Contextualising the Impact opportunity of Urban Energy Transition

A Case Study at CKT College, Panvel, Maharashtra, India

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[this work has been carried out with contribution from Ashish Mehta (founder of Second Nature Sustainable Solutions, LLP), and Minus CO2 Pvt. Ltd. (where Ashish is a co-founder)]

1. Introduction

Energy transition: Energy transition refers to the global shift in energy production, distribution, and consumption from fossil fuel-based systems to renewable energy sources like solar, wind, hydropower and geothermal.[1]

The global energy system remains heavily dependent on fossil fuels which has grave environmental, economic, and social consequences. In 2018, 89% of global CO_2 emissions came from fossil fuels and industry, with coal alone causing 0.3°C of the 1°C increase in average global temperatures.[2] Beyond climate impacts, fossil fuel combustion contributes to severe air pollution, responsible for 7 million premature deaths yearly around the world and annual health costs estimated at $8.1 trillion globally.[3] Economically, 60% of oil rents could be lost under ambitious decarbonisation policies.[4] If countries continue to rely on fossil fuels, they may expose themselves to stranded asset risks as well as volatile energy prices.

On the other hand, renewable energy provides both environmental and macro-socio-economic benefits. Transitioning to renewable energy reduces greenhouse gas emissions, lowers health-related costs, and stimulates employment. According to a recent report, up to 90% of renewable energy projects newly commissioned in 2024, are more cost-effective than fossil fuel alternatives.[5] This global context brings to attention the necessity for countries, including India, to accelerate their energy transition.

Distributed solar:

Distributed solar energy generation produces electricity close to where it is consumed, which in turn reduces transmission losses and pressure on centralised grids. Additionally, it improves energy efficiency and reliability especially during events like power outages. From an economics point of view, it lowers electricity costs for users, which reduces operational costs (acting as microeconomic benefit), supports energy independence, and promotes local investment and green job creation. These benefits generate positive spillover effects on the

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[1] United Nations Development Programme. “What Is the Sustainable Energy Transition and Why Is It Key to Tackling Climate Change?” *Climate Promise*, 3 Feb. 2025, climatepromise.undp.org/news-and-stories/what-sustainable-energy-transition-and-why-it-key-tackling-climate-change.

[2] ClientEarth. “Fossil Fuels and Climate Change: The Facts.” *ClientEarth*, 27 Mar. 2025, https://www.clientearth.org/latest/news/fossil-fuels-and-climate-change-the-facts/.

[3] United Nations. *Renewable Energy – Powering a Safer Future*. United Nations, www.un.org/en/climatechange/raising-ambition/renewable-energy. Accessed 16 Oct. 2025.

[4] Jensen, Lars. "The Economic and Fiscal Transition Costs of Global Climate Mitigation in Fossil Fuel Export Dependent Economies." *Resources Policy*, vol. 96, Sept. 2024, article 105234. *ScienceDirect*, https://doi.org/10.1016/j.resourpol.2024.105234

[5] Reuters. "Around 90% of Renewables Cheaper than Fossil Fuels Worldwide, IRENA Says." *Reuters*, 22 July 2025, https://www.reuters.com/business/energy/around-90-renewables-cheaper-than-fossil-fuels-worldwide-irena-says-2025-07-22/.

regional economy. From an environment perspective, it cuts carbon emissions by replacing fossil fuel-based power, helps transition toward sustainable energy systems that will satisfy the needs of current and future generations, and contributes to climate change mitigation.[6]

2. The 3P framework of the Impact Economy

Impact Economy

Thought leaders have framed the complex socio-economic-ecological challenges of our times as the imperative to solve the three pronged challenges of social & economic inequity, climate change, and natural ecosystem degradation and proposed that Impact is the viable and necessary alternative[7]. In an impact economy, economic activity itself becomes regenerative, creating social, environmental, and financial value simultaneously.[8]

The Triple Bottom Line:

The triple bottom line is a framework for measuring a firm's social and environmental impact in addition to its financial performance. It focuses on three Ps: Profit, Planet, and People. As the categories' names suggest, profit focuses on the profit a firm generates for stakeholders, planet is concerned with environmental impact, and people emphasises societal impact. These categories can be used by firms to identify any negative externalities that they might be creating, and instead work towards integrating sustainable practices with positive impact into their business operations. A commitment to the triple bottom line can foster innovation and long-run profitability, generate positive spillover effects and economic growth, improve resource allocation, and internalise environmental and social externalities.[9] It highlights how environmental and social improvement also creates economic value, aligning with the core principles of welfare and sustainable economics.

The triple bottom line aligns with the broader goals of sustainable development. It ensure economic viability, environmental protection, and social well-being while maintaining intergenerational equity. Intergenerational equity is the concept of distributive justice between past and future generations. It operates on the assertion that future generations have a right to inherit an environment that is unharmed by their predecessors.[10]

In the context of the urban energy transition, the Distributed Renewable energy (DRE) sector illustrates this principle in action. Rooftop solar has the potential to reduce carbon emissions (planet impact), create local employment in a growth sector (people impact), and increase ROI for consumers and investors (profit impact). By *simultaneously* creating social, economic, and environmental value, the impact economy can support both present and future generations. These multiple dimensions of value facilitate progress toward sustainable

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[6] U.S. Environmental Protection Agency. "Distributed Generation of Electricity and Its Environmental Impacts." *EPA*, 2 Apr. 2025, https://www.epa.gov/energy/distributed-generation-electricity-and-its-environmental-impacts. Accessed 6 Oct. 2025.

