

## UNIT IV

# Sustainable Data Centers, Cloud Infrastructure and Carbon Management

*From code and devices to the infrastructure and policy layer — data centres, cloud efficiency, ESG reporting, and carbon markets.*

**08 Hours**

Dr. Sneha Thombre

MKSSS's Cummins College of Engineering for Women, Pune

Faculty Orientation Deck · Open Elective — Third Year AI & Data Science · Savitribai Phule Pune University

# Unit at a Glance

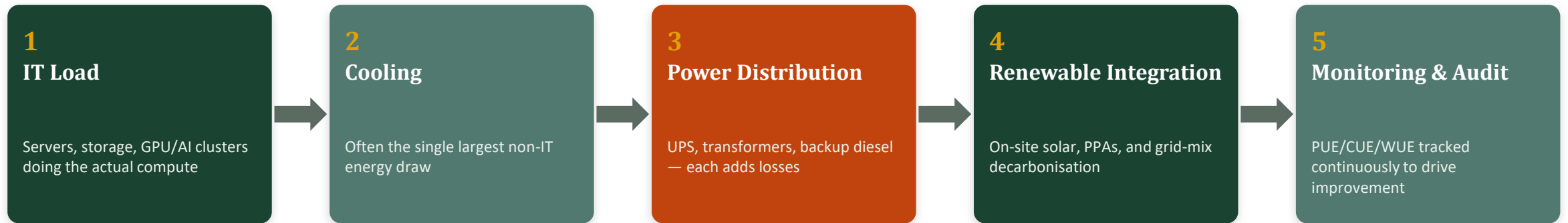
**Purpose:** Expands the lens to infrastructure scale and to policy/finance — connecting engineering decisions to ESG reporting, BRSR compliance, and carbon markets that industry recruiters actually care about.

- Energy consumption challenges in modern data centres & AI infra
- Green data centre design: servers, cooling, power management, renewables
- Sustainability metrics: PUE, CUE, WUE
- Sustainable cloud computing: virtualisation, consolidation, carbon-aware scheduling
- Sustainable AI infrastructure: GPU clusters, efficient training pipelines
- Green audits & sustainability assessments for IT infrastructure
- ESG reporting frameworks & BRSR (India, SEBI-mandated)
- Carbon credit mechanisms, carbon markets, carbon credit calculation
- MRV (Measurement, Reporting, Verification) systems
- Future trends: carbon-neutral data centres, climate-aware computing, edge computing

*Maps chiefly to CO5 (Evaluate sustainable computing practices) · Case study: Green Cloud Data Center Architecture and Carbon Accounting Practices*

## CORE CONCEPT

# Where a Data Centre's Energy Actually Goes



Teaching sequence tip: introduce PUE right after this diagram — it is literally "Total Facility Energy ÷ IT Equipment Energy," so once students see the diagram, the metric explains itself.

## CORE CONCEPT

# The Three Core Data-Centre Sustainability Metrics

*All three follow the same logic: total resource used ÷ resource used by IT equipment alone. Lower is better; PUE's theoretical ideal is 1.0.*



## Power Usage Effectiveness

Total facility power ÷ IT equipment power. Industry average is roughly 1.5–1.6; leading hyperscalers report figures close to 1.1.



## Carbon Usage Effectiveness

Total CO<sub>2</sub> emissions from the facility ÷ IT equipment energy — brings PUE's logic directly into carbon-accounting terms.



## Water Usage Effectiveness

Total water used (largely for cooling) ÷ IT equipment energy — an increasingly critical metric as data centres cluster in water-stressed regions.

## CORE CONCEPT

# Sustainable Cloud Computing and AI Infrastructure

- Virtualisation lets many logical servers share one physical machine — dramatically raising utilisation and cutting idle/wasted capacity versus one-application-per-server setups.
- Workload consolidation and right-sizing avoid the common problem of servers running at 10–15% utilisation yet still drawing near-peak power.
- Carbon-aware scheduling shifts flexible workloads (batch jobs, model training) to times or regions where the electricity grid is cleaner.
- Sustainable AI infrastructure applies the same logic to GPU clusters: efficient training pipelines, better job scheduling, and hardware utilisation monitoring reduce the AI-specific slice of data-centre demand.
  - Edge computing (processing data closer to its source) can reduce network and central data-centre load for certain workloads — a forward-looking theme for this unit.

**1.4→9 GW**

India's data-centre capacity growth projected by 2030

**0.8%→~3%**

Data centres' share of India's total electricity demand, 2024 → 2030

Sources: IEEFA (2023), S&P Global Commodity Insights, India Datacenter Outlook

## CORE CONCEPT

# From Engineering to Policy: Audits, ESG, and Carbon Markets

*This unit connects technical infrastructure decisions to reporting and finance — the layer that gives sustainability work its career relevance:*

### **GA** Green Audits

Systematic assessment of IT infrastructure's energy, water, and emissions performance against benchmarks — the starting point for any improvement plan.

