



case study:

# Tracks of Transformation: Indian Railways' Path to Net Zero



# Introduction

Indian Railways, often described as the lifeline of the nation, is one of the largest railway networks in the world, carrying more than 8 billion passengers and over 1.2 billion tonnes of freight every year. Beyond being a mode of transport, it is also one of the largest consumers of energy in India. Historically, the system has relied heavily on diesel and coal-based electricity to power locomotives, stations, workshops, and other operations. As India strives to meet its climate commitments under the Paris Agreement and its national targets of achieving net-zero emissions by 2070, the decarbonization of Indian Railways becomes a crucial part of the country's sustainability journey.

Recognizing this, Indian Railways has committed itself to an ambitious target: becoming a net-zero carbon emitter by 2030—a full four decades ahead of India's national net-zero goal. This makes it one of the first major government institutions in the country to announce such an aggressive decarbonization pathway. The vision is not only bold but also transformative, as it seeks to align economic growth with climate action.

The journey toward this goal rests on three main pillars: electrification of the railway network, expansion of renewable energy sources, and improved energy efficiency. Electrification has been progressing at an unprecedented pace, with Indian Railways aiming for 100% electrification of its broad-gauge routes by 2030. As of 2025, more than 98% of the network has already been electrified, reducing dependency on diesel and enabling a shift toward cleaner energy. However, electrification alone is not enough if the source of electricity remains coal-based, which still dominates India's power mix.

This is where renewable energy comes into the picture. Indian Railways has started integrating solar and wind energy into its operations. Large-scale solar projects have been commissioned on railway land, rooftops of stations, and production units. Wind farms have also been developed. As of now, Indian Railways has commissioned around 231.5 MW of solar and 103.4 MW of wind capacity, with a plan to scale up to 30 GW of renewable energy by 2030 through a mix of ground-mounted, rooftop, and off-site solar projects. These efforts will not only reduce emissions but also bring down the cost of energy, given that solar power is already cheaper than grid electricity in most parts of India.

Railway stations, in particular, represent untapped potential in this transition. With thousands of stations spread across the country, many with large rooftops and open spaces, there is immense opportunity to install solar panels at scale. This can directly power station operations, lighting, and passenger amenities, while surplus energy can be fed back to the grid. A few pilot projects, such as the fully solar-powered Guwahati Railway Station, have

already demonstrated the feasibility of this approach. If scaled up nationally, solarizing railway stations could significantly reduce Indian Railways' dependence on fossil fuel-based electricity.

Another key opportunity lies in leveraging Corporate Social Responsibility (CSR) funding. Since almost every major company in India depends on the railways for freight movement, they indirectly contribute to its carbon footprint. A collaborative model where corporates fund solar installations on railway land and stations through their CSR budgets could accelerate renewable energy adoption. This would create a win-win: companies meet their CSR obligations and sustainability goals, while Indian Railways moves faster toward its net-zero vision.

Despite these positive developments, the road ahead is not without challenges. The demand for electricity in a fully electrified railway system will be enormous, and meeting this through renewables alone will require unprecedented investment and coordination. Integrating variable renewable energy with the national grid, ensuring reliable supply, managing financing, and maintaining installations across such a vast network are hurdles that must be addressed. Furthermore, questions have been raised about whether the 2030 net-zero target is realistic or simply a case of over-ambitious "green branding."

This case study explores Indian Railways' renewable energy and net-zero journey, highlighting its progress, challenges, and opportunities. It emphasizes how railway stations and CSR-driven solar initiatives could play a game-changing role in reducing emissions. The study also places Indian Railways' efforts within the broader context of India's climate commitments, making it clear that the success or failure of this initiative will have far-reaching consequences for the country's sustainable development pathway.

# Why Renewable Energy for Railways?

Railways are not only the backbone of India's transport system but also a key consumer of electricity on a national scale. With over 8 billion passenger journeys annually and nearly 1.5 billion tonnes of freight carried every year, the operational energy demand of Indian Railways is immense. While electrification has already reduced dependence on imported diesel, the transition to renewable energy is not just an environmental choice—it is a strategic, economic, and geopolitical necessity.

