



Metro Rail through Solar Energy?

A Case Study of Blue Line of Namma Metro in Bengaluru

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Urban rail transit is the backbone of sustainable mobility, but it is also energy intensive. As Indian cities scale up metro networks, the question is no longer whether we can decarbonise public transport, but how quickly we can do it without compromising reliability or financial viability. A recent collaborative feasibility study by the Indian Institute of Science (IISc), Bengaluru and Bangalore Metro Rail Corporation Limited (BMRCL), funded by HSBC answers this with compelling clarity: Bengaluru's upcoming ~55 km Blue Line can be powered significantly, and eventually entirely, by solar energy.

The study demonstrates that 30 MWp of rooftop solar can be integrated immediately into the corridor's traction power network without curtailment, grid export, or modification to existing infrastructure. This alone offsets 36.5% of annual energy demand, delivers a ~2 year payback, and avoids over 44,500 tonnes of CO₂ annually.

With strategic use of viaduct parapets, station canopies, depot rooftops, and net metering at priority high-tension nodes, installed capacity can scale to ~83 MWp, achieving 100% annual solar coverage on a net-metered basis. The technology is proven, the land is available, the regulatory pathway exists, and the economics are decisive. Solarising metro corridors is no longer a pilot concept; it is infrastructure ready.

The Study & Core Objectives

The Blue Line (Phases 2A & 2B) will connect Central Silk Board to Kempegowda International Airport, serving 30 elevated stations and operating on a 750V DC third-rail system fed through a 33 kV closed-loop ring network. Under ultimate operational conditions (21 trains, 2-minute headway), the corridor will consume approximately 152 GWh of electricity per year.

Recognising the misalignment between growing urban energy demand and Karnataka's renewable deployment pace, the

study was structured around four industry-critical objectives:

1. **Technical Compatibility:** Determine how much solar PV can be safely integrated into the existing traction power architecture without disrupting N-1 reliability, protection coordination, or feeder ampacity.
2. **Hosting Capacity Thresholds:** Identify the maximum solar capacity that can be absorbed in real-time by traction and auxiliary loads without reverse grid export or curtailment.
3. **Estate & Resource Mapping:** Quantify usable solar real estate across BMRCL-owned assets (station rooftops, depots) and model generation potential using Bengaluru's irradiance profile.
4. **Commercial & Carbon Viability:** Develop bankable business cases with clear financial metrics (LCOE, IRR, NPV, payback) and quantify emission reductions to support investment and policy decisions.



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5. Network-Wide Scenario Analysis & Scalability: Model progressive sustainable transport scenarios (ST1-ST5) against 2031 travel demand forecasts to evaluate how solar integration scales from a single corridor to Bengaluru's entire proposed 317 km metro network, quantifying compounding fiscal savings, air-quality co-benefits, and long-term decarbonisation pathways.

Crucially, the study was designed for both implementation and academia. Every recommendation aligns with existing BMRCL substation typologies, KERC net metering regulations, CEA safety standards, and SCADA governance protocols.

Key Outcomes & Strategic Implications

1. Technical Integration Without Compromise

Solar generation is not injected into the 750 V DC third rail. Instead, it is fed at the 33 kV AC busbar of Auxiliary and Traction Substations through dedicated inverter feeder bays, stepped up via transformers, and protected by IEC 62116-compliant anti-islanding relays. This architecture ensures:

- Zero modification to the DC propulsion network
- Real-time absorption by traction loads during daytime operation
- Preserved N-1 reliability and

protection selectivity

- No increase in evening peak stress, as solar generation naturally aligns with midday demand troughs

The study establishes a zero-export threshold of ~38 MWp, with a conservative planning limit of 30 MWp to maintain a 7 MW absorption buffer for seasonal irradiance variation, regenerative braking coincidence, and load fluctuations.

