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Measuring the Carbon Footprint of Higher Education Institutions: Economic Implications for Resource Optimization, Green Investment, and Institutional Sustainability

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Abstract: This paper explores the carbon price produced by higher education as an economic-oriented thread of GHG accounting, in terms of resource competition, green investment, and institutional sustainability. This study computes a variety of emission indicators like electricity-cost exposure, renewable-energy savings potential and decarbonization avenues using operational data on scope-wise emissions from an Indian higher education institution for FY 2018–19 to FY 2023–24. FY 2023-24 emissions decreased to 14,899.1 tCO_2e from FY 2022-23 at 17,314.0 tCO_2e with the largest source of the last footprint being from Scope 2 purchased energy at 83.01%. This resulted in a reduction of emissions per student from 6.65 to 3.86 tCO2 e and significantly better normalized performance and about 1,033.53 tCO2 offset due to the renewable power output of 1423604 kWh applied annual savings estimated at ₹1.279 crore This finding shows carbon footprint assessment as a strategic economic tool for sustainable campus governance and low-carbon institutional reform in the current resource-constrained and accountability-oriented regulatory settings of global higher education systems.
Keywords: Carbon footprint, Scope 2 emissions, green investment, Sustainability of institutions; Higher education institutions; Resource optimisation.

1. Introduction

Institutions of higher learning are important organizational nodes for tracking carbon, bringing together education, research, residential activity, transit demand, procurement choices, lab energy consumption, and digital infrastructure, in a single operating system. Therefore, sustainability performance for them is not only about taking care of the environment, but also about how well they utilize or leverage their resources and whether they can ensure proper asset allocation as well as infrastructure governance in the long run. A campus carbon footprint is a measure of the greenhouse gas emissions resulting from the direct and indirect activities of a campus. It is a conversion measure that changes incongruent activity data into one measure to help management decisions. In other words, sustainability is about rethinking the same activities but in a frugal way; carbon accounting becomes a tool to reduce energy bills, enable new green investments, insulate operational budgets against rising energy prices and align institutional growth with greening objectives.

Greenhouse gas protocol is a theoretical basis of emission research which classifies greenhouse gases into scope 1, scope 2 and scope 3 . Scope 1 is direct emissions from sources owned or controlled by the institution such as Fixed fuel, Mobile fuel and fugitive gases. Scope 2: emission from the generation of purchased electricity consumed within the organizational boundary Scope 3 includes all indirect emissions from sources other than those covered by Scope 1 and 2 as well as upstream and downstream activities in their extended value chain including commuting of employees, business travel, waste disposal, logistics and procurement related activities. To be able to assign emissions in a scoped way, a valid inventory needs to very precisely define organizational and operational boundaries (World Resources Institute & World Business Council for Sustainable Development [WRI & WBCSD], 2004, 2011).

But the empirical focus is a real case study of Shiv Nadar Institution of Eminence, India where its carbon footprint data from FY 2018-19 to FY 2023-24 has been considered. The existing inventory captures the total emissions for FY 2023-24 as 14,899.1 tCO2e with Scope 1: (976.6 tCO2e), Scope

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2 : (12,367.5 tCO2e) and Scope 3: (1,555.0 tCO2e). This is a fall of nearly 13.95 per cent in one year from 17,314.0 tCO2e in FY 2022-23 to 14,899.1 tCO2e in FY 2023-24 over the same reporting cycle. More analytically useful is the scenario of institutional size increases with concomitant measurable reductions in carbon emissions. Number of students has increased from 2,078 in FY 2019-20 to 3,861 in FY 2023-24 and the built-up area has increased from 2,751,712 sq. ft. to 3,361,597 sq. The Shiv Nadar Institution of Eminence [SNIoE] (2024) has in its report titled Higher Education Market in India – A Base-to-Current Period Analysis over CY2018-25 forecasted high growth prospects for this segment in base and current periods.

The main difficulty for the research community is that carbon footprint inventories are usually at least semi-technical outputs from compliance-driven systems, but institutional decision makers require economic links between emissions and operational costs, resource efficiency measures, investment returns and sustainability strategy. They appear to be seeing an increase in the demand for energy to power air-conditioning, research laboratories, dormitories, digital systems and a larger campus. Decarbonization programmes also need to be financially viable for resource-constrained governance systems. So the institutional value of a carbon footprint assessment is that it shows not just sources of emissions but also exposure to cost, money saved, performance in terms of intensity and payback periods, and decarbonization options.

The study seeks to answer three research questions. First, what is the institutional carbon footprint and how to measure it under a well-defined accounting framework in terms of scope and sources Secondly, which of the two economic variables – power spending, renewable energy (RE) savings, emission intensity and green investment payback – was influenced by carbon emissions? Third: what are the best strategies for optimizing resources and making green investments so as to obtain the maximum aggregate benefits in environmental or economic terms? The contribution is the unification of campus carbon accounting and economic assessment, extending the higher education sustainability literature − from both the campus and system level − from emissions disclosure to financially prudent decarbonization plans.

2. Literature Review and Research Gap

With higher education institutions making sustainability commitments, net-zero pledges and public reporting systems, so is research on carbon footprint. Techniques for organizational carbon accounting, life-cycle assessment and ISO 14064 have all been used and GHG Protocol-based inventories are also available. Emissions from `on campus' operations are likely to be among the most quantified in the literature. Previous studies have shown that the higher education sector is a complex emission system, with many different structures, commuting patterns, resource-intensive research and procurement, student housing and waste streams. Valls-Val and Bovea (2021) show that carbon footprint measurement in universities is not yet directly comparable across borders, emission factors, activity categories and reporting years – the so-called methodological openness for comparability and policy use – being only partially achieved.