## Reducing Energy Cost Burden

Energy expenditure forms one of the largest components of the operational budget of Indian Railways. The annual energy bill runs into thousands of crores, with electricity purchased largely from state utilities at commercial tariffs. Renewable energy, particularly solar and wind, offers a predictable and cheaper source of electricity compared to volatile grid prices. By generating power onsite—through solar panels on station rooftops, workshops, and unused land parcels—the Railways can minimize transmission losses and lower dependence on external suppliers. Over time, this contributes to financial sustainability and frees resources for service improvements.

## Strategic Energy Independence

India's energy sector is heavily dependent on coal for electricity and imported crude for transport fuels. Although Indian Railways has moved away from diesel, complete reliance on grid electricity ties its operations to the same coal-dependent energy system. By diversifying into renewable energy generation, Railways can strengthen national energy security. Producing its own clean power not only reduces exposure to fossil fuel price shocks but also ensures uninterrupted supply in case of grid stress.

## Utilizing Vast Real Estate Potential

One of the Railways' most unique advantages is its land and infrastructure footprint. Thousands of stations, workshops, depots, and offices provide enormous roof area suitable for solar panel installations. Additionally, vacant railway land—often along tracks or near stations—can host ground-mounted solar or hybrid solar-wind projects. Unlike other industries, where access to space is a constraint, Railways has a natural infrastructure advantage to become a leading renewable energy producer.

## Driving Industry-Wide Decarbonization

Railways are a common carrier for almost every industry—steel, cement, coal, automobiles, food, and consumer goods. Any shift by Railways towards renewable-powered operations

automatically lowers the embedded emissions of goods transported. This creates a ripple effect in India's industrial carbon footprint. For companies with net-zero commitments, transporting via a clean-powered railway network could become an attractive option to decarbonize their supply chains.

## Alignment with Global Sustainability Norms

Globally, rail transport is considered one of the most energy-efficient modes of mass transit. However, international benchmarks increasingly look beyond efficiency and focus on the share of renewables in operations. By shifting to renewable energy, Indian Railways not only strengthens its domestic sustainability goals but also enhances its reputation in global climate rankings. This is especially important as India aspires to project its infrastructure models in other developing countries.

## CSR and Public-Private Synergies

Another significant driver for renewables in Railways is the opportunity for corporate social responsibility (CSR) participation. Since nearly every major corporation uses Railways for freight movement, there is a natural alignment in supporting decarbonization projects such as solar installations on stations or electrification of rail sheds. This collaboration model not only reduces the carbon footprint of Railways but also allows industries to meet their CSR and ESG reporting obligations.



## Current Progress

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### 1. Electrification Milestone

- a. As of July 31, 2025, 98% of Indian Railways' broad-gauge network is electrified. Whole states and zones have achieved 100% electrification, including major ones like Maharashtra, Uttar Pradesh, Delhi, and more.
- b. The Northeast Frontier Railway (NFR) has reached 94% electrification, and remaining zones are close behind.
- c. Electrification efforts have accelerated drastically—from 1.4 km/day (2004–14) to nearly 20 km/day in recent years.

This electrification revolution enables Indian Railways to phase out diesel locomotives and lays the foundation for greener traction.

### 2. Renewable Energy Capacity

- a. By June 2024, IR had commissioned 231 MW of solar and 103 MW of wind energy capacity.
- b. As of February 2025, solar installations increased further to 209 MW across 2,249 railway stations and service buildings—a 2.3-fold increase over five years.
- c. IR has secured renewable energy through Power Purchase Agreements (PPAs) totaling 4,260 MW solar and 3,427 MW wind energy, spanning rooftop, ground-mounted, and land-based projects. Additionally, a 170 MW PPA from Madhya Pradesh at ₹2.15/kWh further strengthens the renewable pipeline.

These integrations make solar and wind reliable contributors to traction and station energy needs, gradually reducing reliance on conventional grid power.

