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Regulating Water Consumption by AI Data Centers in Pakistan: An Environmental Law Framework for Sustainable Liquid-Cooling Technologies

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Abstract

The expansion of artificial intelligence (AI) is increasing demand for high-density computing infrastructure and advanced thermal-management systems. Although the environmental debate surrounding data centres has focused heavily on electricity and carbon emissions, water consumption is an increasingly important issue because cooling can require substantial quantities of water, often in locations where water resources are already under pressure. The legal problem is particularly relevant to Pakistan, where environmental and water governance is distributed across constitutional, federal, provincial, policy and technical instruments. This article examines whether Pakistan's existing framework can adequately regulate water consumption by AI-intensive data centres, with particular attention to liquid-cooling technologies. It uses doctrinal legal research and comparative regulatory analysis of Pakistan's environmental and water instruments alongside ISO/IEC 30134-9:2022, ASHRAE guidance and the European Union's data-centre sustainability framework. The analysis finds that Pakistan does not have an absence of environmental regulation; rather, it has a sector-specific regulatory gap. Existing instruments address environmental assessment, water conservation, groundwater protection, building water efficiency and, more recently, data-centre efficiency within the Pakistan Green Taxonomy, but they do not yet form a coherent regime requiring data centres to measure and disclose water consumption, identify water sources, assess cooling-system water risks and apply standardized water-performance requirements. The article proposes a water-risk-based framework built around Water Usage Effectiveness (WUE), absolute water-use reporting, source controls, groundwater safeguards, cooling and heat-rejection assessment, water reuse, location-sensitive permitting, verification and enforcement. The framework deliberately avoids prescribing liquid cooling as a universally superior technology. Instead, it regulates the environmental performance of the complete thermal-management system. The article concludes that integrating existing Pakistani environmental and water principles with internationally recognized data-centre metrics can provide a legally practicable basis for supporting AI infrastructure while protecting water resources.

Keywords: *artificial intelligence, data centres, environmental law, Pakistan, water consumption, Water Usage Effectiveness, liquid cooling, groundwater, sustainable cooling, Environmental Impact Assessment (EIA), Initial Environmental Examination (IEE)*

1. Introduction

Artificial intelligence is increasing the computational intensity of digital services and accelerating investment in high-performance computing infrastructure. Modern AI systems depend on dense servers, graphics processing units and other accelerators that generate substantial heat during operation. As rack densities increase, thermal management becomes a central infrastructure issue rather than a secondary engineering function. Data centres therefore have environmental impacts that extend beyond electricity consumption to water use, land, materials and local resource demand (Masanet et al., 2020; International Energy Agency [IEA], 2025).

Water deserves particular attention because its environmental effects are spatially concentrated. Data centres may consume water directly through cooling systems and indirectly through electricity generation. Direct consumption can occur through cooling towers, evaporative systems and other processes in which water is lost from the facility, while indirect consumption occurs at power-generation facilities supplying electricity to the data centre (Mytton, 2021; Ristic et al., 2015). These pathways should not be treated as interchangeable. A facility can have low direct water use but operate on an electricity system with substantial water requirements, while another facility may have a large direct cooling-water demand.

The scale of the issue is demonstrated by recent research. Lawrence Berkeley National Laboratory estimated direct water consumption by United States data centres at approximately 66 billion liters in 2023 and projected substantial growth by 2028 under modeled scenarios (Shehabi et al., 2024). These estimates concern the U.S. data-centre sector as a whole and are not measurements of AI-only facilities; they therefore cannot be applied directly to Pakistan. Their significance lies instead in demonstrating how data-centre water demand can become a material infrastructure issue as computing capacity expands.

AI adds another layer of complexity. Li et al. (2025) show that AI's water footprint includes onsite cooling as well as water associated with electricity generation and that the footprint varies with location, infrastructure and operational conditions. Lei et al. (2025) similarly report more than 10,000-fold variation in workload-level water use. Their analysis identifies server efficiency, electricity-related water factors, server utilization, cooling technology, infrastructure efficiency, climate zone, inactive servers and hardware refresh cycles as major determinants. These findings weaken any simplistic assumption that a particular cooling technology or a single water threshold can be optimal everywhere.