[7] Mehta, Ashish. *The Impact Revolution is here – are you ready?* July 2020, https://india.fes.de/e/the-impact-revolution-is-here-are-you-ready.html.

[8] UBS Sustainability and Impact Institute. *The Rise of the Impact Economy: Evolving to the Next Level*. May 2023, https://www.ubs.com/global/en/sustainability-impact/our-insights/publications/reports/impact-economy.html.

[9] Harvard Business School Online. "The Triple Bottom Line: What It Is & Why It's Important." *Harvard Business School Online*, 8 Dec. 2020, https://online.hbs.edu/blog/post/what-is-the-triple-bottom-line. Accessed 6 Oct. 2025.

[10] "Intergenerational Equity." *ScienceDirect Topics*, www.sciencedirect.com/topics/earth-and-planetary-sciences/intergenerational-equity. Accessed 18 Oct. 2025.

development goals like SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), and SDG 13 (Climate Action).

3. Project Parameters for our Case Study

A. Urban transition in macro environment

Indian context:
In India, energy transition means moving away from a heavily coal-dependent industry. From 1990 to 2022, electricity production share of total energy sources in India has risen substantially, with coal accounting for 77% of total energy production in FY23.[11,12] Recently, in March 2025, India surpassed one billion tonnes of coal production, a record high. As of 2023, India is the third largest emitter globally of carbon dioxide[13] and around 40% of all GHG emissions are created by the energy sector.[14]

India's heavy reliance on coal emphasises the urgent need for climate action. The energy transition should be a critical component of India's climate mitigation strategy.

The country has set ambitious renewable energy targets through its five climate action targets called Panchamrit. As part of the pledge made at COP26, India aims to increase non-fossil electricity generation capacity to 500 GW by 2030, meet 50 percent of its energy requirements from renewable energy by 2030, reduce the total projected carbon emissions by one billion metric tons from 2022 through 2030, reduce the carbon intensity of its economy by at least 45 percent by 2030 compared to 2005 levels, achieve the target of net zero by 2070.[15]

These targets and renewable energy commitments represent a policy-driven response to these climate challenges, aiming to reduce carbon intensity while expanding clean energy capacity.

Maharashtra's energy profile
The state has a large installed capacity in centralised generation (for example, thermal plants). Maharashtra's total installed generation capacity (central sector + state) was around 37,348 MW as of 2022, of which renewables was approximately one-third,[16] going up to 34% in FY

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[11] The World Bank. "Electricity Production from Coal Sources (% of Total) – India." The World Bank, 2025, https://data.worldbank.org/indicator/EG.ELC.COAL.ZS?locations=IN.
[12] Koundal, Aarushi. "India Still Heavily Dependent on Coal; Takes 77 Per Cent Share in Total Energy Generation in FY 23, Says MoSPI." *ET EnergyWorld*, 20 Mar. 2024, energy.economictimes.indiatimes.com/news/renewable/india-still-heavily-dependent-on-coal-takes-77-per-cent-share-in-total-energy-generation-in-fy23-says-mospi/108644839.
[13] *Global Carbon Atlas.* "Emissions – Carbon Emissions." Global Carbon Atlas, https://globalcarbonatlas.org/emissions/carbon-emissions/
[14] World Economic Forum, Kearney, and Observer Research Foundation. *Mission 2070: A Green New Deal for a Net-Zero India*. White Paper, November 2021. https://www3.weforum.org/docs/WEF_Mission_2070_A_Green_New_Deal_for_a_Net_Zero_India_2021.pdf.
[15] Deb, Kaushik, and Pranati Chestha Kohli. "Assessing India's Ambitious Climate Commitments." *Center on Global Energy Policy, Columbia University*, 08 Dec. 2022, https://www.energypolicy.columbia.edu/publications/assessing-india-s-ambitious-climate-commitments/.
[16] "Maharashtra's Installed Power Generation Maximum in India." *The Times of India*, https://timesofindia.indiatimes.com/city/mumbai/maharashtras-installed-power-generation-maximum-in-india/articleshow/98745267.cms. Accessed 6 Oct. 2025.

2023.[17] GHGP (Greenhouse Gas Platform) data estimates that *public electricity generation* in Maharashtra accounts for more than 53% of the total emission from the energy sector in the state.[18] Since the state's utility (MAHAGENCO) remains heavily reliant on thermal power, there is room and a need for decarbonisation and switching to cleaner sources.