### 3. Pilot Innovations in Renewable Deployment

- a. In August 2025, the Banaras Locomotive Works (BLW) in Varanasi pioneered India's first removable solar panel system installed between active railway tracks: a 70 m stretch housing 28 bifacial panels totaling 15 kWp. The system generates 880 units per km per day and avoids land acquisition, opening up innovative use of space along rail yards.
- b. The Northeast Frontier Railway (NFR) zone has had six buildings certified as Net Zero Energy Buildings with the Bureau of Energy Efficiency's prestigious "Shunya Label."

These pilots serve as valuable models for scalable, out-of-the-box clean energy solutions across the network.

#### 4. Decarbonizing Traction & Achieving Net Zero

- a. According to IR board estimates, Scope 1 net zero (eliminating direct emissions) is expected by 2025, five years ahead of the 2030 goal. This is largely thanks to nearly 90% reliance on electric traction, which is projected to reach 95% by 2025–26.
- b. Electricity demand for traction is estimated to reach 10 GW by 2030. IR plans to source approximately 3 GW from renewables, 3 GW from thermal and nuclear PPAs, with the remaining through grid tie-ups and distribution networks. This diverse energy mix will support continuous operations while bringing emissions down steeply.

#### 5. Broader Impact & Extended Benefits

- a. IR's clean energy mission goes beyond environmental impact: it is already influencing freight behavior. For instance, Maruti Suzuki shipped over 500,000 vehicles via rail in 2024–25, avoiding 180,000 tonnes of CO<sub>2</sub> emissions compared to road transport.
- b. Metrics like station-level solar savings are demonstrable: Central Railway's solar projects saved ₹4.62 crore by late 2024.

# Powering the Tracks Together

The journey of Indian Railways towards net-zero emissions by 2030 cannot be achieved by government efforts alone. With nearly more than 7000 stations and vast land parcels across the country, railways hold enormous potential for solar, wind, and energy-efficient projects. At the same time, India's corporate sector is under pressure to not only meet CSR obligations but also align with ESG goals and demonstrate visible climate leadership. This creates a unique space for Railways and private companies to collaborate in a win-win framework.

## Why Railways Are a Natural CSR Partner

- **Visibility & Scale:** A solar-powered station or green-certified terminal has direct public visibility—unlike many CSR projects that remain low-profile.
- **Impact & Measurability:** Renewable projects at stations can be directly linked to emission reductions, electricity savings, and community benefits—making CSR impact easier to measure.
- **Nationwide Network:** Since every company, whether FMCG, cement, steel depends on Railways for logistics, investing in Railway sustainability creates shared value for all.

## Pathways for Private Sector Involvement

- **Solar on Station Rooftops and Sheds**
  - Railways have over 50 million sq. meters of rooftop space that can host solar panels.
  - Companies can finance installations as part of their CSR portfolio. For example, NTPC and IRCTC jointly developed solar PV at stations reducing both costs and emissions.
- **Adopt-a-Station Green Model**
  - Similar to the "Adopt-a-School" CSR model, firms could sponsor solar, rainwater harvesting, LED lighting, and EV charging infrastructure at stations.
  - This creates branding opportunities (co-branded stations) while contributing to net-zero goals.
- **Green Freight Corridors**
  - Logistics-heavy industries can co-invest in solar/wind farms tied to freight corridors.
  - Example: Dedicated Freight Corridor Corporation of India (DFCCIL) has already signed agreements with renewable power suppliers to green its operations. Expanding this with CSR funding would multiply the impact.
- **Public-Private Innovation Labs**
  - Startups supported by corporate CSR funds could test energy-efficient cooling systems, AI-based energy management, or bio-toilets at railway facilities.
  - For instance, Siemens Mobility partnered with Indian Railways to pilot energy-efficient locomotives, showing how CSR-backed R&D can benefit the sector.



## Why it's a win-win

- For Companies: Visibility, ESG compliance, carbon credit opportunities, employee pride, and alignment with national climate targets.
- For Indian Railways: Reduced financial burden, faster deployment of renewable projects, and progress towards its 2030 net-zero mission.
- For Society: Lower emissions, better air quality, reduced dependence on coal power, and improved passenger experience.