Recent studies show that the most frequent emission categories reported by universities are power, transportation and fuel consumption. Paredes-Canencio et al. (2024) studied 50 Carbon Footprint Reports of higher education institutions. Seventy-eight percent of these studies reported on electricity use, 74 percent reported on transportation and 64 percent fuel use, the sources said. This pattern has significance for economic valuation as electricity generally relates to ongoing operating expense, transportation relates to behavioral and mobility governance, and fuel use relates to operational control and technology replacement. The evidence therefore lends support to a scope-wide paradigm where Scope 2 emissions are predominantly the most domestically harsh and monetarily actionable source of emissions whereas Scope 3 emissions need more complex institutional engagement.

Scope 3 emissions are becoming more widely recognized in carbon footprint calculations, but remain the most difficult reporting boundary to control. The indirect emissions associated with commuting, business travel, meals and purchased goods and services can be significant, but the data

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quality varies across institutions. There is a significant amount of reliance on estimates (less than 5% of direct measurements). Deda et al. Integrated carbon assessment generally requires a hybrid process-economic approach, which they argue is partly because, as in higher education as elsewhere, straight metering cannot capture value-chain activities (2025). This is especially important for universities as activity data can be obtained from utility bills, fuel log books, vehicle trip records, contractors' invoices and survey and waste management papers. Resilient carbon accounting therefore depends on a blend of indicators with quantified data, verified assumptions and visible emission factors.

The economic literature on campus sustainability suggests that until environmental success can be monetized, decarbonization will remain in direct competition with other institutional expenditure. Renewable energy, energy-efficiency retrofits, effective HVAC systems, LED lighting, smart metering and electric transportation will likely reduce emissions, while also reducing ongoing expenses. In this regard, Robinson et al. uncover the practical gap between university carbon management intention and realization, which shows the significant constraints on implementing it through formal governance framework as well as financing and accountability (2015). Clabeaux et al. And (2020) identify life-cycle emissions hotspots beyond operational energy that can help campuses better understand sustainability impacts.

The financial bridge brings together sustainability goals and institutional decision making in the field of green investment analysis. Public Policy, Business and Technology Avoided electricity purchases Avoided emissions Payback period Net present value Return on investment Use to evaluate rooftop solar PV energy management systems demand-side efficiency measures water reuse infrastructure low-carbon transport mobility waste minimization; This logic is particularly compelling in the context of universities, where operational budgets are recurring, energy is used continuously, and campuses often have long-lived facilities that are conducive to incremental retrofit strategies. The economic carbon assessment increases accountability by linking environmental indicators to measurable institutional savings.

A considerable research gap stems from the disagreement between the measurement of carbon-footprint (on its aggregate emission) and its economic interpretation. Several studies report aggregated emissions and scope-specific contributions. However, such inventories are seldom transformed into details of resource intensity, exposure to electricity-cost changes, avoided-cost estimates, investment assessment or decarbonization scenarios. In particular, we want to bridge this gap with a real university specific carbon emissions data including India specific emission factors for energy, tariff-based avoided-cost estimates and mitigation plans framed by designing possible scenarios. Instead of a stand-alone sustainability report, the resulting model situates carbon accounting within the context of market governance of higher education institutions.

3. Data, Boundary Conditions, and Numerical Calculation Base

The present empirical study is based on the publicly declared carbon footprint inventory of Shiv Nadar Institution of Eminence for the financial year 2018-19 to 2023-24. Location The institute's 286-acre campus is located in Uttar Pradesh, India and has 87.72-acre green cover, 3,361,597 sq. Students Category Staff Category 1 Government Sector A. Current reporting pact Population of students, instructors and staff: 4,459. FY 2019-20 Student Enrolment = 5485 Faculty & Staff = 733 Total Campus Population=6750 Built-up area=87.10 acres FY 2023-24 the Base to Current Comparison shows the increase in Student Enrolment by 80.82%, Faculty & Staff by 32.59%, Total Campus Population by 76.31% and Built-up area by 22.16.(SNIoE, 2024).

The organizational border is the institutional functioning border at the campus level described in this SNIoE inventory. Fugitive emissions Scope 1 Scope 2 is electricity bought from the grid. For Scope 3: Upstream transportation and distribution, waste generated in operations, employee business travel, employee commuting and downstream transport. The inventory is suitable for economic interpretation as it has historic scope-wise emissions and source wise FY 2023-24 emissions in bounded range for trend analysis, hotspot analysis and development of mitigation

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scenarios.

The six-year inventory also shows a non-linear path for carbon. Your number is a total emissions was 11,440.4 tCO2e in FY 2018-19 and increased to 13,814.0 tCO2e in FY 2019–20 Emissions declined to 8066.0 tCO2e in FY 2020-215 primarily due to the academic year disrupted by the pandemic, then increased again in FY 2021-22 (10,140.0 tCO2e), provided a high for the second reference period in FY 2022-23 (17,314.0 tCO2e) and quickly returned to another low between these two years ((14,899.1tCO2erange)). The inventory at scope level is shown in Table 1.

Table 1. Scope-wise carbon footprint of the higher education institution, FY 2018-19 to FY 2023-24

Year	Scope 1 (tCO2e)	Scope 2 (tCO2e)	Scope 3 (tCO2e)	Total (tCO2e)
FY 2018-19	743.0	9,668.4	1,029.0	11,440.4
FY 2019-20	738.0	10,649.0	2,427.0	13,814.0
FY 2020-21	497.0	6,277.0	1,292.0	8,066.0
FY 2021-22	1,219.0	7,168.0	1,753.0	10,140.0
FY 2022-23	2,765.0	11,679.0	2,870.0	17,314.0
FY 2023-24	976.6	12,367.5	1,555.0	14,899.1

In the context of absolute emissions, year-on-year trends are largely driven by institutional landscape, campus growth, power use and post-lockdown normalization. Scope 2 Emissions in FY23 Reporting Year In FY 2019-20 total emissions rose by 20.75% and fell by 41.61% in FY 2020–21. The next year saw an increase of 25.71% for FY 2021–22, which surged by a whopping 70.75% for FY 2022–23 before reducing down to -13.95 for FY 2023-24* The total reduction in emissions is only attributed to emissions from Scope 2 only which alone accounts for 83.01% of the total emissions in this reporting year. This supports energy as the biggest carbon and cost hot spots. Scope shares and year-on-year change for FY 2023-24 is provided in Table 2.