Maharashtra ranks 5th in India in terms of renewable installed capacity. A jump in renewable capacity (19% growth over two years) shows momentum and ~~possible~~ policy support and market attractiveness for solar/wind investments.[19] An additional 281 MW by JSW Energy is a sign of ongoing investments in renewables within the state.[20]

Rooftop solar in Maharashtra has crossed the 2,000 MW mark.[21] But large‑scale/ground‑mounted solar is much larger (for example, Maharashtra has over 4.25 GW ground-mounted solar, plus other renewables).[22]

Mumbai Suburban total consumption of electricity is 15,196.6 MUs in 2022-23, showing the scale of energy use in the region.[23]

B. The Case of CKT College

To illustrate the above macro-level trends at the institutional level, this study examines Changu Kana Thakur (CKT) College as a representative example of distributed solar adoption in the urban education sector.

CKT College Background:
CKT College is located in New Panvel, Navi Mumbai, Maharashtra. It is a private arts, commerce, and science college established by the Janardhan Bhagat Shikshan Prasarak Sanstha, a non-profit organisation. The college is permanently affiliated with the University of Mumbai and recognised under Sections 2(f) and 12(B) of the University Grants Commission (UGC).[24]

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17 "Renewable Energy." *Maharashtra State Data Bureau*, https://mahasdb.maharashtra.gov.in/DSP/renewEnergy. Accessed 6 Oct. 2025.
18 "Maharashtra's Dilemma." *ResearchGate*, https://www.researchgate.net/publication/370471185_Maharashtra's_dilemma. Accessed 6 Oct. 2025.
19 Sen, Somit. "Installed Capacity of Renewable Energy in Maharashtra Up 19% in Two Years." *The Times of India*, https://timesofindia.indiatimes.com/city/mumbai/installed-capacity-of-renewable-energy-in-maharashtra-up-19-in-two-years/articleshow/118791740.cms. Accessed 6 Oct. 2025.
20 "JSW Energy Adds 281 MW of Renewable Capacity in Maharashtra." *The Machine Maker*, https://themachinemaker.com/news/jsw-energy-adds-281-mw-of-renewable-capacity-in-maharashtra/. Accessed 6 Oct. 2025.
21 "Rooftop Solar Installed Capacity Crosses 2000 MW Mark in State." *The Times of India*, https://timesofindia.indiatimes.com/city/mumbai/rooftop-solar-installed-capacity-crosses-2000mw-mark-in-state/articleshow/112973180.cms. Accessed 6 Oct. 2025.
22 "Maharashtra's Solar Surge: Powering RE Growth with Solar Energy." *Energetica India*, https://www.energetica-india.net/news/maharashtras-solar-surge-powering-re-growth-with-solar-energy. Accessed 6 Oct. 2025.
23 Maharashtra Energy Development Agency. "Infrastructure 2023." *Maharashtra Energy Development Agency*, https://mahades.maharashtra.gov.in/files/publication/Infra2023.pdf. Accessed 6 Oct. 2025.
24 Changu Kana Thakur Arts, Commerce and Science College. "About the College." *CK Thakur College*, https://www.ckthakurcollege.net/home/about. Accessed 6 Oct. 2025.

CKT College operates as a Grant-in-Aid and Self-Financing institution. It offers undergraduate, postgraduate, and research programs across various disciplines. While it charges tuition fees, it primarily focuses on providing quality education and is not driven by profit motives. The college has also been granted autonomous status by the UGC and the University of Mumbai, allowing it to design its own curriculum and assessment systems.

CKT College emphasises sustainability in its mission statement: *"to create a committed generation for sustainable harmony and integration."*[25] This vision aligns closely with its initiative to adopt solar energy on campus. Adopting solar energy reflects a commitment to reducing its negative environmental impact and promoting renewable solutions within the education sector.

C. Method of Study: Rooftop Solar System at CKT College

452 solar panels totalling a capacity of 150 kW were installed at CKT college in March 2019 by the solar EPC company Minus CO2. The cost of purchase, installation, and maintenance amounts to Rs. 6,000,000 until March 2022.[26] The excess electrical power generated by solar panels is exported by the system to the electricity board (MSEB). Exported units are compensated in the actual consumed units. This compensation reduces the net monthly bill from the electrical company, thereby reducing the electricity expenses by CKT.

Data used:

- From Aug-2017 till Feb-2022, CKT diligently recorded its monthly electrical energy consumption from the grid. This included the period before and after installation of solar, and as expected the grid consumption reduced after March 2019.
- With the help of the Minus CO2 team and with CKT providing their electricity bills, we obtained generation data for the most recent 09 months of 2025.
- Since solar units substitute for the units from the grid, we can compute the savings to CKT based on prevailing grid tariff.
- We use the public information on CO2 emissions and system losses to estimate the impact on emission reduction by installing solar.
- We use Minus CO2's in-house data on human resource requirement for construction and maintenance to estimate the employment and wage impact of the project.

4. Computing the 3P Components of Solar Plant at CKT College

Profit

This section will assess the financial viability and returns of distributed solar generation by comparing the electricity cost savings generated from solar energy against the payments that would have been made to the electricity company for this particular customer, CKT College. The avoided expenditure on electricity bills represents avoided opportunity costs for the college and demonstrates the economic value of distributed renewable energy investments.

