



Towards a Reflexive Infrastructure

Partnership with AI in green data centers and green infrastructure development

Abstract

Artificial intelligence now sits at the core of global infrastructure design, financing, construction, and operation. Yet the same technology that promises efficiency everywhere else also demands unprecedented energy and material inputs.

Over 2020–2025, investment in data-center capacity has surged into the hundreds of billions of dollars worldwide, reshaping land use, grid planning, and climate policy, and raising questions of data sovereignty controls, national industrial priorities and cross-border investments and capital flows.¹

To be sustainable, AI must itself become reflexive — able to measure, predict, and reduce the environmental footprint of its own digital infrastructure. Partnering with AI in this will bring benefits to other types of digital infrastructure including smart city systems.

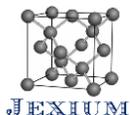
1. Context and Motivation:

AI now plays a critical role in planning, financing, and operating complex infrastructure, from engineering studies, ‘digital twins’, financial modelling and project management to post-COD operations & maintenance. Yet AI model training and inference require massive amounts of “compute”, placing significant pressure on power grids and water systems. Data centers, once just passive digital warehouses or the nexus of “compute”, have themselves become active components of complex energy and climate systems.

Global data center build-out is now perhaps the defining capital allocation trend of this decade. North America and APAC countries lead with hundreds of billions in announced spend, and global pipelines exceeding several trillion USD are now under construction.

Industry sources (see Annexe A) suggest that in 2025 alone, roughly 10 gigawatts (GW) of new hyperscale and colocation capacity will break ground worldwide, with a further 7 GW reaching completion. That represents on the order of \$170 billion in assets seeking development or permanent financing in a single year. Asia Pacific is widely described as a \$100+ billion construction

¹ Annexe A summarises regional investment and build-out trends in data-centre infrastructure 2020 to 2030.



wave and an \$800 billion opportunity this decade, while the United Kingdom has seen tens of billions of dollars in announced AI data center investments, including a £3.9B 1.6 GW project in Scotland.

In the rush to build, however, some issues of sustainability are being overlooked, but it is the position of this paper that AI itself holds the key to the sustainability of its host infrastructure.

To achieve genuine sustainability, AI digital infrastructure such as data centers must evolve toward **reflexive systems**—platforms that continuously measure, predict, and improve their own environmental performance. *The infrastructure of AI must become intelligent about infrastructure.*

As AI reshapes how we plan, finance and build our physical world, its own footprint in terms of energy, water, and heat has become part of the climate challenge. If data centers are the new factories of the 21st century, they must evolve into **reflexive systems** that continuously optimize their own energy and water consumption, wastewater, heat and CO₂ emissions, and overall resilience, seeking to be as circular as possible. This paper outlines a framework for achieving this, combining AI, green finance, and sustainable infrastructure development, with AI as a fellow architect and steward of a low-carbon digital world.

2. Conceptual Framework:

This framework identifies three mutually reinforcing layers:

A. Cognitive Layer – Intelligent Sensing and Prediction

- AI models analyse power imported from the grid, onsite power generation (e.g., of embedded onsite solar plants and battery storage systems), power consumption, power usage effectiveness (PUE), cooling dynamics, water use, heat and exhaust emissions.
- Digital twins simulate the environmental behaviour of data centers and grid interactions.

B. Operational Layer – Adaptive Optimization: Reinforcement-learning algorithms dynamically shift workloads to low-cost / low-carbon time periods and optimize cooling and battery storage.

- AI agents coordinate distributed networks of data centers for maximum efficiency and minimal emissions.

C. Governance Layer – Data Integrity and Transparency

- Automated resource-use and emissions accounting and reporting are embedded in system operations.
- Transparent, auditable metrics enabling regulators, investors, and consumers to track true sustainability performance.

Taken together and integrated, these layers will form a **reflexive loop** where AI continuously refines the energy and carbon performance of its host infrastructure.