# Impacts and Challenges of Indian Railways' Renewable Energy Transition

The Indian Railways' journey toward renewable energy and net-zero by 2030 is one of the most ambitious sustainability projects in the world. If achieved, it will not only transform India's transport sector but also set a global benchmark for large-scale green transitions. However, as with any systemic change, the impacts are multi-dimensional—some highly positive, while others raise concerns and practical challenges.

## Positive Impacts

- Reduction in Carbon Emissions
  - Indian Railways is the largest electricity consumer in the country, using around 2% of India's total power demand. By shifting to solar, wind, and hydro sources, it reduces dependence on coal-based electricity.
  - This directly cuts greenhouse gas (GHG) emissions, helping India move closer to its 2070 net zero target and the Nationally Determined Contributions (NDCs) under the Paris Agreement.
- Energy Security and Cost Savings
  - Renewable energy projects reduce the risk of fluctuating fossil fuel prices.
- Job Creation and Local Economy Boost
  - Setting up solar parks on railway land and rooftop panels at stations creates employment for engineers, technicians, and local labor.
  - Ancillary industries (manufacturing of panels, maintenance services) also benefit.
- Global Leadership
  - With plans to become a net zero transporter by 2030, IR positions itself as one of the most ambitious rail networks in the world.
  - This attracts global investors, partners, and climate finance opportunities.
  - A greener railway network improves public perception and passenger satisfaction.

## Negative Impacts

- High Initial Costs
  - Large-scale renewable deployment requires huge capital. Even if operational savings come later, upfront costs put pressure on Railway finances.
- Land Use Conflicts
  - While Railways has vast land, installing large solar and wind farms competes with other development needs, such as housing, agriculture, and urban expansion.



- Grid Dependence and Intermittency
  - Solar and wind are variable. Without large-scale storage, Railways still depends on coal-based grid supply at night or during poor weather. This slows the movement to 100% clean energy.

## Challenges

- Grid Integration and Reliability
  - Many stations and routes still depend on coal-heavy state grids. Connecting renewable plants to the grid and ensuring uninterrupted power supply is complex and time-consuming.
- Policy and Coordination Gaps
  - Indian Railways needs to work with state electricity boards, central agencies, and private developers. Misalignment in policies and delays in approvals often slow projects.
- Technology Readiness
  - Large-scale battery storage, green hydrogen locomotives, and AI-based energy management are still emerging technologies. Without rapid adoption, IR's net zero vision faces delays.
- Funding and Private Participation
  - Attracting CSR funds and private investments requires clear business models and risk-sharing frameworks. Some companies hesitate without guaranteed returns.

The positive impacts of renewable transition for Indian Railways are much stronger than the negatives, but the challenges show why execution is not straightforward. For every MW of solar capacity added, there is not only a benefit of reduced emissions but also the responsibility of managing land, recycling, and cost recovery.

What stands out is that Indian Railways is not just building projects—it is testing a national model of how a giant public utility can decarbonize. If IR succeeds, it sets a precedent for other sectors like highways, ports, and aviation.

## Conclusion: Towards a Green Railway Future

The dream of making Indian Railways net zero by 2030 may sound like a distant milestone, but every great journey begins with a single step. Railways, after all, is not just about moving people and goods—it is about moving the nation forward. And today, the tracks of progress must also lead towards a greener, cleaner future.

Yes, the path is full of challenges: high costs, old infrastructure, new technologies that need scaling. But challenges are not roadblocks; they are signals telling us where to innovate. Every solar panel on a railway rooftop, every wind turbine powering a station, every energy-efficient engine on the track is proof that ambition can be turned into action.

What makes this goal unique is that the Railways already has the resources: vast land, endless rooftops, and the ability to carry millions every day. By reimagining these resources, the system can transform itself into one of the world's largest renewable-powered networks. Add to this the strength of government policy, the speed of private partnerships, and the push from India's growing green industry—and suddenly, the impossible starts to look possible.

The journey to net zero is not just about cutting emissions. It is about cleaner air for cities, reduced dependence on coal, new jobs for youth, and energy security for India. In short, it is about making life better for people.

In the end, the story of Indian Railways can become the story of India's resilience and innovation. With the right mix of ambition, action, and accountability, the Railways can truly become the backbone of a sustainable India.



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