Table 2. Year-on-year emission movement and scope contribution

Year	Total emission change	Scope 1 share	Scope 2 share	Scope 3 share
FY 2018-19	Base	6.49%	84.51%	8.99%
FY 2019-20	20.75%	5.34%	77.09%	17.57%
FY 2020-21	-41.61%	6.16%	77.82%	16.02%
FY 2021-22	25.71%	12.02%	70.69%	17.29%
FY 2022-23	70.75%	15.97%	67.45%	16.58%
FY 2023-24	-13.95%	6.55%	83.01%	10.44%

The analytical framework links campus activity data with scope-wise accounting, economic exposure, resource optimization, green investment appraisal, and institutional sustainability outcomes. This logic is presented in Figure 1.

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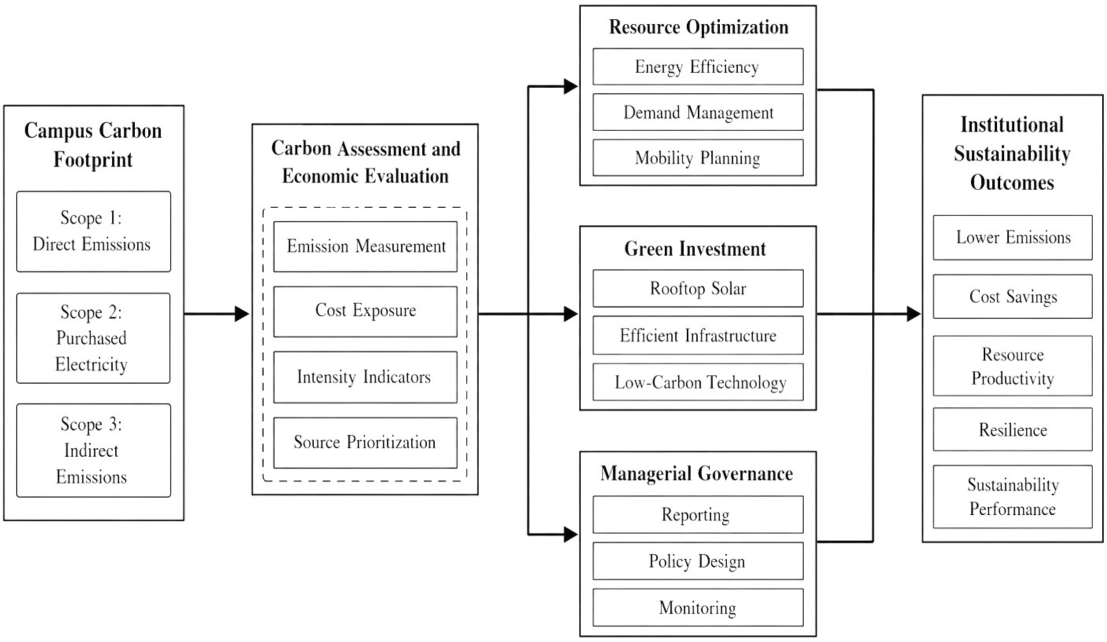

Figure 1. Analytical framework linking campus carbon footprint, economic efficiency, green investment, and institutional sustainability

The visual emissions trend shows that Scope 2 remains the structural driver across all six years, while Scope 1 and Scope 3 fluctuate more sharply with fuel use, mobility, and operational conditions. The six-year pattern is shown in Figure 2.

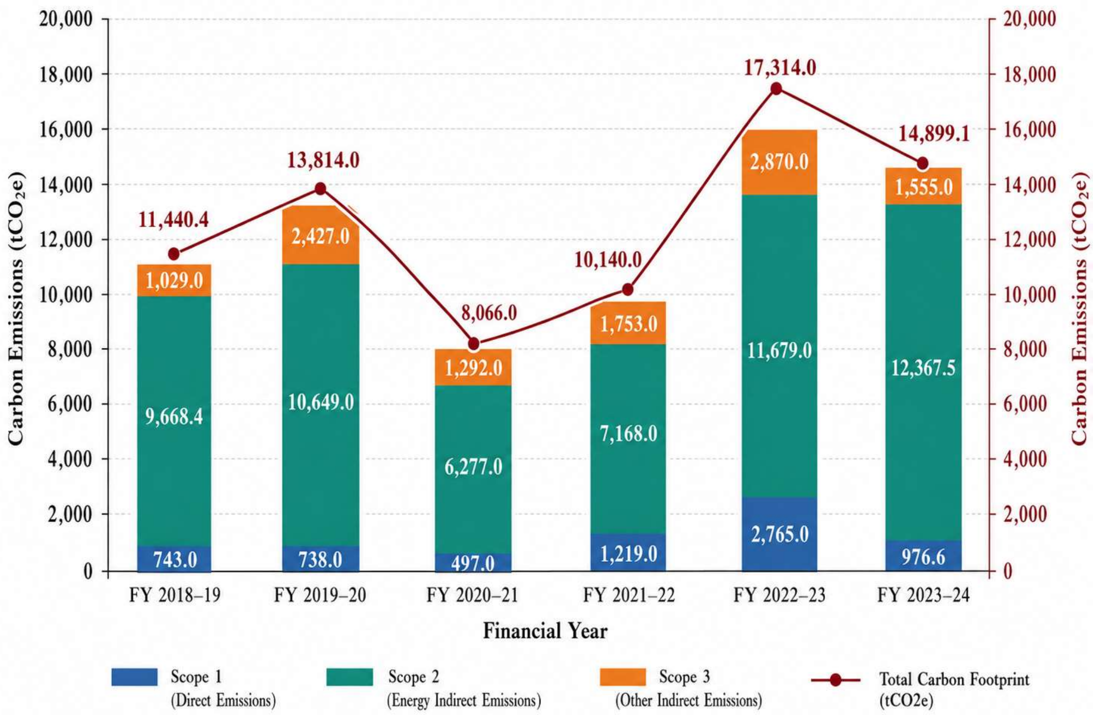

Figure 2. Six-year scope-wise emission trend and total carbon footprint movement

4. Methodology and Economic Assessment Model

It layers on four layers over the standard carbon inventory. At the first layer, total campus population, student enrollment, built-up area and campus acreage are calculated. Intensity indicators are normalized by student enrollment. The Layer-2 estimates the exposure to power-cost by