Liquid cooling has consequently become important for AI data centres. Compared with air cooling, liquid-based approaches can transfer heat more efficiently and support higher-density computing. ASHRAE's thermal guidance recognizes multiple liquid-cooling classes and identifies operating conditions under which higher liquid supply temperatures can reduce dependence on mechanical refrigeration and facilitate more efficient heat rejection (ASHRAE, 2021, 2023). Yet liquid cooling is not synonymous with zero-water cooling. A closed-loop coolant system at the chip or rack level can still rely on an evaporative cooling tower at the facility level. By contrast, liquid cooling combined with dry heat rejection can substantially reduce operational water consumption. The environmental result therefore depends on the complete cooling chain.

This development creates a regulatory question for Pakistan. Pakistan already has a broad environmental framework, national water policy, climate policy, a Green Building Code and, since 2025, a Green Taxonomy that includes data-centre efficiency among ICT

activities. These instruments perform different functions. Environmental legislation establishes approval and enforcement mechanisms; water policy establishes principles of conservation and sustainable groundwater use; the Green Building Code contains water-efficiency and metering provisions; and the Green Taxonomy is primarily a classification framework for sustainable finance. They do not yet constitute a single regulatory system specifically designed to manage the water footprint of AI-intensive data centres (Government of Pakistan, 1997, 2018, 2021; Pakistan Engineering Council [PEC], 2023; Ministry of Climate Change and Environmental Coordination [MoCC&EC], 2025).

The latest sector-wide figure identified for Pakistan is provided in the *OICCI Digital Report 2025*, published in 2026. It records 22 data centres in the country: 10 in Karachi, 8 in Lahore and 4 in Islamabad (Overseas Investors Chamber of Commerce and Industry [OICCI], 2026). The report further identifies both private and public-sector operators and documents the emergence of AI-oriented infrastructure, including an AI-focused, solar-powered data centre in Karachi. The geographical concentration of these facilities is important from an environmental-law perspective because Karachi, Lahore and Islamabad differ in their climatic conditions, water-supply systems, groundwater characteristics and broader environmental pressures. The reported number should be understood as the latest sector-wide published industry figure rather than as a statutory national registry, since Pakistan does not currently maintain a single consolidated register of all data-centre facilities.

The growing number of facilities also raises an immediate legal question concerning environmental approval. Under the Pakistan Environmental Protection Act, 1997, environmental assessment is not optional for projects falling within the statutory assessment framework. Section 12 requires a project proponent to submit an Initial Environmental Examination (IEE) or, where the project is likely to cause an adverse environmental effect, an Environmental Impact Assessment (EIA) and to obtain the requisite approval before construction or operation (Government of Pakistan, 1997). The important legal distinction is therefore between a mandatory environmental approval and a mandatory full EIA for every data centre. The latter does not automatically follow merely because a project is classified as a data centre.

The research problem is therefore not a complete absence of law. It is a problem of regulatory integration: broad environmental and water principles have not been fully translated into measurable, enforceable and location-sensitive obligations for AI data-centre water use. This article asks:

1. What legal and policy foundations already exist in Pakistan for regulating data-centre water use?
2. What regulatory lessons can be taken from international water and cooling standards?
3. What environmental-law framework can integrate those principles into a workable Pakistani model?

2. Methodology

The study uses doctrinal legal research combined with comparative regulatory analysis. Primary materials include the Constitution of Pakistan, the Pakistan Environmental Protection Act, 1997, environmental assessment regulations, the National Water Policy 2018, the National Climate Change Policy 2021 and the Green Building Code of Pakistan 2023. The analysis also considers the Pakistan Green Taxonomy 2025 because it provides a recent national sustainability classification for ICT activities.

The comparative component examines ISO/IEC 30134-9:2022 on WUE, ASHRAE thermal guidance on liquid-cooled equipment and Commission Delegated Regulation (EU) 2024/1364 on data-centre sustainability reporting. Scholarly and institutional literature is used to interpret water footprints and cooling technologies.