2. Phased Deployment & Resource Potential

The corridor's solar real estate is substantial and strategically distributed:

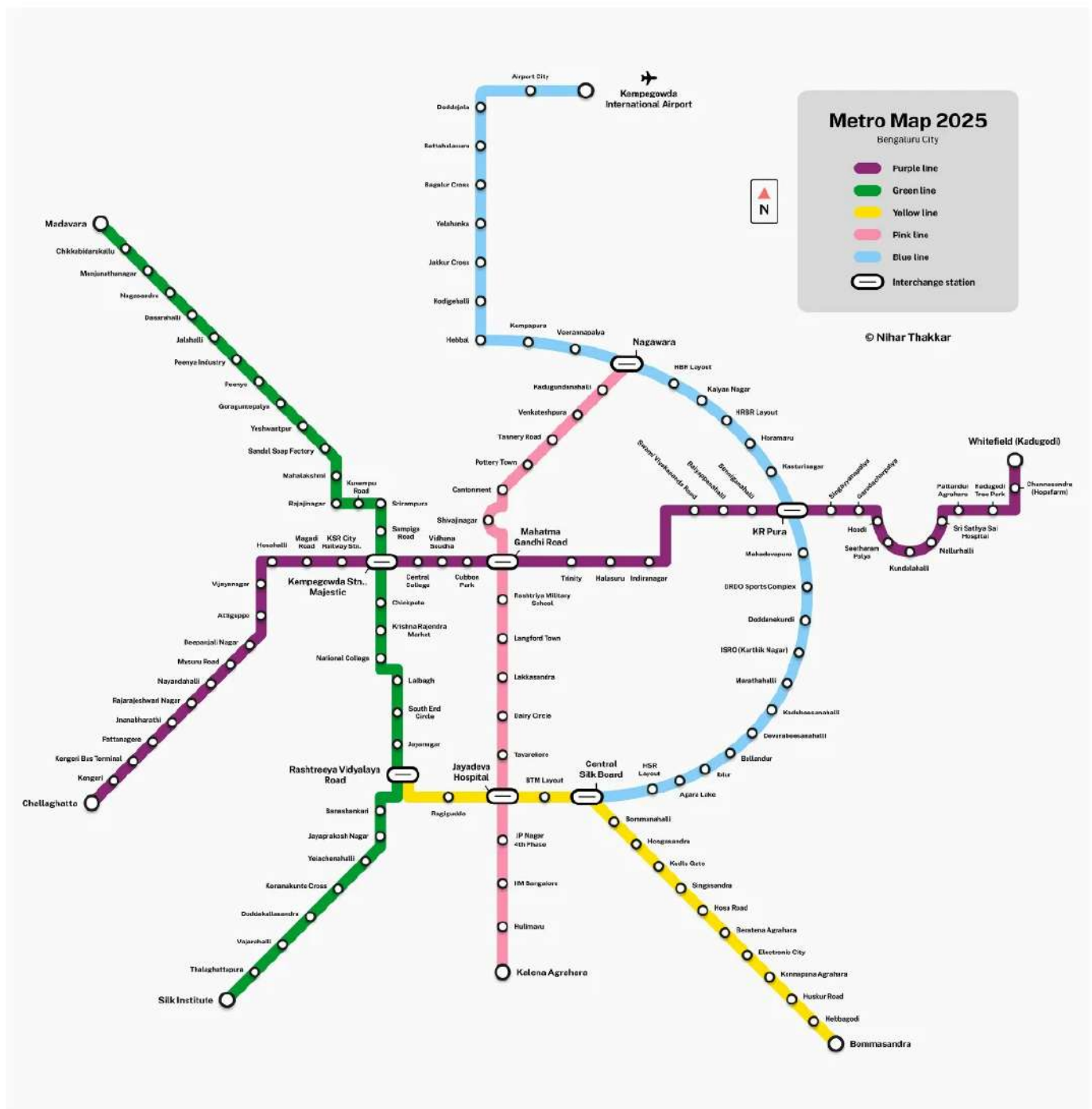
SUSTAINABLE TRANSPORT

- Phase 1 (Immediate): 30 station rooftops → 29.75 MWp, generating 54.3 GWh/yr. No net metering required. Every unit is self-consumed.
- Phase 2 (Scale-Up): Viaduct parapets (~15.2 MWp), station side canopies (~9.1 MWp), and depot rooftops

(~8-12 MWp, pending structural survey) ~54-83 MWp total. Requires net metering at 8-10 priority high tension (HT) nodes (Silk Board, Yelahanka, KR Puram, Nagawara, BBS Depot, Airport Depot, etc.).