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converting the Scope 2 emissions to inferred grid electricity consumption using the India grid emission factor. This third layer gives an estimate of the avoided emissions and avoided power from renewable energy purchases, and calculates the benefits of these actions. The fourth layer is the mitigation scenario. This layer includes the combination of efficiency, renewable power, decrease of commuting, replacement of transport, reduction of waste and transition of fuels.

The power emission factor is obtained from the CO2 baseline database of the Central Electrical Authority of India. The weighted average grid emission factor with imports for FY 2023–24 is 0.727 tCO2/MWh and the combined margin with imports is 0.757 tCO2/MWh (Central Electricity Authority [CEA], 2025). The tariff proxy is based on the approved rate schedule for private entities under LMV-4 in UP FY 2023–24 which stipulates an energy charge of Rs.9.00/kWh (Uttar Pradesh Power Corporation Limited [UPPCL], 2023). The price value of capital cost for rooftop solar has been fixed at Rs. 40,838/kW which is the benchmark-cost references for grid-connected rooftop solar systems up to above 100 kW and various ranges found in benchmarking subtleties sorted out of all costs costing far below 500 kW limits. Table3 shows the key assumptions on emission-factors, tariffs and investments.

Table 3. Emission-factor, tariff, and investment assumptions used for economic calculation

Variable	Value	Unit	Use in calculation
Weighted average grid emission factor	0.727	tCO2/MWh	Avoided emissions and implied electricity consumption
Combined margin emission factor	0.757	tCO2/MWh	Sensitivity and policy reference
FY 2023-24 renewable generation	1,421,631.2	kWh	Avoided grid electricity purchase
Private institution electricity tariff	9.00	Rs./kWh	Avoided cost and electricity exposure
Rooftop solar benchmark capital cost	40,838	Rs./kW	Investment appraisal
Discount rate for NPV	8.00	percent	25-year green investment valuation
Project life	25	years	Solar investment valuation

Normalized indicators are central to interpretation because absolute emissions can rise when universities expand, while emissions per student, per person, or per unit of built space may improve. From FY 2019-20 to FY 2023-24, total emissions increased by 7.86%, but student enrollment increased by 85.80% and total campus population increased by 76.31%. As a result, per-student emissions fell from 6.65 tCO2e/student to 3.86 tCO2e/student, while per-person emissions fell from 5.46 tCO2e/person to 3.34 tCO2e/person. The normalized indicators are presented in Table 4.

Table 4. Normalized carbon intensity indicators for base and current reporting years

Indicator	FY 2019-20	FY 2023-24	Change
Total emissions (tCO2e)	13,814.0	14,899.1	7.86%
Student enrollment	2,078	3,861	85.80%
Faculty and staff	451	598	32.59%
Campus population	2,529	4,459	76.31%
Built-up area (sq. ft.)	2,751,712	3,361,597	22.16%
Per-student emissions (tCO2e/student)	6.65	3.86	-41.95%
Per-person emissions	5.46	3.34	-38.83%

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(tCO2e/person)			
Built-up intensity (tCO2e/1,000 sq. ft.)	5.02	4.43	-11.71%
Campus-area intensity (tCO2e/acre)	-	52.09	-
Revenue intensity (tCO2e/crore)	-	41.21	-

The decomposition indicates that campus growth substantially exceeded emission growth, producing lower normalized intensity even though absolute emissions remained higher than the base year. The intensity decomposition is displayed in Figure 3.

