UNIT I

Foundations of Sustainable Development and Green Computing

Why every engineer — not just environmental scientists — must now think in terms of carbon, energy, and lifecycle impact.

05 Hours

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

Unit at a Glance

Purpose: Builds the conceptual vocabulary the whole course depends on — sustainability, Green IT, digital carbon footprint, and GHG accounting — before students meet hardware, software, or data-centre detail.

- Sustainable development & UN SDGs (17 goals)
- Role of digital tech (AI, IoT, cloud, analytics) in SDGs
- Green IT: concept & evolution (1.0 → 2.0)
- Digital carbon footprint of computing infrastructure
- Three pillars: environmental, economic, social
- Stakeholders: government, industry, academia, citizens
- Energy use of AI/ML models; sustainable AI principles
- GHG emissions, carbon footprint, CO_2e
- GHG Protocol: Scope 1, 2, 3 emissions
- Basic sustainability metrics: carbon footprint, energy intensity, resource efficiency

Maps chiefly to CO1 (Interpret sustainability concepts in computing) · Prescribed case study: AI Model Carbon Footprint Analysis

HOW THE UNIT PROGRESSES

From Global Sustainability to Computing-Specific Carbon Accounting

1
Sustainable Development
Brundtland definition; needs of present vs future generations

→

2
Triple Bottom Line
People · Planet · Profit — tech judged on all three

→

3
Green IT & Digital Footprint
Computing's own energy, material & emissions impact

→

4
AI / SDG linkage
How AI, IoT, cloud support — and burden — the 17 SDGs

→

5
Carbon Accounting
GHG Protocol Scope 1/2/3; CO_2e; sustainability metrics

Teaching sequence tip: open with the Brundtland definition of sustainable development, then immediately connect it to computing — most AI/DS students assume software is inherently "clean"; this unit corrects that assumption before any technical content is introduced.

CORE CONCEPT

Sustainable Development, SDGs, and the Triple Bottom Line

- Sustainable development (Brundtland, 1987): development that meets present needs without compromising the ability of future generations to meet theirs.
- 17 UN Sustainable Development Goals (SDGs, adopted 2015, target 2030) give this idea measurable targets — from SDG 7 (Affordable & Clean Energy) to SDG 13 (Climate Action).
- Triple Bottom Line (Elkington): technology must be evaluated on three pillars — Environmental, Economic, and Social sustainability — not on performance alone.
  - Digital technologies (AI, IoT, cloud, data analytics) are dual-edged: they can accelerate SDG progress (smart grids, precision agriculture, climate modelling) while also consuming significant energy and resources themselves.
  - Stakeholders in delivery: government (policy/regulation), industry (adoption & disclosure), academia (research & talent), citizens (demand & behaviour).

17

UN Sustainable Development Goals, all targeted for 2030

3

Pillars of the Triple Bottom Line: People, Planet, Profit

2070

India's Net Zero target year (announced at COP26)

Source: UN 2030 Agenda; Government of India COP26 commitments

CORE CONCEPT

Green IT Evolution and the Digital Carbon Footprint

- Green IT 1.0 focused narrowly on energy-efficient hardware and power management (PCs, servers).
- Green IT 2.0 broadens the scope to the full lifecycle and to using IT as a tool for sustainability elsewhere in the economy (smart buildings, teleworking, logistics optimisation).
- Digital carbon footprint = total greenhouse gases emitted directly and indirectly by digital devices, networks, and data infrastructure across their lifecycle.
  - Every AI/ML pipeline has a footprint: data collection → storage → model training → inference → retraining — each stage draws electricity from a grid with its own emissions intensity.
  - **Common student misconception to correct explicitly: "software has no physical footprint." In reality, cloud platforms and AI workloads have measurable, growing ecological footprints.**

1–1.5%

Share of world electricity used by data centres today (IEA, 2024)

→3%

Projected share by 2030 as AI/cloud demand accelerates

Source: International Energy Agency, Energy & AI report

CORE CONCEPT

Carbon Accounting: GHG Emissions and the Scope 1–2–3 Framework

Every organisation's emissions — including a data-centre operator's or an AI company's — are reported under the globally-used GHG Protocol in three scopes:

1 Scope 1 — Direct

Emissions from sources owned/controlled directly by the organisation: company vehicles, on-site generators, fuel combustion.