3. Application Domains:

- A. **Green Data centers:** AI-optimized energy flows, thermal management, and renewable-integration scheduling.
- B. **Grid and Energy Systems / Use:** Predictive analytics for balancing renewable variability and demand from AI workloads, capture of heat emissions for circular energy generation.
- C. **Urban Infrastructure:** AI-driven resource efficiency in water, transport, and waste systems using shared computing platforms, with AI embedded in smart-city systems that network and control traffic lights, streetlights, electric road signage, emergency response dispatch, public facility security systems, air quality and water quality monitoring, etc.²
- D. **Project Preparation and Finance:** Use of AI-powered project portfolio management systems to develop, evaluate, structure, arrange financing for and monitor green infrastructure investments.
- E. **Extending Reflexivity to Corporate AI Systems:** While data centres represent the most visible node of AI's environmental footprint, the principle of reflexive infrastructure can extend across most corporate operations. Industrial and manufacturing AI systems — in sectors such as food processing, electronics, and logistics — can be designed to measure and mitigate their own energy and material use and emissions. For example, an AI managing process optimisation in a chocolate factory or electronics assembly line could incorporate internal sustainability metrics into its reward function, ensuring that production efficiency gains are balanced against emissions, energy and water consumption, and waste generation. In this way, corporate AI deployments become active participants in the improved sustainability and decarbonisation of their host industries, mirroring the self-regulating ethos of sustainable data centres.

4. Enabling Technologies:

Some of the key enabling components of which we are aware today include:

- A. **Semantic knowledge graphs**³ that link infrastructure assets with sustainability data;
- B. **Natural-language inquiry** and retrieval to surface best practices; and
- C. **Multi-agent coordination** across energy, water / cooling, and cloud systems.

² Prototypes of these smart reflexive systems have been developed and applied in 'smart' networked district heating and cooling systems, e.g., in Malmö, Sweden.

³ Digital maps that connect data points such as technologies, projects, financiers, impacts, and development outcomes through defined relationships. Using these, AI systems can recognise context, meaning, and demonstrable chains of causality, allowing optimisation of high-level precursor options and stronger management-by-results.

Emerging tools in edge AI⁴, renewable-predictive modelling⁵ and other areas with which we are not yet familiar or even aware will underpin next-generation ‘self-optimizing’ data centers and green digital infrastructure. Some of these approaches and systems will be AI-designed.

5. Public Policy Implications:

Implementing this framework will move faster if the public sector is actively engaged in:

- A. **Setting Standards:** Development of shared benchmarks and operating standards for sustainable AI operations (carbon, water, materials).
 - B. **Balanced Zoning:** Regulations which acknowledge and mitigate the environmental and social impact of large data centers on their host communities and their local governments.
 - C. **Creating Incentives:** A system to monitor and reward (e.g., through tax incentives) measurable digital infrastructure resource-use minimization and decarbonization.
 - D. **Forging Partnerships:** Collaboration among technology firms, utilities, investors and lenders, and public agencies to align digital and climate goals.
 - E. **Building Capacity:** Through training programs and knowledge-sharing that build interdisciplinary expertise in AI, data governance, sustainability analytics, systems engineering, sustainable/green infrastructure project preparation, development, and financing, as well as other relevant fields
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6. The Global Dimension:

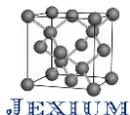
AI and the construction of data centers to host it are fully global already, with large investments and data center build-out taking place at a breakneck speed in North America, Asia, Oceania, the UK and Europe. Annex A provides an indicative breakdown of AI and other data center projects in key regions.

7. Financing Implications:

None of the concepts presented here require specialized financing approaches – data centers are industrial projects which can and are being financed rapidly using standard corporate and project

⁴ *Edge* refers to the “edge” of the network: devices, sensors, or local servers where data is generated (for example, a wind turbine controller, an irrigation sensor, or a traffic-light hub). *Edge AI* means those devices can analyze and act locally, instead of sending everything to a data center.

⁵ This refers to AI systems that forecast renewable energy generation and optimize its integration into grids or microgrids. Predictive models use historical and real-time data (satellite, weather, demand, etc.) to forecast production minutes, hours, or days ahead to manage battery storage and reduce the need for fossil-based “backup” generators.



finance approaches. Public sector agencies, regulators, and local governments may seek to use “blended financing”⁶ to facilitate and “crowd in” private investment in the greenest data centers.

8. Toward Reflexive Infrastructure:

The future of sustainable infrastructure depends on systems that *learn how to achieve, monitor, and sustain their “greenness”*. AI must become not only a tool for optimizing other sectors but also a custodian of its own ecological footprint.