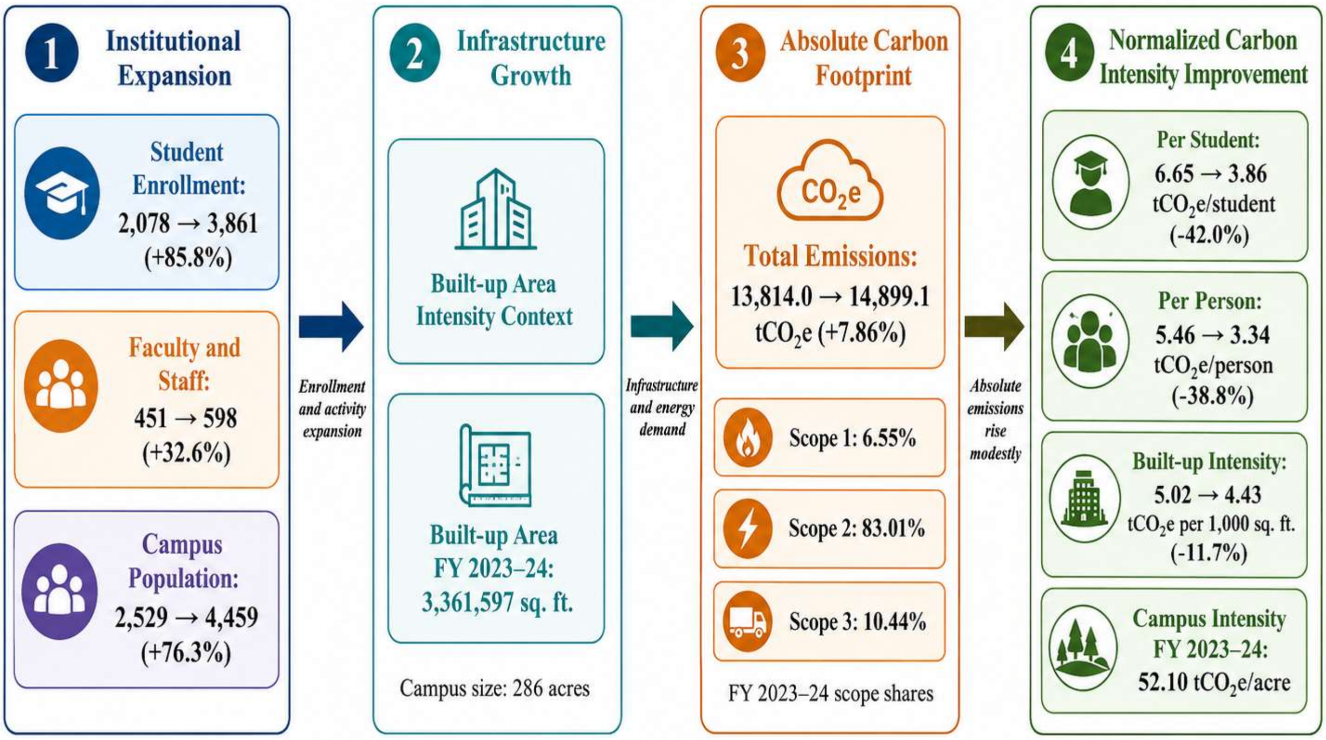

Figure 3. Carbon intensity decomposition across institutional growth and emissions performance

5. Results: Carbon Footprint, Resource Intensity, and Emission Hotspots

Practice data show a carbon footprint that is dominated by the electricity. Electricity purchased for FY 2023-24: 12,367.5 tCO2e (83.01% of emissions) Scope 1 and Scope 3 accounted for 6.55% and 10.44% of the total emissions, respectively, with 1,555.0 tCO2e. Such a breakdown shows that the main environmental and economic exposure of the organization is a power purchase. This trend is in line with the broader higher education carbon footprint assessments where energy use is the most commonly assessed and generally considered to be the largest source of campus emissions (Paredes Canencio et al., 2024).

The year-on-year decrease in total emissions in FY 2023-24 was mainly due to decrease in quantity of both scope 1 and scope 3. In FY 2023-24: Scope 1 decreased from 2,765.0 tCO2e in FY 2022-23 to 976.6 tCO2e (decreased by 1,788.4 tCO2e or 64.68%) Scope 3 decreased from 2,870.0 tCO2e (45.82%) to 1,555.0 tCO2e (-1,315.0 tCO2e). Scope 2 increased from 11,679.0 tCO2e to12,367.5 tCO2e – a net increase of 5.90%. The decline of fossil-fuel based horticulture and the increasing number of electric vehicles driven on campus are the reasons behind the reduction of Scope 1 emissions. The decrease of other indirect or Scope 3 emissions (SNIoE, 2024) is explained by improvements in waste management and declining levels of business travel.

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Source-wise inventory for FY 2023-24 highlighted potential management hotspots. Scope 1 — fugitive: 409.6 tCO_2e; stationary fuel: 391.4 tCO_2e; mobile fuel: 175.6 tCO_2e The present value of scope 3 emissions associated with the project (1,4) is 1,079.2 tCO_2e from employee commuting, 283.9 tCO_2e from corporate air travel (U.S. and worldwide), 146.4 tCO_2e from upstream transportation and distribution (all locations mode-dependent), 37.0 tCO_2e from waste generated within its operations and finally a total of around 8.5 tCO_2e from downstream transportation and distribution! In Table 5 we provide a source-wise profile.

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Table 5. FY 2023-24 source-wise carbon footprint breakdown

Scope	**Emission source**	**Emissions (tCO_2e)**	**Share of total emissions**
Scope 1	Stationary fuel consumption	391.4	2.63%
Scope 1	Mobile fuel consumption	175.6	1.18%
Scope 1	Fugitive emissions	409.6	2.75%
Scope 2	Purchased electricity	12,367.5	83.01%
Scope 3	Upstream transportation and distribution	146.4	0.98%
Scope 3	Waste generated in operations	37.0	0.25%
Scope 3	Business air travel	283.9	1.91%
Scope 3	Employee commuting	1,079.2	7.24%
Scope 3	Downstream transportation and distribution	8.5	0.06%
Total	All sources	14,899.1	100.00%

A new approach to Scope 3 management. Employee commuting accounted for 69.40% of Scope 3 and 7.24% of the total emissions among the five emission sources studied (Fig. Business air travel accounts for 18.26% of Scope 3 emissions and only 1.91% of all emissions The data indicate that commuting and travel are not minor categories but the major indirect behavioural emissions under current reporting boundaries. Reduce the travelling staff numbers with campus accommodation, car sharing, electric shuttle services, cycle lanes and flexible working practices and route optimization. Virtual conferences, hybrid academic collaboration, travel-approval standards and carbon-aware budgeting could help rein in business air travel.

The handle with the amount of emission is incoming bogus data. Purchased power is the highest-emission/high-control category with control over procurement decisions, efficiency investments, solar generation, load management and building operations. has a relatively lower score on direct control, but is still of significant relevance, since the mode choice can be influenced by institutional transport policy. At the same time, business air travel is also less than commuting but more controllable by policy, due to institutional regulations around conference travel, international academic mobility and meeting formats. Fig. 4 illustrates the differences in control over management.