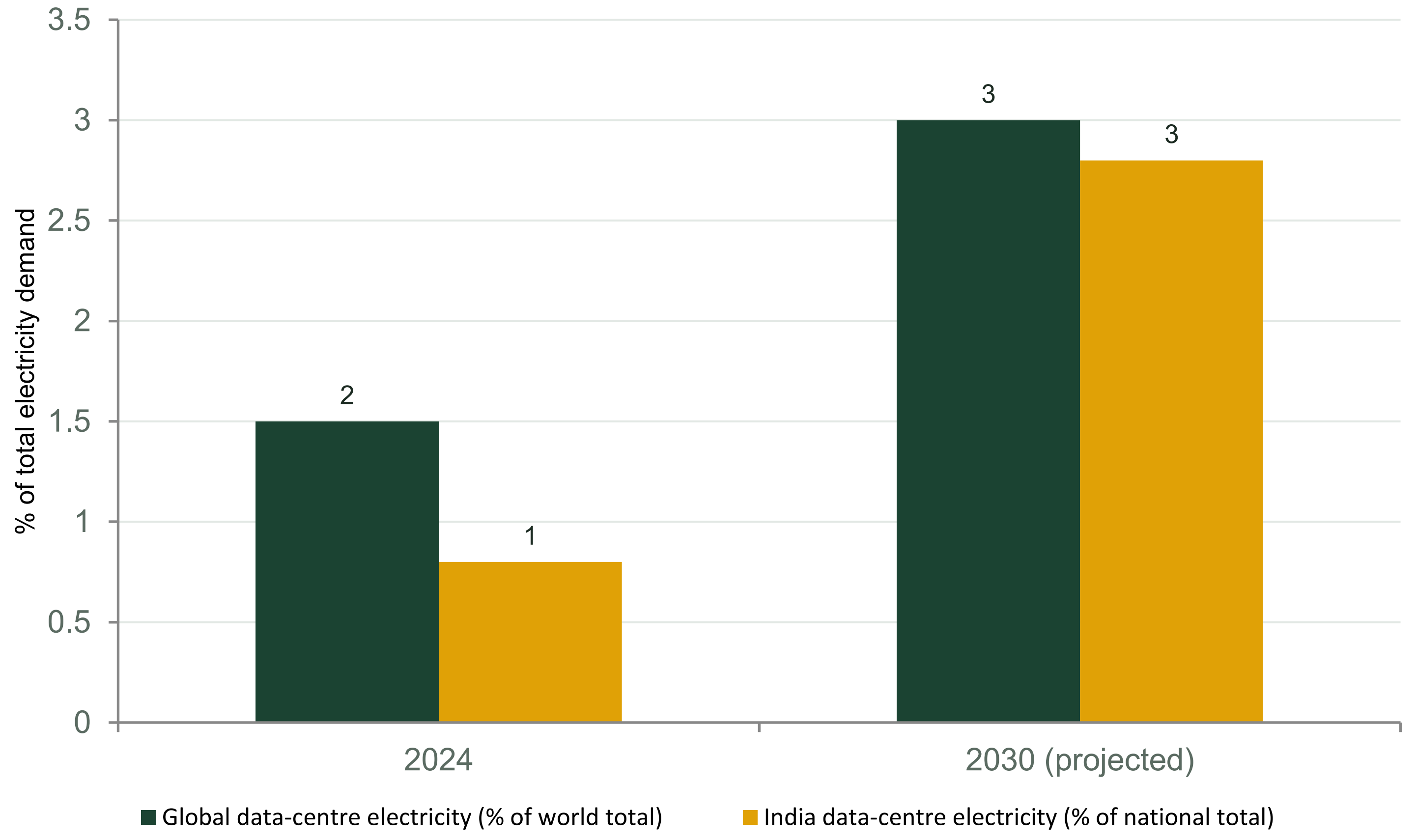
2 Scope 2 — Energy Indirect

Emissions from purchased electricity, steam, heating and cooling — the biggest category for data centres and cloud platforms.

3 Scope 3 — Value Chain

All other indirect emissions: hardware manufacturing, employee travel, cloud services used, e-waste disposal, upstream supply chain.

Digital Infrastructure's Rising Share of Electricity Demand



Why this matters

Data-centre electricity use is doubling its share of the grid in both the world and in India within a single decade — driven overwhelmingly by AI training and inference workloads. This is the single strongest justification you can give faculty and students for why AI/DS engineers must study sustainability.