At 83.3 MWp, annual

solar generation matches the corridor's full 152 GWh demand. This represents 100% net annual solar coverage under internationally accepted renewable accounting standards, with the grid acting as a virtual battery via net metering. No stationary storage is required.



3. Unmatched Financial Returns

The economic case is among the strongest seen in Indian public infrastructure:

- LCOE: ₹1.26-1.42/kWh vs. BESCOM HT-2 grid tariff of ₹6.7/kWh
- Payback: ~2 years across all scenarios (even at worst-case CapEx of ₹25/W)
- IRR: 53-74% depending on capacity and procurement route
- 25-Year NPV: ₹370-624 Crore
- Annual Bill Savings: ₹36.4 Cr (Phase 1) → ₹61.2 Cr (Phase 2)

The study strongly recommends a CAPEX/ownership model over RESCO or PPA structures, as BMRCL captures the full long-term value of a 25-year asset with minimal upfront capital (₹48-63 Cr for Phase 1).

4. Decarbonisation at Scale

Solar integration delivers immediate and measurable climate co-benefits:

- Phase 1: 44,526 tCO₂ avoided annually (~19,000 petrol cars

off the road)

- Phase 2: 77,900 tCO₂ avoided annually (~3.2 million trees planted)
- Future upside via India's Carbon Credit Trading Scheme (CCTS) could add ₹2.2-3.9 Cr/yr in carbon revenue, not included in base financials.

5. Scaling the Vision: 2031 Scenario Modelling & Network-Wide Impact

To understand long-term scalability, the study modelled five progressive sustainable transport (ST) scenarios against a 2031 business-as-usual baseline, using Bangalore Metropolitan Region travel demand forecasts. Scenario ST1 considers the expansion of metro network coverage through the addition of approximately 55.8 km of the Blue Line, reflecting planned infrastructure growth under ongoing project.

Building upon this, sustainable transport scenario ST2 incorporates solar energy integration by utilizing 100% of the Phase 2A solar potential along with the expanded metro network. Scenario ST3 further extends this approach by including both Phase 2A and Phase 2B solar

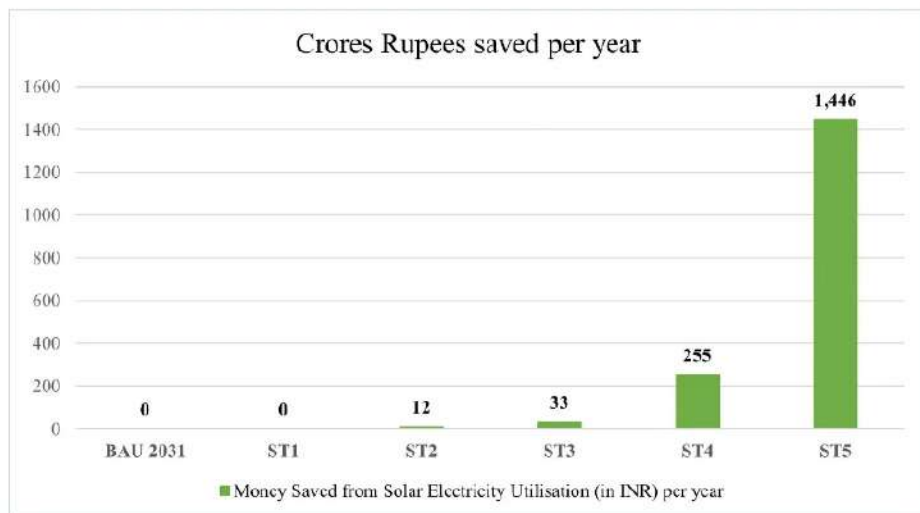


Field experiments cannot replay the same sce For transit authorities and urban planners, the sustainable transport pathway proves that corridor-level solarisation is the essential, financially self-justifying foundation for a zero-emission metro network. nario two hundred times. They cannot hold the weather constant while you change the gradient. A simulator can".

energy potential, representing a more comprehensive adoption of renewable energy within the system.