The study is normative rather than empirical. It does not claim to measure water consumption of Pakistani AI data centres because verified facility-level operational datasets are not publicly established in the sources reviewed. Consequently, international quantitative estimates are used as evidence of the regulatory problem, not as proxies for Pakistani consumption.

3. AI Data Centres and the Water-Consumption Problem

Data-centre water use should be understood through both facility-level and system-level pathways. Direct water consumption typically arises when water is evaporated or otherwise removed from immediate reuse in cooling or associated operations. Indirect water consumption can occur through electricity production, particularly where thermal power generation requires cooling water. Mytton (2021) emphasizes that the sector has historically had limited transparency on these quantities and that reporting practices have varied across operators.

Ristic et al. (2015) demonstrated that the water footprint of data centres depends strongly on both cooling design and electricity supply. This matters for law because a regulatory standard that examines only onsite cooling can understate the environmental footprint of facilities located on water-intensive electricity systems. At the same time, indirect water estimates are more difficult to attribute to a particular facility and may involve assumptions about the electricity mix. A practical first-generation legal regime should therefore focus on measurable onsite water use while requiring disclosure of electricity sources as contextual information.

Recent evidence confirms substantial variability. Lei et al. (2025) identify more than 10,000-fold variation in workload-level water use, driven by technical and locational factors. Li et al. (2025) likewise emphasize that AI water footprints vary across time and geography. WUE is therefore useful for comparison, but it should be combined with absolute water volumes and source information because a low-intensity facility can still consume large quantities of water.

The U.S. evidence illustrates why this distinction matters. Shehabi et al. (2024) estimate direct water consumption by U.S. data centres at 66 billion liters in 2023. The figure is modeled and sector-wide, not AI-specific. Its relevance to Pakistan is methodological rather than quantitative: a regulatory framework should be in place before infrastructure expansion makes water reporting difficult to establish retrospectively.

4. Liquid Cooling: Technical Opportunity and Regulatory Challenge

Liquid cooling moves heat using a liquid medium rather than relying entirely on air as the primary heat-transfer medium. Direct-to-chip systems, rear-door heat exchangers and immersion-based approaches are among the technologies relevant to high-density computing. ASHRAE (2021, 2023) recognizes several liquid-cooling classes and provides environmental conditions for liquid-cooled IT equipment.

The potential environmental advantage is not simply that liquid absorbs heat more effectively. Higher-temperature liquid loops can increase opportunities for economization and reduce the need for low-temperature chilled water. In suitable climates, this may reduce mechanical refrigeration and associated energy demand (ASHRAE, 2023). Aili et al. (2024)

similarly found, using physics-based modeling, that free-cooling configurations can produce substantial energy or water savings depending on system integration; one configuration produced an annual average water-saving potential of about 84%.

However, server-level cooling and facility-level heat rejection must be distinguished. A liquid can circulate in a closed loop with little direct loss while the facility nevertheless rejects heat through a cooling tower that consumes makeup water. This means that a legal rule saying "liquid cooling is water efficient" would be too general. The relevant regulatory unit is the complete cooling and heat-rejection system.

This also supports a technology-neutral approach. Lei et al. (2025) conclude that there is no single recipe for minimizing data-centre water use under all site and workload conditions. Environmental law should therefore establish performance obligations and require applicants to demonstrate why a proposed cooling design is appropriate for the specific site.

5. Pakistan's Existing Environmental and Water Framework

Pakistan's legal foundation is broader than the current sector-specific debate sometimes suggests. The Constitution (Twenty-Sixth Amendment) Act, 2024 inserted Article 9A, providing that every person is entitled to a clean, healthy and sustainable environment. The provision creates an express constitutional basis for environmental protection and strengthens the legal relevance of sustainability in infrastructure decisions (Constitution of the Islamic Republic of Pakistan, 1973; Constitution (Twenty-Sixth Amendment) Act, 2024).