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[25] Changu Kana Thakur Arts, Commerce and Science College. "Our Vision, Our Goals and Objectives." *CK Thakur College*, https://www.ckthakurcollege.net/home/visionmissiongoals. Accessed 6 Oct. 2025.

[26] Thakur, P. S., and G. U. Patil. Deployment of Grid Connected PV System for Reduction in Electricity Bill: Case Study. Educreator Research Journal, vol. 9, no. 2, 2022, pp. 72–77. Zenodo, https://doi.org/10.5281/zenodo.11108144

Bill amount saved per data published by CKT after installation:

Period	Electricity bill savings (Rupees)
March 2019 to February 2020	699,113
March 2020 to February 2021	1,726,069
March 2021 to February 2022	2,219,391

For the period Oct 2024-Sep 2025, the team at Minus CO2 calculated the total savings for CKT to be Rs. 2,290,880.

The first year is lower, since the setup was not complete and further CKT started maintaining the plant better as it got more experience and the expertise of a seasoned solar service provider in Minus CO2. In fact, the performance of solar degrades marginally (by less than 1% yoy) so we should expect a decrease in savings as time elapses. Two reasons explain the increase in savings at CKT in subsequent years of operation:

1. Improvement in operations and maintenance cycle
2. Increase in grid tariff costs; whereas once installed, solar does not see cost increments.

Based on the savings of over 22,00,000 per year; the break-even for CKT is just 3 years. Note that the lifetime of a well-maintained solar system is 25 years, ie. there will continue to be further increase in savings (profit) after break-even. In absolute terms, in just 10 years of operation, CKT's ROI would be over 300%.

Total profit for CKT college:

- Annual: Rs. 22 lac
- From commissioning till date (6.5 years): Rs. 1.4 cr
- Lifetime (project life of 25 years): Rs. 5.5 cr

These results indicate that the rooftop solar installation in CKT College has significant positive economic viability. Self-generation replacing grid dependency lowers the average cost of energy consumption in the long run.

Another key advantage of reduced dependence on the grid is the reduction in cost uncertainty. For example, CPI (2018) finds that solar‑based revenues are substantially less variable compared to coal-based generation.[27] Moreover, Navia Simon et al. (2025) show that solar and wind deployment reduces the sensitivity of power prices to market and fuel shocks.[28] This provides an *insurance value* against tariff volatility. While macro-level studies examine system-wide price stabilisation effects, the same principle applies at the institutional level to CKT College. By generating a portion of its electricity on-site, the college mitigates exposure to rising or unpredictable retail tariffs. The project contributes to greater price stability and resource efficiency, aligning with the principles of sustainable economic growth. The

[27] Jena, Labanya Prakash, Chavi Meattle, and Gireesh Shrimali. *Getting to India's Renewable Energy Targets: A Business Case for Institutional Investment.* Climate Policy Initiative, March 2018. https://climatepolicyinitiative.org/wp-content/uploads/2018/03/Getting-to-Indias-Renewable-Energy-Targets-A-Business-Case-for-Institutional-Investment.pdf

[28] Navia Simon, Daniel, and Laura Diaz Anadon. "Power Price Stability and the Insurance Value of Renewable Technologies." *Nature Energy*, vol. 10, 2025, pp. 329-341. *Nature*, https://www.nature.com/articles/s41560-025-01704-0

financial outcomes thus reinforce the microeconomic rationale for distributed renewable energy adoption in the education sector.

Planet

Assumptions:

Parameter	Value/range
Installed capacity	150 kW
Daily generation per kW	1.5 – 4.5 kWh/day (seasonal variation)
Average daily generation per kW	3.0 – 3.5 kWh/day (1^{st} year of operation)
1^{st} year generation per kW (range)	1100–1300 kWh
Grid Weighted Average Emission Factor (EF)	0.727 tCO_2/MWh (2023–24)[29]
Rooftop losses	1-2%
Centralised losses	15.29%

Operational data from Minus CO2 from Jan ’25 – Sep ‘ 25

- Total units from solar = 109056
- Total number of days = 273
- Installed capacity = 150 kW
- Average daily generation = 2.7 kWh/kW/day

Note: the reduction in yield to 2.7 kWh/kw/day (from the lower boundary of 3.0) can be explained due to a) system degradation over time; b) the most recent 9 months have experienced poorer solar irradiation and a longer monsoon; c) shutdowns at CKT, both scheduled and unscheduled; d) need for further optimization of O&M cycles; e) solar panels today have significantly better performance than those from 2018.

The subsequent section(s) proceed with an average estimate of generation of 3.0 kWh/kW/day.