Sources: IEA "Energy and AI" (2025); S&P Global Commodity Insights, India Datacenter Outlook (2025)

CASE STUDY (SYLLABUS-PRESCRIBED)

Case Study: AI Model Carbon Footprint Analysis

- Training OpenAI's GPT-3 (175 billion parameters) consumed an estimated 1,287 MWh of electricity and emitted roughly 500–550 metric tons of CO_2e — comparable to driving an average car from New York to San Francisco about 400+ times.
- By contrast, BigScience's BLOOM model (176 billion parameters, similar scale) was trained on a French supercomputer powered mainly by nuclear/low-carbon electricity, and emitted only about 25–50 tons of CO_2e for a comparable training run.
- A peer-reviewed estimate places GPT-4's training emissions at roughly 7,000+ tons of CO_2e — about 12 times GPT-3 — reflecting the trend toward ever-larger models.
- Takeaway for the classroom: the gap between GPT-3 and BLOOM shows that emissions depend as much on where and how a model is trained (grid carbon intensity, hardware efficiency, scheduling) as on model size itself.

Discuss in class

- Why did BLOOM emit ~10–20x less CO_2e than GPT-3 despite a similar parameter count?
- If your college procured GPU compute for a class project, what factors would determine its carbon footprint?
- Should model "accuracy leaderboards" also report a training-emissions figure? Why might companies resist this?
- How would you estimate the CO_2e of a modest student ML project using an activity-based (Scope 2) approach?

Suggested Pedagogy for Unit I

1. **Anchor with a relatable footprint calculator**
   Open the first lecture with a live carbon-footprint estimate of a common activity (a video call, a Google search, a ChatGPT query) to make CO_2e tangible before introducing formal frameworks.

2. **Flipped reading + concept-mapping in class**
   Assign the Green IT chapter as pre-reading; use class time to co-build a concept map linking SDGs → Green IT → Scope 1/2/3 on the board.

3. **Think–Pair–Share on stakeholder roles**
   Give each pair one stakeholder (govt / industry / academia / citizen) and 5 minutes to list what sustainable-computing action that stakeholder should take.

4. **Guest-speaker or video: a data-centre operator or ESG analyst**
   A 15-minute recorded talk or a Green Software Foundation webinar clip strongly reinforces industry relevance for an open elective audience.

5. **Numerical worked example on Scope 2 emissions**
   Walk through a simple calculation: kWh consumed × grid emission factor (kg CO_2e/kWh) = Scope 2 emissions, using India's own grid factor (~0.7-0.8 kg CO_2e/kWh).

6. **Cross-branch framing for the open elective**
   Since non-CS/AI students may attend, use everyday examples (smartphone charging, streaming, e-commerce delivery) alongside the AI-specific ones so every branch finds a foothold.

Faculty tip: *This unit is mostly conceptual — resist the urge to rush to formulas. Spend real class time on the SDG–Green IT–Scope 1/2/3 storyline; it is what students will be examined on and what justifies every later unit.*

Evaluation Techniques for Unit I

Assessment Component	Weight	How it maps to this unit
Class Continuous Evaluation (CCE) quiz	**5 Marks**	Short-answer / MCQ on SDGs, Triple Bottom Line, Scope 1/2/3 definitions, and terminology (CO_2e, Green IT 1.0 vs 2.0).
Reflective assignment	**5 Marks**	"Estimate and justify the carbon footprint of one digital habit" — tests ability to apply Scope 2 logic, not just recall it.
Case-study discussion / viva	**5 Marks**	Oral or written response to the GPT-3 vs BLOOM case — probes whether students can reason about causes, not just quote numbers.
End-Semester theory question	**Included in 35 Marks**	A conceptual/descriptive question (e.g. "Explain the three GHG Protocol scopes with computing examples") typically anchors Unit I in the end-semester paper.

Since this is an open elective for mixed branches, keep CCE weighting concept-based rather than calculation-heavy in Unit I — save numeric rigor for the LCA and emissions-calculation units (II & III).

KEY TAKEAWAYS

Unit I — Key Takeaways for Faculty

- ✓ Sustainability in computing rests on three pillars — environmental, economic, social — not environment alone.
- ✓ Digital systems have a real, measurable carbon footprint; "software is clean" is a myth this unit must dismantle.
- ✓ The GHG Protocol's Scope 1/2/3 framework is the common language used across every later unit (LCA, green software, data centres) — teach it thoroughly here.
- ✓ AI and data science students should leave this unit understanding why their discipline is directly implicated in the sustainability conversation.

For faculty-led discussion

- Is it fair to hold AI/DS engineers responsible for emissions decided by cloud providers?
- Which SDG is most directly advanced, and which most directly threatened, by widespread AI adoption?
- Should India's Net Zero 2070 target apply equal urgency to the IT sector as to heavy industry?