The Pakistan Environmental Protection Act, 1997 established the principal environmental protection framework, including environmental assessment and enforcement mechanisms. The 2000 IEE/EIA Regulations identify projects subject to environmental examination and provide procedures for review. Environmental assessment can therefore provide an institutional entry point for considering data-centre water impacts (Government of Pakistan, 1997; Pakistan Environmental Protection Agency, 2000). Following devolution, provincial authorities are central to environmental approval and enforcement, making nationally consistent minimum requirements important.

The National Water Policy 2018 provides a stronger substantive basis. It describes Pakistan's emerging water crisis and establishes principles of conservation, sustainable management, groundwater protection, demand management, environmental integrity and stakeholder participation. It specifically recognizes groundwater as an important resource requiring protection from pollution and unsustainable abstraction and calls for stronger monitoring and management of abstraction at sustainable levels (Government of Pakistan, 2018).

The National Climate Change Policy 2021 supports water conservation, groundwater protection and wastewater treatment, recycling and reuse, which are relevant to reducing dependence on potable cooling water (Government of Pakistan, 2021). The Green Building Code of Pakistan 2023 adds water-efficiency, metering and monitoring provisions and prohibits once-through cooling with potable water. These provisions show that domestic technical rules already provide building blocks for data-centre water regulation (PEC, 2023). The Pakistan Green Taxonomy 2025 also recognizes data-centre efficiency under the ICT sector, but it is primarily a sustainable-finance classification framework rather than an operational water regulation (MoCC&EC, 2025).

5.1 Data-Centre Environmental Assessment and EIA Status

The presence of 22 data centres makes the question of environmental assessment particularly relevant. The *OICCI Digital Report 2025* identifies 10 facilities in Karachi, 8 in Lahore and 4 in Islamabad (OICCI, 2026). However, the existence of these facilities does not by itself establish whether each is required to undergo a full EIA.

Section 12(1) of the Pakistan Environmental Protection Act, 1997 provides that no project proponent may commence construction or operation unless an IEE has been filed or, where the project is likely to cause an adverse environmental effect, an EIA has been filed and the required approval obtained (Government of Pakistan, 1997). Thus, environmental approval is a mandatory legal requirement, but a full EIA is not automatically mandatory for every data centre.

Under the federal Pakistan Environmental Protection Agency (Review of IEE and EIA) Regulations, 2000, projects listed in Schedule I are subject to IEE and projects listed in Schedule II require EIA. The regulations also provide a mechanism through which the competent agency may require assessment for an unlisted project where it is likely to cause an adverse environmental effect (Pakistan Environmental Protection Agency, 2000). Significantly, "data centre" is not expressly identified as a standalone project category in the federal schedules. The same regulatory issue arises in the provincial framework. Punjab's environmental assessment regulations, for example, establish schedules for projects requiring IEE or EIA and retain provision for assessment of projects that may cause adverse environmental effects (Government of the Punjab, 2022). Sindh follows its own environmental assessment regulations under the Sindh Environmental Protection Agency framework (Government of Sindh, 2014).

Accordingly, the correct legal conclusion is not that Pakistan's data centres are exempt from environmental assessment, nor that all 22 facilities must necessarily have undergone a full EIA. The applicable obligation depends on the characteristics of the individual project, its classification, associated infrastructure, location, environmental sensitivity and the determination of the competent environmental authority. A large facility may also contain components—such as major power-generation, water-treatment, waste-management or other infrastructure—that independently trigger environmental assessment requirements.

The publicly accessible material reviewed for this article does not provide a consolidated IEE/EIA compliance register showing the environmental approval status of all 22 data centres identified by OICCI. It would therefore be methodologically and legally inappropriate to claim that all existing data centres have obtained EIA approval or, conversely, that they are operating without the legally required approval. Establishing compliance would require examination of project-specific records maintained by the relevant federal or provincial environmental authority. This lack of consolidated sector-specific visibility nevertheless strengthens the case for a dedicated data-centre registration and environmental-monitoring mechanism.