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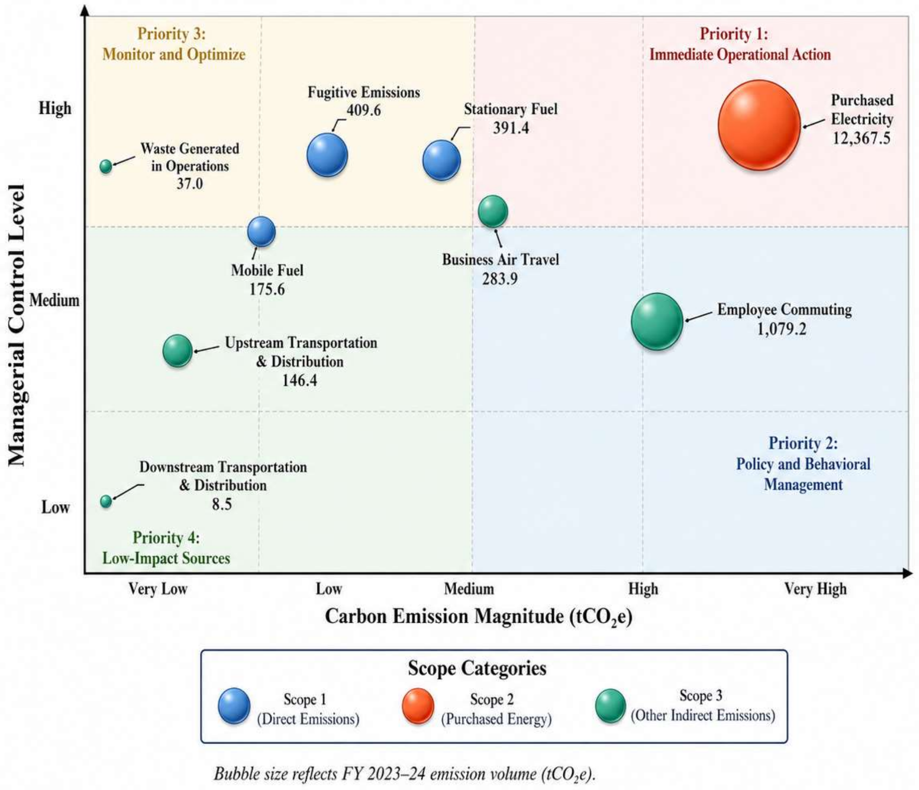

Figure 4. FY 2023-24 carbon hotspot map by source and managerial control level

Renewable power generation is a good example of resource optimization. Data shows that in FY 2019-20 captive renewable generation was 384126 kWh and it climbed to 1421631.2 Kwh in FY 2023-24 which is an increase of 1037505.2 kWh or a whopping rise of around more than +270.10% Renewable energy generation increased by 8150 (92) kWh or by 1334.8 % from 606,539 kWh in FY2022-23 to 1,421,631.2 kWh. The expansion yielded a quantifiable avoided-cost potential along with a reduction of grid power requirements. The expansion of renewables also increases institutional resilience by reducing the exposure to purchased power costs and local emissions.

6. Economic Implications, Green Investment, and Scenario Analysis

In economic activity, the carbon footprint begins with exposure to energy. The energy consumption equivalent to the grid is about 17.01 million kWh and is derived by using FY 2023-24 Scope 2 emissions of 12,367.5 tCO_2e and CEA weighted average grid factor of 0.727tCO_2/MWh This results in an annual exposure to variable power costs of Rs. 15.31 crore (Rs. 9.00/kWh per annum). The figure is not a complete power bill due to the variability in demand charges, taxes, surcharges and more specific tariff structures but does provide a reasonable value for variable cost-from an economic carbon perspective. The size of this suggests that power efficiency is not only an environmental strategy, it is a financial risk mitigation strategy.

Calculating the renewable energy provides an immediate economic payback. Electricity Generation in FY 2023-24 Renewable 1,421631.2 kWh = 1,421.631 MWh This leads to avoided emissions of 1,033.53 tCO2 equivalent using the CEA weighted average grid factor of 0.727 tCO2/MWh. Annual saved purchase value at Rs. 9.00/kWh grid price Rs. 12,794,680.80 or Rs. 1.279 crore per annum The saved cost per tonne of CO2 prevented is Rs. 12,379.64/tCO2 Table 6 shows the calculation of saved cost and renewable power.

Table 6. Renewable electricity, avoided emissions, and cost-saving calculation

Indicator	Value	Calculation basis
Renewable generation	1,421,631.2 kWh	Reported FY 2023-24 renewable electricity

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Renewable generation	1,421.631 MWh	kWh/1,000
Grid emission factor	0.727 tCO_2/MWh	CEA weighted average factor
Avoided emissions	1,033.53 tCO_2	1,421.631 x 0.727
Electricity tariff	Rs. 9.00/kWh	UPPCL LMV-4 private institution tariff
Avoided electricity cost	Rs. 12,794,680.80	1,421,631.2 x 9
Avoided electricity cost	Rs. 1.279 crore/year	Rupee value converted to crore
Savings per avoided tonne	Rs. 12,379.64/tCO_2	Avoided cost/avoided emissions

There is a similar economic logic that applies to the valuation of green investments. 1.0 MWp rooftop solar investment (Rs. 40,838/kW) – indicative capex of Rs. The annual avoided cost for each month by maintaining the annual generation at the levels of actual renewable generation number of 1,421,631.2 kWh in FY 2023-24 and calculating tariff savings @ Rs. 9.00/kWh is as under: The internal rate of return is 31.33%, the basic payback time is 3.19 years, and at a discount of 8%, the net present value after 25 years will be approximately Rs.9.57 crore These data suggest that rooftop solar should be seen as a financial investment asset, rather than just a symbolic campus sustainability expense. Investment evaluation is shown in Table 7.