Annual Generation

Annual generation per kW = 3.0 x 365 = 1095 kWh
Total Annual generation at CKT = 1095 x 150 = 164250 kWh

Carbon dioxide emissions avoided

According to the Central Electricity Authority, 0.727 kg of CO_2 is emitted per kWh (1 unit) of grid electricity. This means that every 1 kWh of solar generated electricity avoids approximately 0.727 kg of CO_2 or 0.000727 tCO_2 if it displaces average grid electricity.[30]

[29] Central Electricity Authority. *CO_2 Baseline Database for the Indian Power Sector: User Guide, Version 20.0*. Ministry of Power, Government of India, Dec. 2024, https://cea.nic.in/wp-content/uploads/2021/03/User_Guide_Version_20.0.pdf

[30] Central Electricity Authority. *CO_2 Baseline Database for the Indian Power Sector: User Guide, Version 20.0*. Ministry of Power, Government of India, Dec. 2024, https://cea.nic.in/wp-content/uploads/2021/03/User_Guide_Version_20.0.pdf

It is worth noting that the emission factor is dynamic since the grid is becoming cleaner over time. For example, in India's National Electricity Plan, the average emission factor is projected to drop to around 0.548 kg CO_2/kWh by 2026–27.[31]

CO_2 avoided per kW per year:

Generation (kWh/kW/year)	CO_2 avoided (kg)	CO_2 avoided (tCO_2/kW/year)
1095	1095 × 0.727 = 796.065	0.796

Total CO_2 avoided at CKT annually:

Generation (kWh/kW/year)	Annual generation (kWh/year)	CO_2 avoided (kg CO_2/year)	CO_2 avoided (tCO_2/year)
Daily (3.0 kWh/kW)	164250	119409	119.4

Seasonal variation:

Season (daily generation)	Monthly generation (kWh/day)	CO_2 avoided (kg/month)
Rainy months (1.5 kWh/kW/day)	1.5×150 = 225.0	225×30x0.727 = 4,907
Best months (4.5 kWh/kW/day)	4.5x150 = 675.0	675×30x0.727 = 14,722

Seasonal variations in generation introduce uncertainty in the supply of energy, which can affect the economic value of solar output. It brings to attention the need for risk-adjusted planning in investments in the energy sector.

Total CO2 avoided by CKT college:

- Annual: 119 tons
- From commissioning till date (6.5 years): 776 tons
- Lifetime (project life of 25 years): 2985 tons

Beyond just a reduction in carbon emissions, distributed solar contributes to local environmental justice by reducing reliance on coal-fired generation which typically impacts communities near thermal power plants disproportionately. It not only mitigates climate change but also addresses localised environmental and public health externalities. This is in line with intergenerational equity principles.

Adjustment for distribution/transmission losses (grid vs rooftop)

Centralised grids usually suffer high distribution losses due to technical issues like energy dissipation in equipment and conductors and non-technical issues like energy theft, faulty meters, and administrative errors. Thus, to deliver 1 kWh to the user the grid must generate more than 1 kWh.

$$Generation\ required = \frac{1}{1-loss}$$

[31] Press Information Bureau. "Central Electricity Authority Notifies the National Electricity Plan for the Period of 2022–32." *Press Information Bureau*, Ministry of Information and Broadcasting, Government of India, 31 May 2023, https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=1928750

According to the Bureau of Energy Efficiency's *Energy Audit Report for MSEDCL (Mumbai Region), FY 2020–21*, the transmission and distribution (T&D) losses were reported at 15.29%.[32]

Rooftop generation consumed onsite avoids that extra upstream generation and therefore avoids more CO_2 than the simple per-kWh factor. This can have positive economic implications for electricity pricing and overall welfare. We adjust the per-kWh avoided CO_2 by the ratio of the generation required.

$$Generation\ required = \frac{1}{1-0.1529} \approx 1.180$$

- If centralised losses = 15.29%, replacement multiplier ≈ 1.180.
- So, for every 1 kWh delivered from the grid, 1.18 kWh must be generated.
- I calculate the adjusted avoided CO_2 per kWh of distributed assuming distributed losses to be around 1.5% which are negligible compared to centralised losses (meaning they are small enough to be ignored)
- Adjusted per-kWh CO_2 avoided = 0.727×1.180 = 0.857 kg CO_2/kWh.
- Annual system-level CO_2 avoided ≈ 164,250 × 0.857 = 140,762.25kg CO_2/year ≈140.8 tCO_2/year

Scope categorisation

The HECS Carbon Footprinting Guide for Indian Businesses (2025) provides a useful framework for understanding the emissions impacts of the rooftop solar system at CKT College. The standard Scope 1/2/3 categorisation is commonly used in carbon accounting.

The rooftop solar system primarily offsets Scope 2 (indirect electricity) emissions.
For the rooftop solar case:

- Scope 2 would be primary (indirect emissions from electricity purchased from grid that rooftop solar offsets).
- Scope 1 (secondary) might include any minimal generator fuel use if still present at the site.
- Scope 3 could involve upstream emissions (manufacture of solar modules, transportation, installation).

While scope 1 and scope 3 emissions lie outside the quantified scope for this study, they are acknowledged as part of a broader sustainability perspective. They are recognised in our qualitative discussion.

While CKT College is not a commercial entity, adopting carbon measurement and reduction strategies can allow it to reap institutional benefits beyond just bill savings. For a college, carbon footprinting can demonstrate sustainability credentials and prepare the institution for any future reporting or compliance expectations.