### **ESG** ESG & BRSR Reporting

Business Responsibility and Sustainability Reporting is mandated by SEBI for India's top listed companies — data-centre and IT metrics feed directly into it.

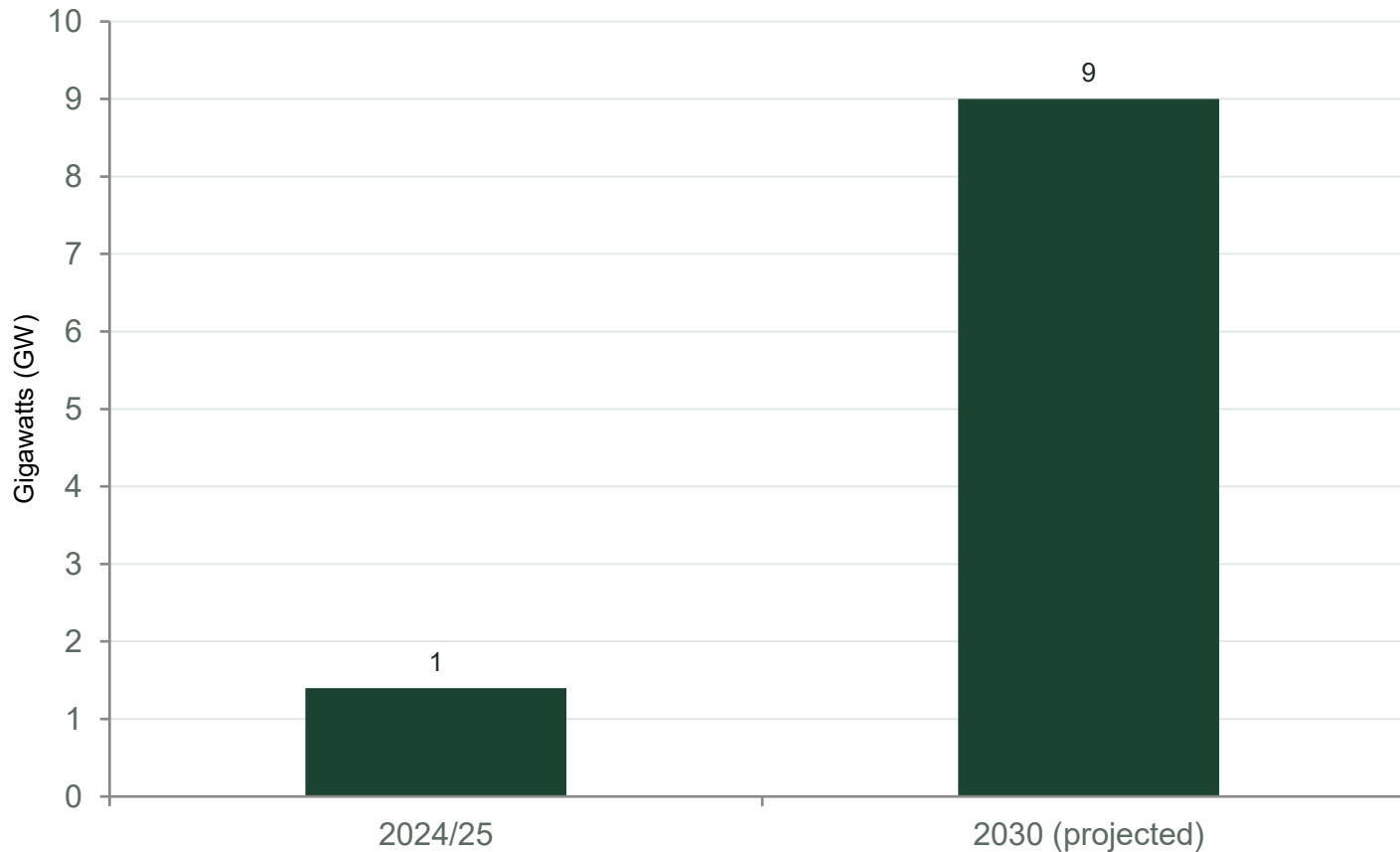
### **CC** Carbon Credits & Markets

Organisations that cut emissions below a baseline can earn tradeable carbon credits, creating a financial incentive for efficiency investment.

### **MRV** MRV Systems

Measurement, Reporting, and Verification systems ensure claimed emission reductions are real, auditable, and comparable across organisations.

# India's Data-Centre Capacity Is Set to Grow Roughly Sixfold by 2030



## Why this matters

India is projected to grow data-centre capacity from about 1.4 GW to 9 GW by 2030 — a nearly sixfold increase — driven by AI and cloud demand. Each new facility built today locks in its PUE and grid-mix profile for a decade or more, making design-time sustainability decisions especially consequential.