Table 7. Green investment appraisal for a 1.0 MWp rooftop solar expansion

Indicator	**Value**	**Interpretation**
System capacity	1.0 MWp	Rooftop solar expansion case
Benchmark capital cost	Rs. 40,838/kW	Indicative rooftop solar benchmark
Total capital cost	Rs. 4.0838 crore	1,000 kW x Rs. 40,838
Annual generation	1,421,631.2 kWh	Observed renewable generation benchmark
Annual savings	Rs. 1.279 crore	Avoided grid purchase at Rs. 9/kWh
Avoided emissions	1,033.53 tCO_2/year	Generation x 0.727 tCO_2/MWh
Simple payback	3.19 years	Capital cost/annual savings
Simple ROI	31.33%	Annual savings/capital cost
25-year NPV at 8%	Rs. 9.57 crore	Discounted savings minus capital cost

They are given a different degree of economic attractiveness the more the abatement potential can be realized. The model shows that the largest emission reductions come from grid-electricity efficiency, as power purchases are a primary source of emissions. Rooftop solar provides immediate recurring savings and a short payback period but for every 15% efficiency gain in grid there is more absolute yearly abatement, per year. Decisions about commuting, travel, waste and fuel transition are likely to lead to lower expected savings, but they help to create an institutional culture of sustainability and reduce Scope 3 uncertainty. Figure 5 shows the relationship of marginal abatement and payback.

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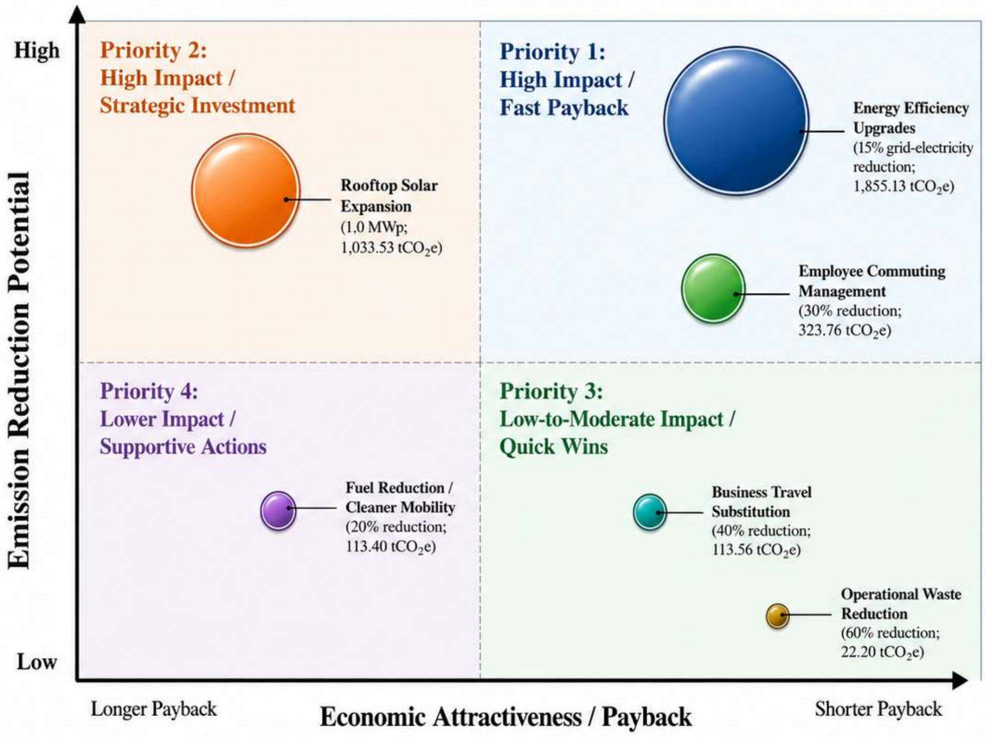

Figure 5. Marginal abatement and payback matrix for campus decarbonization options

A decarbonization scenario for 2030 includes operational efficiency, renewable substitution and behavioral interventions. A 15% reduction in grid-electricity will cut down emissions by 1,855.13 tCO2e and also save nearly Rs. 2.297 crore per annum the alternative of rooftop solar of 1.0 MWp would be equivalent to reduction of 1504.15 tCO2 and saving of Rs. 1.279 crore per annum. This included 30% of staff commuting (323.76 tCO2e prevented); 40% substitution of corporate air travel (113.56 tCO2e); 60% reduction in operational waste (22.20 tCO2e); and 20% reduction in stationary and mobile fuel (113.40 tCO2e). This ultimately resulted in 3,461.57 tCO2e reduction in emissions thereby reducing FY 2023-24 emissions from 14,899.1 tCO2e to 11,437.53 tCO2e which is a change of −23.23%. Table 8 illustrates the case.

Table 8. Decarbonization scenario and 2030 pathway based on FY 2023-24 baseline

Mitigation measure	Reduction assumption	Annual emission reduction (tCO2e)	Annual saving
Grid-electricity efficiency	15% reduction in Scope 2 electricity	1,855.13	Rs. 2.297 crore
Additional rooftop solar	1.0 MWp substitution benchmark	1,033.53	Rs. 1.279 crore
Employee commuting	30% reduction	323.76	Policy-dependent
Business air travel	40% substitution	113.56	Policy-dependent
Operational waste	60% reduction	22.20	Indirect saving
Stationary/mobile fuel	20% reduction	113.40	Fuel-cost dependent
Combined pathway	Integrated scenario	3,461.57	Rs. 3.576 crore plus indirect savings
Residual emissions	Post-scenario total	11,437.53	23.23% reduction from baseline

The integrated pathway begins with annual carbon accounting and moves through electricity-cost exposure, efficiency improvement, renewable investment, mobility governance, waste and fuel transition, and continuous monitoring. The pathway translates sustainability from disclosure into financial and operational governance. The integrated pathway is presented in Figure 6.

