benchmarked in your country's data centres?**

- ☐ Yes
- ☐ No
- ☐ Not Sure

**2. Which types of water sources are currently used for data centre cooling in your country?**

- ☐ Potable water
- ☐ Recycled/greywater
- ☐ Closed-loop systems
- ☐ Rainwater harvesting
- ☐ Other ______________________

3. **How feasible is it to scale non-potable, recycled, or closed-loop water systems for data centres across urban, peri-urban, and rural sites in your country?**

4. **What risks do data centres pose to water availability and quality in your country, especially in water-scarce or rapidly urbanising areas?**

5. **What planning or regulatory measures could help reduce the water footprint of future data centre developments?**

6. **Please share any best practices or case studies (local or international) that could inform ASEAN-level guidance on water management in data centres**

**SECTION 6 OF 8 – E-WASTE AND CIRCULARITY**

*Trilemma Link: Environmental Sustainability*

1. **What formal or informal mechanisms exist for e-waste recovery, refurbishment, or safe disposal in your country?**

**2. Are Extended Producer Responsibility (EPR) schemes or take-back programmes applied to ICT or data centre components?**

- ☐ Yes
- ☐ No
- ☐ Not Sure

**3. How aware are data centre developers and ICT suppliers in your country of circular economy principles?**

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

(1 = Not aware at all, 5 = Highly aware and engaged)

**4. What infrastructure or regulatory gaps currently limit the recycling or material recovery of high-impact components (e.g., batteries, servers, cables)?**

**5. Which international best practices in ICT or e-waste management could be adapted for your national context?**

- ☐ EU WEEE Directive
- ☐ Japan’s Home Appliance Recycling Law
- ☐ Singapore’s Resource Sustainability Act
- ☐ Other ____________________

**SECTION 7 OF 8 – REGULATORY AND POLICY FRAMEWORKS**

*Trilemma Link: Digital Expansion, Environmental Sustainability, Resilience & Resource Security*

**1. Which of the following best describes the current state of sustainability policies for data centres in your country?**

- ☐ Enforceable and specific to data centres
- ☐ Broad ICT or infrastructure-level environmental policies (not data centre-specific)
- ☐ Sustainability covered under general EIA or building regulations
- ☐ No formal sustainability requirements for data centres
- ☐ Not sure

**2. Please describe any national data centre sustainability policies in your country:**

**3. How do these policies compare to those in neighbouring ASEAN Member State?**

**4. How well are sustainability-related regulatory mandates (e.g., energy, water, ICT, construction) coordinated in your country?**

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

(1 = Not coordinated at all, 5 = Fully integrated)

**5. Where do coordination gaps or regulatory silos most commonly occur in your national data centre governance?**

**6. Which policy instruments are currently used or would be most effective in promoting sustainable data centre development in your country**

☐ Green permitting schemes
☐ Climate-aligned investment incentives
☐ Environmental licensing tied to energy/water performance
☐ Land-use zoning or building codes
☐ None in place
☐ Other ______________________

**7. How aligned is your country's current policy guidance with international frameworks such as ISO/IEC 30134, the EU Code of Conduct for Data Centres, or Singapore's SS 564?**

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

(1 = Not aligned at all, 5 = Fully aligned)

**8. What ASEAN-wide voluntary principles or sustainability standards would be useful to reduce regulatory gaps and support cross-border investment in green data centres?**

**SECTION 8 OF 8 – BEST PRACTICES AND ENABLING TECHNOLOGIES**
*Trilemma Link: All three pillars*

**1. Which of the following sustainable technologies are currently being explored, piloted, or deployed in your country's data centre sector?**

- ☐ Immersion cooling
- ☐ AI-enabled thermal management
- ☐ Modular or edge data centres
- ☐ Grid-interactive or demand-responsive systems
- ☐ None
- ☐ Other ____________________

**2. How widely are green certifications or standards (e.g., LEED, ISO 50001, Green Mark) adopted in the data centre sector in your country**

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

(1 = Not adopted, 5 = Widely adopted)

**3. Which of the following enabling factors are most important for scaling best practices in your country?**

- ☐ Public financing or incentives
- ☐ Skills development / technical training
- ☐ Regulatory clarity or incentives
- ☐ GPublic–private partnerships
- ☐ Pilot or demonstration projects
- ☐ Other ____________________

**4. How can your country better support public–private collaboration to localise, pilot, or scale innovative solutions for sustainable data centres?**

**5. What type of regional knowledge-sharing platform or mechanism would help accelerate the adoption of sustainable solutions across ASEAN**

# ASEAN GUIDE FOR SUSTAINABLE DATA CENTRE DEVELOPMENT

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