People

We now shift our attention to the impact on incremental jobs created at each rooftop solar site, which are typically during the installation & construction (I&C) stage and once the plant is operational – for operations and maintenance (O&M). It is important to acknowledge that

[32] Maharashtra State Electricity Distribution Co. Ltd. *Energy Audit Report of MSEDCL for the Year 2020–21*. Submitted by PPS Energy Solutions, 10 June 2022, https://beeindia.gov.in/sites/default/files/inline-images/MSEDCL_EA_20-21.pdf. Accessed 6 Oct. 2025.

these are green sector jobs, and therefore can be considered all site personnel as either skilled or semi-skilled.

Data shared by Minus CO2
Based on internal analysis by the Minus CO2 team, the following are the personnel requirements for a project of capacity 100 kWp.

During I&C:

Type of Worker	Number of personnel	Approx daily wages (Rs.)	Number of person days
Skilled	1	1500	60
Semi-skilled	3	1000	180

For ongoing O&M:

Type of Worker	Number of personnel	Approx daily wages (Rs.)	Number of person days (per year)
Skilled	1	1500	2
Semi-skilled	2	1000	46

At CKT, with an installed capacity of 150 kW, therefore:

- # of Person-days of work for I&C = 240 x 1.5 = 360
- Total wages for work for I&C= (1500 x 60 + 1000 x 180) x 1.5 = 4,05,000
- # of Person-days for O&M per year = 48 x 1.5 = 72
- Total wages for O&M per year = (1500 x 2 + 1000 x 46) x 1.5 = 73,500

Construction Jobs (Distributed)
Generally higher than centralised projects, because installation is scattered, requires more small teams.

Convert Jobs to Wage/Economic Impact per MW

Category	Person-Days		Annual Wage Impact (₹)	
	Distributed	Centralised	Distributed	Centralised
Maintenance	480	80	4,90,000	1,00,000
Construction	2400	400	27,00,000	5,00,000
Total	2880	480	31,90,000	6,00,000

Distributed solar involves more person-days per kW compared to large centralised energy plants because installation and maintenance are more labour-intensive and geographically dispersed. According to a Bridge to India (2014) report, small rooftop solar installations generate approximately six times the number of jobs per megawatt (MW), compared to jobs per MW for ultra-mega scale utility plants.[33] This sharp contrast highlights the higher labour intensity and equity and distributional benefits. Distributed solar increases local economic activity (n sign of positive production externalities). Local employment generation contributes to labour income and has multiplier effects on consumption creating a regional

[33] Bridge to India. *Beehives or Elephants? How Should India Drive Its Solar Transformation?* Bridge to India Pvt. Ltd., Sept. 2014.

economic impact. Policymakers should eliminate the notion that centralised power generation is more effective than distributed power generation at creating jobs.

Converting person-days to wage impact quantifies the direct contribution of distributed solar to the local economy. These earnings circulate through local consumption, generating secondary economic benefits (induced effects) beyond the initial labour payment.

Incorporating human rights best practices
The 2025 Renewable Energy & Human Rights Benchmark highlights that renewable energy projects that adhere to human rights standards:[34]

- Protect labour rights and provide fair wages
- Implement grievance mechanisms for workers and communities
- Offer community benefit-sharing and just transition measures

CKT College can align its distributed solar project with these standards by

- Ensure fair and safe working conditions for local staff
- Promote benefits such as upskilling and capacity-building
- Avoid potential disputes or operational disruptions, which translates into economic savings

Distributed solar projects at CKT College can generate not only direct employment but also broader socio-economic value by following rights-respecting practices. The Benchmark shows that projects adhering to fair labour and benefit-sharing principles report better social outcomes and contribute to sustainable economic development.

5. Sector-level Extrapolation

Assumptions:

1. All colleges have the space, budget, orientation, and sun exposure for optimal solar panels
2. Colleges have the operational commitment to maintain the systems properly
3. Energy demands are similar to CKT College such that similar savings per kW can be expected
4. Exported surplus is credited at rates similar to the ones in the CKT case

Profit

CKT College saved Rs. 4,644,573 over 3 years.
It’s electricity savings from Oct 2024 to Sep 2025 = Rs. 2,290,880.

	Number of colleges	**Total annual savings (Rupees)**
City Level (Mumbai)	1,315 colleges[35]	1,315 × 2,290,880= 3,012,507,200 ≈ 3.012 billion
State Level (Maharashtra)	4,685 colleges[36]	4,685 × 2,290,880 = 10,732,772,800≈ 10.732 billion

[34] Business & Human Rights Resource Centre. *Renewable Energy and Human Rights Benchmark 2025*. 17 Sept. 2025, https://www.business-humanrights.org/en/from-us/briefings/renewable-energy-and-human-rights-benchmark-2025/?utm_source=twitter_bhrrc&utm_medium=twitter_bhrrc&utm_campaign=2509REB&utm_content=social.
[35] “Colleges in Mumbai.” *Shiksha.com*, Shiksha.com, https://www.shiksha.com/colleges/mumbai. Accessed 18 Oct. 2025.
[36] CEIC Data. *Number of Colleges: Maharashtra*. Ministry of Education, 2021, https://www.ceicdata.com/en/india/number-of-colleges/number-of-colleges-maharashtra. Accessed 18 Oct. 2025.