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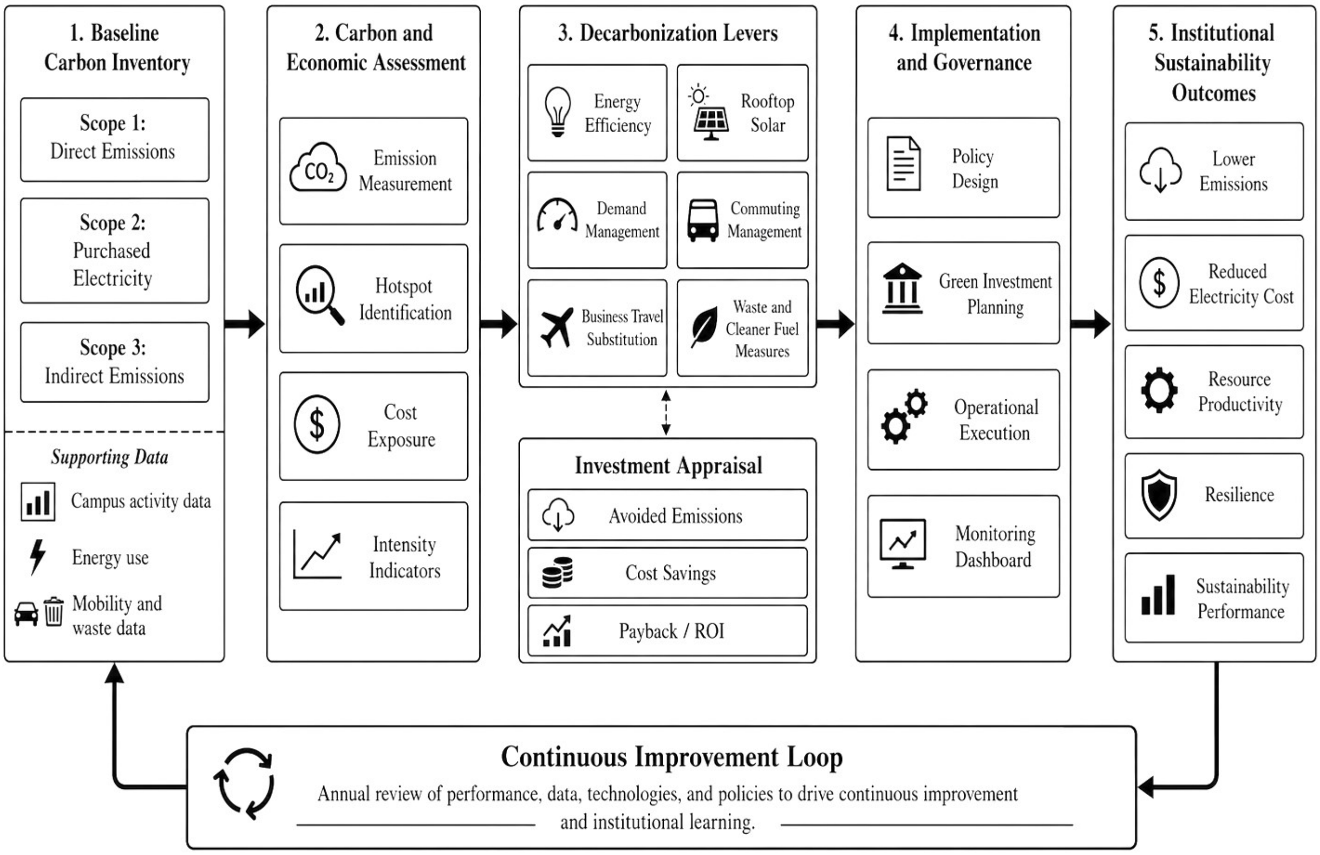

Figure 6. Integrated economic decarbonization pathway for higher education institutions

The condition has implications for the functioning of the higher education administration. In that combination, the largest climate and cost benefit comes from power savings first, as generally purchased electricity represents the biggest emitting sources household and tariff-linked operational exposure. Number two fossil free power offer great long run quality, short simple pay-back periods and excellent return on capital. Third, commuting and travel are two obvious areas for institutional emissions, and at the very least if anyone is seeking to claim credibility on their report through a scope 3 action (which by its nature is arguably going to end up being socially visible). Fourth, metrics of intensity are a critical element of fair performance evaluation; campuses may grow while their carbon footprint improves. Fifth, when you frame emissions the same way you do other metrics, sustainability offices can speak the same language as finance committees, infrastructure teams, procurement departments, academic leadership, and any other external stakeholders.

7. Conclusion

As institutions measure the carbon footprint for economic reasons, this research shows that the measurement through MIT methodology is more strategic in nature. The case study shows that the institution is able to reduce its total emissions by 13.95% from FY 2022-23 to FY 2023-24, even with campus expansion and increase in academic size. From the relevant base year of FY 2019-20 to FY 2023-24, students enrolled increased by 85.80%, population on campus rose by 76.31% and built-up area increased by 22.16%. In the same period, emissions per student decreased by 41.95%, person intensity by 38.83% and built-up intensity by 11.71%. This implies that even in the presence of an institutional development pressure for absolute emissions, normalized carbon production could still be increased. This paper considers the fraction of electricity bought-in via a distribution network. Energy efficiency, renewable generation, demand-side management and building-performance governance are key FY 2023-24 objectives with Scope 2 emissions accounting for 83.01% of the carbon footprint. Economic estimates suggest that renewable power avoided at the

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observed generation level, may lead to tariff-linked savings of Rs. 1.279 crore per year to the tune of about 1,033.53 tCO2. Based on the above assumptions, the simple payback period for a 1.0 MWp rooftop solar investment is 3.19 years. The combined scenario indicates a potential decline of 23.23% from the base level of FY 2023-24. These findings challenge the characterization of carbon accounting as a management and economic governance tool. Universities need an annual inventory by scope, emission factors need to be transparent, normalized intensity metrics and investment-oriented exposure mitigation planning. Scope 2 emission reductions are the least costly emission reductions. Scope 3 commuting and business travel emission reductions support institutional legitimacy and behavioral sustainability. Therefore, a carbon strategy for higher education will involve the precise assessment of many factors, in addition to funding, infrastructure design, mobility governance and continuous monitoring. The economic model developed in this paper provides a reproducible framework for firms to relate carbon reduction with resource efficiency, green investment and long-term sustainability performance.

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