Scenario ST4 evaluates the transition of the entire Blue Line to solar-powered operations, while Scenario ST5 represents an ambitious long-term vision where the entire proposed 317 km metro network operates on solar energy, demonstrating the maximum achievable decarbonization potential of the urban metro rail system.

- BAU Scenario 2031: Baseline scenario representing existing conditions without additional interventions.



- ST1: Expansion of metro network coverage with ~55.8 km addition of the Blue Line.
- ST2: Expanded metro network + 100% utilization of Phase 2A solar energy potential.
- ST3: Expanded metro network + 100% utilization of Phase 2A and 2B solar energy potential.
- ST4: Entire Blue Line operating on solar energy.
- ST5: Entire proposed 317 km metro network running on solar energy, representing maximum decarbonization potential.

The results reveal a clear progression from incremental gains to transformative returns as solar coverage scales across the network. ST1, which adds the 55.8 km Blue Line to the existing network without renewable integration, yields negligible environmental or fiscal benefits. The curve begins to shift with scenarios ST2 and ST3, which layer solar incrementally: harnessing 100% of Phase 2A's potential (ST2) avoids roughly 12,541 tonnes of CO₂ and saves ₹12 crore annually.

Scaling this to the entire proposed 317 km metro network under ST5 amplifies the impact dramatically, preventing 1.53 million tonnes of CO₂ emissions and generating ₹1,446 crore in system-wide savings each year (see Figure 2: Rupees Saved Per Year Across Scenarios). Critically, the modelling confirms that solar integration is not a marginal sustainability add-on, but a structural decarbonisation lever: emissions and operational costs fall proportionally with network scale, while grid dependency and tariff escalation are

permanently hedged.

The Road Ahead for Bengaluru Namma Metro

The study removes the traditional barriers to renewable integration in metro systems. There is no need for new legislation, experimental technology, or land acquisition. The pathway is clear:

1. Tender Phase 1 immediately. Station rooftops require no net metering, no grid upgrades, and deliver rapid ROI.
2. Initiate KERC/BESCOM net metering pre-applications for the 8 priority HT nodes to unlock Phase 2 surplus crediting.
3. Commission structural surveys for depot rooftops and viaduct parapets to confirm load-bearing capacity and finalise mounting designs.
4. Adopt CAPEX ownership to maximise lifecycle savings and retain asset control.

For metro operators, urban planners, and state discoms, the Blue Line study offers a replicable blueprint. Solar-traction integration is no longer a sustainability add-on; it is a core infrastructure strategy that reduces operational expenditure, hedges against tariff escalation, and future-proofs urban transit against climate mandates.

Closing Note

Bengaluru's Blue Line is more than a transit corridor; it is a testbed for India's sustainable infrastructure future. The IISc-BMRCL-HSBC study proves that solar-powered metro operations are technically sound,

financially compelling, and immediately actionable. With phased deployment, strategic net metering, and decisive procurement, Namma Metro can set a national benchmark: urban metro rail that moves people, powers itself, and leaves no carbon footprint behind.

For other Indian metro networks, the blueprint is equally clear: solar integration demands no experimental technology or land acquisition, only a corridor-specific hosting threshold aligned with daytime traction loads; existing state net-metering frameworks are sufficient to scale from partial self-consumption to 100% annual coverage; and with solar LCOE nearly five times lower than grid tariffs, direct CAPEX ownership unlocks unmatched lifecycle value. The electrical architecture, domestic supply chain, and compliance pathways are already mature. What Bengaluru has validated, Delhi, Mumbai, Chennai, Hyderabad, Kochi etc. can replicate at scale.

The tracks are laid. The sun is ready. All that remains is to switch on.

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