Country Level (India)	43,796 colleges[37]	43,796 × 2,290,880 = 100,331,380,480 ≈ 100.331 billion

Widespread adoption of distributed solar could reduce institutional energy expenditures significantly. If all colleges adopt CKT-sized rooftop solar, Rs. 3.012 billion could be saved annually in Mumbai, 10.732 billion in Maharashtra, and Rs. 100.331 billion in India. At a macroeconomic level, this could improve institutional budgeting, allowing colleges to reallocate funds to infrastructure, research, or scholarships. Essentially, it could free up resources for investment in human capital and innovation. Since these calculations include both private and public institutions, electricity savings in the public sector would reduce government expenditure on electricity and enable a more efficient use of tax revenue. Annual savings highlight the potential for energy cost reduction both state-funded and private institutions to become a driver of efficiency and resilience.

<u>Planet</u>

Average rooftop solar capacity of 150 kW per institution (similar to CKT College)
Annual CO_2 avoided per college (as calculated earlier) = 140,762.25 kg CO_2

	Number of colleges	**Total annual CO_2 avoided for all colleges**
City Level (Mumbai)	1,315 colleges[38]	1,315 × 140,762.25 = 185,102,358.75 kg CO2 = 185,102.35875 tCO2
State Level (Maharashtra)	4,685 colleges[39]	4,685 × 140,762.25 = 659,471,141.25 kg CO2 = 659,471.14125 tCO2
Country Level (India)	43,796 colleges[40]	43,796 × 140,762.25 = 6,164,823,501 kg CO2 = 6,164,823.501 tCO2

Scaling distributed solar in colleges contributes to decarbonisation on multiple levels. It produces positive production externalities such as reduced public health costs, lower greenhouse gas emissions, and enhanced climate resilience. 659,471 tCO_2 avoided annually in Maharashtra could help meet Maharashtra's renewable energy targets while helping decarbonise a state heavily reliant on thermal power. 6.16 million tCO_2 avoided annually at a national level highlights the large-scale mitigation potential of distributed solar in education.

<u>People</u>

[37] Ministry of Education. *Ministry of Education Releases All India Survey on Higher Education (AISHE) 2020-2021*. Press Information Bureau, 29 Jan. 2023, https://www.pib.gov.in/PressReleasePage.aspx?PRID=1894517.
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	Number of colleges	Total I&C person-days (first year)	Total O&M person-days/year	I&C wages/year (Rs)	O&M wages/year (Rs)
City Level (Mumbai)	1,315 colleges[41]	1,315 × 360 = 473,400	1,315 × 72 = 94,680	1,315 × 4,05,000 = 532,575,000	1,315 × 73,500 = 96,652,500
State Level (Maharashtra)	4,685 colleges[42]	4,685 × 360 = 1,686,600	4,685 × 72 = 337,320	4,685 × 4,05,000 = 1,897,425,000	4,685 × 73,500 = 344,347,500
Country Level (India)	43,796 colleges[43]	43,796 × 360 = 15,766,560	43,796 × 72 = 3,153,312	43,796 ×4,05,000 = 17,737,380,000	43,796 × 73,500 = 3,219,006,000

For large-scale macro adoption, these numbers support the same trends of employment, skill development, and multiplier effects as the micro adoption. The installation and commissioning (I&C) of rooftop solar systems would cumulatively generate around 473,400 person-days in Mumbai, 1,686,600 in Maharashtra, and 15,766,560 million nationwide. The decentralised nature of rooftop solar makes it inherently labour-intensive, which is beneficial for equitable job creation across regions.

Given that the DRE sector in India is projected to employ almost 89,000 people (Power for All, 2022), a coordinated rollout of rooftop solar in educational institutions across Maharashtra could contribute meaningfully to that job pool, generating thousands of person-days annually in the state alone.[44]

While livelihood-oriented DRE technologies (such as solar looms and refrigerators) directly raise incomes (90 per cent of users in CEEW's 2023 study reported income growth) institutional distributed solar, such as CKT College's rooftop plant, contributes indirectly to the same impact economy by creating local installation and maintenance jobs and by reducing dependence on coal-based grid electricity for essential services.

6. Issues and Challenges and Future areas of focus

A. Issues and Challenges

Rooftop solar adoption in urban educational institutions faces multiple barriers. Regulatory uncertainty, frequent revisions in net-metering policies, and resistance from distribution companies can delay implementation. Additionally, high upfront capital costs and low access

[41] "Colleges in Mumbai." *Shiksha.com*, Shiksha.com, https://www.shiksha.com/colleges/mumbai. Accessed 18 Oct. 2025.

[42] CEIC Data. *Number of Colleges: Maharashtra*. Ministry of Education, 2021, https://www.ceicdata.com/en/india/number-of-colleges/number-of-colleges-maharashtra. Accessed 18 Oct. 2025.