By embedding adaptive AI into the heart of data center and infrastructure design, we can ensure that the digital transition reinforces—not undermines—the green transition. These lessons can be applied to a wide range of digital and networked infrastructure as well, on a smaller scale, to IoT⁷-networked devices in industry and smart cities.

9. A Way Forward:

Realizing the promise of reflexive infrastructure will require cross-sector experimentation but can begin with piloting concrete applications in ongoing projects. Governments, utilities, data center investors and lenders, and technology developers can jointly pilot AI-enabled data center and infrastructure models that learn from their own operational footprints.

Early applications could link renewable micro-grids, district heating and cooling systems, and AI data platforms capable of real-time sustainability reporting. Over time, these self-optimizing systems can serve as standard-bearers in a new *reflexive* green digital infrastructure—proof that artificial intelligence, properly guided and integrated, can become a valued partner in both the architecture *and* the stewardship of a low-carbon built environment.

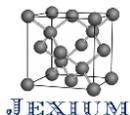
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⁶ Using public funds to reduce risk or cost to borrowers by including lower-cost concessional (public) funds in a bundled transaction which also includes market-rate private financing.

⁷ “IoT”: Internet of Things.

Annexe A – Indicative Data-Center Investment / Construction Trends 2020-2030 (see endnotes for sources):

Region	2020-22 (realised)	2023-25 (committed/under construction)	2026-30 (indicative pipeline)
North America	Hundreds of billions USD cumulative; major hyperscale campus deals announced	Large-scale AI/data-centre campus deals (\$10 B+), institutional capital stampeding	Billions per year required; US share of ~\$6-7 T global compute capex
United Kingdom	Tens of billions USD of commitments by cloud/AI firms; multiple multi-billion sites	UK rapidly increasing planning & grid access approvals for hyperscale	Sustained double-digit-billion annual spend expected as UK positions for AI compute hub
Rest of Europe	Continued hyperscale builds across Germany, Nordics, Iberia	Multi-billion Euro programs under way; EU digital/AI infrastructure push	Pipeline tied to EU AI & digital sovereignty targets, tens of billions annually
China	Large domestic cloud/AI/hyperscale build-out; state & private capital combined	Massive expansions; less transparent, but major share of global capacity	Continued rapid growth in AI-data infrastructure; leading share of APAC build
India	Emerging hyperscale/edge build-out; multi-billion-USD annual announcements post-2023	Accelerating growth across major metros; cloud/AI firms investing	Strong pipeline as digital-sovereignty and AI localisation push accelerate
ASEAN (Southeast Asia)	Starting from a lower base; expanding regional interest in data centres, particularly in southern Malaysia and Singapore	USD ~\$13.7 B market value in 2024; projected ~30 B by 2030	Strong growth trajectory (CAGR ~14 %); larger regional pipelines emerging

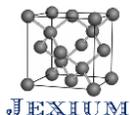


Rest of Asia Pacific (incl. Australia/NZ, Japan, Republic of Korea)	Strong activity in Rep. of Korea, Japan, Australia despite some land-power-grid limitations	APAC > \$100 B planned 2023-25; region seen as ~\$800 B opportunity this decade	Continued growth; APAC forecast to overtake US in co-location capacity by ~2030
Latin America / Middle East / Africa	Smaller but rising; hundreds of millions to low billions per campus	Early hyperscale/edge deals in MENA, South America; rising localisation	Emerging market growth driven by renewables + data-sovereignty + edge compute
Global Total	Capacity growth ~17.7 % in 2025; global build financing ~\$170 B in 2025	Global compute/dc capex required ~\$6.7 T by 2030; AI workload infrastructure ~\$5.2 T	Massive investment wave; multi-trillion USD global pipeline, infrastructure risk + opportunity

Endnotes / Sources:

The following references were used to compile Annexe A. They represent a cross-section of publicly available market analyses, industry briefings, and official announcements from 2024–2025. The data are directional rather than definitive, reflecting trends in capital expenditure, geographic distribution, and policy focus across the global data center and AI infrastructure ecosystem fitting the scope of this paper.

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10. **Blackstone Group / AirTrunk Reports** – *Global Data Center Investment Outlook 2024–2030* – April 2024.
(press releases and interviews cited in Financial Times and Bloomberg 2024)