6. The Regulatory Gap

The Pakistani framework contains relevant environmental and water principles, but these operate in separate institutional and regulatory channels. Environmental approval addresses project impacts; water policy addresses sustainable management; the Green Building Code addresses building water efficiency; and the Green Taxonomy supports sustainable investment classification. None, in the reviewed framework, functions as a

dedicated data-centre water-performance regime comparable to international arrangements that expressly define and report WUE.

The resulting gap is therefore precise: Pakistan lacks an integrated sector-specific mechanism that connects environmental approval with standardized measurement of data-centre water consumption, source disclosure, cooling-system assessment, groundwater safeguards and continuing performance monitoring.

This is not merely a reporting problem. Without standardized data, regulators cannot readily compare facilities, set location-sensitive permit conditions, assess cumulative demand or determine whether a facility's proposed water use is consistent with local resource constraints. The legal contribution of this article is consequently to translate existing principles into a coherent regulatory architecture rather than proposing a wholly separate environmental statute.

7. International Regulatory Benchmarks

7.1 ISO/IEC 30134-9:2022

ISO/IEC 30134-9:2022 establishes Water Usage Effectiveness as a key performance indicator for quantifying water consumption during the use phase of a data centre. It defines measurement categories and provides a consistent basis for calculation and reporting (ISO, 2022). In practical terms, WUE relates annual data-centre water consumption to IT equipment energy use, commonly expressed in liters per kilowatt-hour.

Its value for Pakistan is standardization. A regulator needs a common methodology if reported water data are to be comparable. However, WUE should not become the sole regulatory measure because it does not, by itself, indicate the sustainability of the water source or the absolute quantity consumed.

7.2 European Union

The European Union provides a useful example of reporting-based regulation. Commission Delegated Regulation (EU) 2024/1364 establishes sustainability indicators for covered data centres, including PUE, WUE, energy reuse and renewable-energy factors. It requires WUE to be calculated from water input and IT energy and provides for aggregated public reporting (European Commission, 2024).

The European model demonstrates that water measurement can be embedded in data-centre regulation rather than treated as voluntary corporate reporting. Pakistan can adapt this principle without copying the European institutional structure.

7.3 ASHRAE

ASHRAE provides the technical reference needed to connect regulation with actual cooling engineering. Its liquid-cooling guidance recognizes different supply-liquid temperatures and corresponding opportunities for system design and heat rejection (ASHRAE, 2021, 2023). The technical lesson is that cooling should be assessed as a system: IT-side liquid temperature, heat exchangers, chilled-water requirements, economization, cooling towers and dry coolers all affect water performance.

8. Proposed Environmental Law Framework for Pakistan

A practical regulatory framework should use existing institutions and add sector-specific conditions. Six core requirements are proposed.

First, Water Sustainability Assessment. Covered AI data centres should prepare a Water Sustainability Assessment at the environmental-approval stage. The assessment should

state projected annual withdrawal, consumption, peak demand, water sources, groundwater dependence, cooling architecture, expected WUE, reuse opportunities and local water risks.

Second, mandatory WUE measurement. WUE should become a required operational metric. The ISO/IEC 30134-9 methodology should be adopted through regulation, technical guidance or permit conditions. WUE should be accompanied by absolute annual water consumption because efficiency alone does not show total resource pressure.

Third, water-source reporting. Operators should separately report potable water, groundwater, surface water and reclaimed or other non-potable sources. Routine use of potable water for cooling should be restricted where a technically viable non-potable alternative exists.

Fourth, groundwater controls. Facilities using groundwater should provide metering, baseline groundwater information, lawful abstraction documentation and a monitoring plan. This would operationalize the National Water Policy's emphasis on sustainable abstraction.

Fifth, cooling-design assessment. Applicants should demonstrate that the proposed system has been assessed against feasible alternatives, including air cooling, direct-to-chip liquid cooling, rear-door systems, immersion where relevant, dry heat rejection, evaporative systems and hybrid configurations. The regulatory question should be whether the chosen configuration provides acceptable combined water, energy and environmental performance for the proposed location.

Sixth, continuing verification. Water meters should record operational data at defined points, while larger or higher-risk facilities should undergo independent verification. Permit conditions should establish reporting frequency and corrective-action procedures.