[43] Ministry of Education. *Ministry of Education Releases All India Survey on Higher Education (AISHE) 2020-2021*. Press Information Bureau, 29 Jan. 2023, https://www.pib.gov.in/PressReleasePage.aspx?PRID=1894517.

[44] Power for All. "Power for All Releases Distributed Renewable Energy Job Report—Focus on India." *Power for All*, 27 Sept. 2022, https://www.powerforall.org/news-media/press-releases/power-all-releases-distributed-renewable-energy-job-report-focus-india. Accessed 6 Oct. 2025.

to affordable financing discourage investment. This especially affects institutions like colleges.

At the institutional level, technical and administrative hurdles continue to pose issues. Limited rooftop space and maintenance challenges can lower efficiency and reliability in the long term. Moreover, low awareness and capacity among colleges regarding subsidy mechanisms and system optimisation hinder widespread adoption. To scale rooftop solar as a solution within India's urban energy transition, addressing these issues is imperative.

B. Future areas of focus

Looking forward, rooftop solar adoption in educational institutions can be a bigger part of a broader impact economy.

By combining solar with energy efficiency measures (LEDs, smart meters, improved AC), Institutions can further increase economic saving by combining solar with energy efficiency measures such as LEDs, improved AC, smart meters. This increases the marginal economic benefit per kWh generated. Operational costs can be reduced and productivity can be increased in tandem with fostering local employment and reskilling workers. By simultaneously improving cost-effectiveness and long-run sustainability, distributed solar can maximise its economic returns while contributing to environmental goals. Thus enhancing its overall 3P value proposition.[45]

While the impacts of distributed solar at the institutional level can be measured, evaluating the broader social and economic effects of a Just Energy Transition (JET) is considerably more complex. A JET recognises the economic and social challenges of shifting away from fossil fuels; the coal industry employs around 5 lakh mine workers across more than 350 coal mines; hence, the transition must plan for reskilling to maintain the livelihoods of these workers.[46] A JET framework should consider disparities in the economic, human, social, and political capital of workers with differing skill levels when assessing vulnerabilities in the context of thermal power plant decommissioning.[47] Approximately 85% of India's coal production is concentrated in the five eastern states of Chhattisgarh, Jharkhand, Madhya Pradesh, Odisha, and West Bengal[48] which makes them disproportionately vulnerable in transition. To ensure the shift is equitable, additional efforts must be taken to address the impacts in these regions. Assessing how the transition will affect livelihoods and regional economies involves multiple variables that are difficult to quantify; therefore, while rooftop solar provides a clear, measurable model for economic, environmental, and social impact, the broader JET is a critical area for qualitative analysis and further research.

7. Conclusions and Recommendations

[45] Hubert Enviro Care Systems. "Carbon Footprinting: The Ultimate Guide for Indian Businesses in 2025." *HECS*, 6 June 2025, https://hecs.in/carbon-footprinting-india-busness-guide. Accessed 6 Oct. 2025.

[46] India's Coal Boom: Production Surpasses One Billion Tonnes. Ministry of Coal, 4 Apr. 2025, https://www.pib.gov.in/PressReleasePage.aspx?PRID=2118788. Accessed 2 Oct. 2025.

[47] Khattar, Dhwaj, and Abhishek Kumar. *Human Settlement Framework for Thermal Power Plants in the Context of Just Transition*. Friedrich-Ebert-Stiftung India Office, 2023, https://india.fes.de/fileadmin/user_upload/documents/Human_Settlement_Framework_for_TPPs_in_the_context_of_Just_Transition.pdf.

[48] Sen, Vaibhav, et al. *Vulnerability Assessment of Mineral-Rich States to Energy Transition*. Climate Policy Initiative, May 2023, https://www.climatepolicyinitiative.org/wp-content/uploads/2023/05/Vulnerability-Assessment_Publication.pdf.

The transition to cleaner, primarily renewable sources of energy is deemed a critical step in the global fight against climate change by reducing the GHG emissions from burning fossil fuels. The case study at CKT of a 150 kW rooftop solar plant demonstrates, using actual data, that this transition has a 3P positive impact – as it improves the condition of the planet and people – while increasing profit for CKT. The additional benefit of distributed solutions over centralised approaches – has been highlighted in terms of the employment and wage potential in the green jobs sector.

While CKT is merely one installation, our study provides sufficient evidence that it constitutes an exemplar for the Impact Economy. Our recommendation is for small and distributed commercial establishments like schools, colleges, hospitals, hotels, etc. to actively consider the benefit of adopting rooftop solar (and other clean energy solutions) to enhance their triple bottom line. We also urge the government, policy makers, and think tanks to promote distributed clean energy solutions vis-à-vis centralised installations. It is increasingly evident that faster deployment of solutions such as rooftop solar, will help meet the overall CO2 reduction goals of India thereby reducing the need to expand coal-based thermal energy capacity. The benefits to macroecomic factors such as employment and effective land-use will also be significant.

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