*Sources: IEEFA, "India's power-hungry data centre sector at a crossroads" (2025); Nomura estimates*

## CASE STUDY (SYLLABUS-PRESCRIBED)

# Case Study: Green Cloud Data Center Architecture and Carbon Accounting Practices

- A hyperscale cloud provider operates data centres with a reported PUE close to 1.1 — achieved through free-air/evaporative cooling, AI-optimised cooling control, and aggressive server utilisation, versus an industry average PUE nearer 1.5–1.6.
- The same provider procures renewable energy via long-term Power Purchase Agreements (PPAs), directly lowering its Scope 2 emissions and, by extension, its Carbon Usage Effectiveness (CUE).
- Its ESG/BRSR-aligned reporting discloses these metrics publicly, is externally verified through an MRV-style process, and is used by enterprise customers to assess their own Scope 3 (supply-chain) emissions from cloud usage.
- An Indian data-centre operator, by contrast, may still rely substantially on grid electricity where coal remains the dominant source (over 70% nationally) — showing why grid decarbonisation and PPAs matter as much as facility design.

### Discuss in class

- How much of a hyperscaler's low PUE is genuine efficiency engineering, versus favourable climate/location choice?
- If your college campus were a 'data centre,' what would its rough PUE-equivalent look like, and where are the losses?
- Why might an Indian company's Scope 2 emissions be higher than an identical facility's in a country with a cleaner grid?
- Is buying carbon credits an acceptable substitute for actually reducing a data centre's own emissions? Where should the line be drawn?

# Suggested Pedagogy for Unit IV

1

## Virtual data-centre tour (video)

Show a publicly available hyperscaler data-centre tour video (Google/Microsoft/AWS) — makes cooling, power infrastructure and scale tangible in a way slides cannot.

3

## Mock ESG/BRSR disclosure exercise

Have small groups draft a one-page mock BRSR-style disclosure for a fictional college data centre — connects technical metrics to a real reporting format.

5

## Guest talk or recorded webinar

AWS Sustainability, Google Sustainability Reports, or Green Software Foundation webinars offer ready-made, credible industry content for this unit.

2

## PUE calculation worksheet

Give students a simple worked numerical problem: given total facility power and IT-equipment power, calculate PUE, then discuss what a 'good' vs 'poor' value implies.

4

## Carbon-credit market simulation

A short in-class simulation where 'companies' (student groups) with different baseline emissions trade credits — builds intuition for how carbon markets function.

6

## Close with a forward-looking discussion

End the unit (and the course) discussing edge computing and climate-aware scheduling as live research areas — leaves an open-elective audience curious rather than concluded.

**Faculty tip:** This is the heaviest unit (8 hours) and the most industry-facing — plan at least one session as pure discussion/case-study rather than lecture, since ESG, BRSR and carbon markets reward debate over derivation.

# Evaluation Techniques for Unit IV

Assessment Component	Weight	How it maps to this unit
<b>CCE quiz on metrics &amp; frameworks</b>	<b>5 Marks</b>	Define PUE/CUE/WUE, name BRSR's mandating authority (SEBI), and distinguish carbon credits from carbon offsets.
<b>PUE/carbon-calculation numerical problem</b>	<b>5 Marks</b>	Given facility data, compute PUE or a simple Scope 2 emissions figure — tests applied numeracy, not just definitions.
<b>Case-study / mock-disclosure assignment</b>	<b>10 Marks</b>	Written mock ESG/BRSR-style disclosure or case-study analysis of the Green Cloud Data Center case.
<b>End-Semester theory question</b> <i>Because Unit IV carries the most teaching hours (8) and the broadest scope, consider weighting its share of the end-semester paper and CCE slightly higher than the other units, and use it to test integrative, cross-unit thinking.</i>	<b>Included in 35 Marks</b>	Typically the most substantial descriptive question — often integrates concepts across all four units (e.g. "trace one AI workload's footprint from device to data centre").

## Unit IV — Key Takeaways for Faculty

- ✓ PUE, CUE, and WUE give students a simple, numerically teachable way to evaluate any data centre's sustainability performance.
- ✓ Sustainable cloud computing (virtualisation, consolidation, carbon-aware scheduling) is directly actionable engineering practice, not abstract policy.
- ✓ ESG reporting, BRSR, and carbon markets are where sustainable-computing skills meet real career paths — carbon analyst, ESG analyst, sustainability consultant.
- ✓ India's data-centre sector is projected to grow roughly sixfold by 2030 — this unit's relevance will only increase over a student's career.

### For faculty-led discussion

- Should India mandate PUE/CUE disclosure for all data centres above a certain size, the way BRSR is mandated for large listed companies?
- Can renewable-energy procurement alone make Indian data centres 'green,' given the coal-heavy national grid?
- How should a graduating AI/DS engineer position 'sustainable computing' skills in a placement interview or resume?