9. Location-Sensitive Water Regulation

The proposed framework should avoid a uniform national water threshold from the outset. The environmental meaning of a liter of water depends on where it is withdrawn, when it is withdrawn and whether the source is under stress.

A location-sensitive approach would classify proposed sites using available information on groundwater condition, surface-water reliability, municipal supply constraints, drought exposure and competing demand. The same WUE value could therefore lead to different permit conditions in different locations.

This approach is consistent with evidence that workload-level water consumption is shaped by climate and infrastructure conditions (Lei et al., 2025). A threshold developed from one climate or water system should not automatically become a universal Pakistani limit.

A staged model is preferable. During an initial period, regulation should focus on disclosure and data collection. Once a national evidence base is established, regulators could develop differentiated benchmarks and, later, enforceable performance limits based on water-risk categories.

10. Water Reuse and Circularity

Water reuse should be a central mitigation principle. Where treatment and public-health safeguards permit, data centres should assess reclaimed municipal wastewater, treated industrial water, condensate recovery and other suitable non-potable sources. The objective should be to reduce dependence on potable freshwater and minimize losses from once-through systems.

Pakistan's Green Building Code already demonstrates that water metering, monitoring and restrictions on once-through potable cooling can be incorporated into domestic technical

standards (PEC, 2023). A data-centre regulation could build on this domestic experience rather than introducing an entirely foreign model.

Reuse should nevertheless be based on technical feasibility. Reclaimed water can require additional treatment and may create corrosion, fouling or microbiological risks if not properly managed. Environmental regulation should therefore require water-quality controls rather than simply mandating reuse irrespective of engineering conditions.

11. Disclosure, Enforcement and Institutional Design

Transparency should be treated as a regulatory tool. Covered facilities should submit annual information on total withdrawal, total consumption, WUE, potable-water use, groundwater abstraction, reclaimed-water use and major cooling-system changes. Data should be sufficiently standardized to permit regulatory comparison while protecting genuinely sensitive security or commercial information.

Existing environmental institutions can implement much of this framework. Federal authorities can develop minimum national guidance and coordinate technical standards; provincial environmental agencies can incorporate water conditions into environmental approvals and monitor compliance; relevant water authorities can address abstraction and source legality; and operators can be made responsible for measurement and disclosure.

Enforcement should connect reported performance to permit conditions. Non-compliance could trigger notice, corrective action, administrative penalties and, where authorized by law, restrictions or suspension of operations. The key principle is that water reporting should not be merely an aspirational ESG exercise. Where water conditions are incorporated into an environmental approval, they should become enforceable obligations.

12. Discussion

The analysis supports a performance-based rather than technology-based model. Liquid cooling may improve thermal management, but its water implications depend on the complete heat-rejection system. WUE is useful for benchmarking but cannot substitute for information on absolute consumption, water source and local stress. Pakistan's existing instruments already supply important components; the regulatory need is to connect them through enforceable data-centre conditions. Because transparent Pakistani facility-level data are limited, disclosure should precede the introduction of rigid national WUE limits. This staged approach is consistent with international evidence showing substantial variation among sites and workloads (Lei et al., 2025).

13. Conclusion

The environmental footprint of AI infrastructure includes water as well as electricity and carbon. International research shows that data-centre water use varies with cooling configuration, electricity systems, server efficiency, climate and infrastructure.

Pakistan already has relevant building blocks: the constitutional environmental right, environmental assessment law, the National Water Policy 2018, National Climate Change Policy 2021, Green Building Code 2023 and Pakistan Green Taxonomy 2025. The main deficiency is their lack of integration into a dedicated data-centre water-performance regime.

The proposed framework connects these instruments through WUE measurement, absolute water-use reporting, source disclosure, groundwater protection, cooling-system assessment, reuse, location-sensitive permitting and verification. It does not prescribe liquid cooling as universally superior; it regulates the performance of the complete thermal-management system. A staged approach beginning with measurement and disclosure would

allow Pakistan to develop evidence-based limits while protecting water resources as AI infrastructure expands.

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