Council on Energy, Environment & Water

# Energy Policy Roadmap for the Indian Railways

## ENERGY EFFICIENCY AND RENEWABLE ENERGY INTERVENTIONS

Aditya Ramji ■ Rana Pujari ■ Shubhashis Dey ■ Vikas Gaba ■ Ajit Nafde ■ Varun Anand

An initiative supported by

SHAKTI SUSTAINABLE ENERGY FOUNDATION

Funded by

UNDP

Empowered lives. Resilient nations.

November 2016

# Energy Policy Roadmap for the Indian Railways

## Energy Efficiency and Renewable Energy Interventions

Aditya Ramji ■ Rana Pujari ■ Shubhashis Dey ■ Vikas Gaba ■ Ajit Nafde ■ Varun Anand

CEEW Report
November 2016
ceew.in

Disclaimer



A report on 'Energy Policy Roadmap for the Indian Railways: Energy Efficiency and Renewable Energy Interventions'. This report is for private circulation only.

Team: Aditya Ramji (Programme Lead), Council on Energy, Environment and Water
Rana Pujari and Shubhashis Dey, Shakti Sustainable Energy Foundation
Vikas Gaba, Ajit Nafde, and Varun Anand, KPMG in India

The views expressed in this report are those of the authors and do not necessarily reflect the views and policies of CEEW.

The views/analyses expressed in this report/document do not necessarily reflect the views of Shakti Sustainable Energy Foundation. The Foundation also does not guarantee the accuracy of any data included in this publication nor does it accept any responsibility for the consequences of its use.

The Council on Energy, Environment and Water (http://ceew.in/) is an independent, not-for-profit policy research institution. CEEW addresses pressing global challenges through an integrated and internationally focused approach. It does so through high quality research, partnerships with public and private institutions, and engagement with and outreach to the wider public. CEEW has been ranked as India's top climate change think-tank two years in a row (ICCG Climate Think Tank Ranking). CEEW has been ranked best in India (and South Asia) in several categories two years running in the Global Go To Think Tank Index.

Shakti Sustainable Energy Foundation was established in 2009 to support India's developmental objectives. They facilitate India's transition to a sustainable energy future by promoting policies that encourage energy efficiency, renewable energy and the rapid adoption of sustainable transport solutions. Advancing smart energy policies will be key to meeting the defining challenge of the next generation - how to provide millions of Indians with reliable, affordable, secure access to energy in a sustainable manner. Shakti Sustainable Energy Foundation has a reputation for supporting high-quality research and providing policy makers with specific and practical policy recommendations for an energy secure future. (www.shaktifoundation.in)

KPMG in India, a professional services firm, is the Indian member firm affiliated with KPMG International and was established in September 1993. KPMG's professionals leverage the global network of firms, providing detailed knowledge of local laws, regulations, markets and competition. KPMG has offices across India in Chandigarh, Gurgaon, Noida, Ahmedabad, Vadodara, Mumbai, Pune, Bengaluru, Kochi, Chennai, Hyderabad and Kolkata. KPMG in India offers services to national and international clients in India across sectors. They strive to provide rapid, performance-based, industry-focussed and technology-enabled services, which reflect a shared knowledge of global and local industries and their experience of the Indian business environment. (KPMG.com/in)

# About CEEW

The Council on Energy, Environment and Water (http://ceew.in/) is one of South Asia's leading not-for-profit policy research institutions. CEEW addresses pressing global challenges through an integrated and internationally focused approach. It prides itself on the independence of its high quality research, develops partnerships with public and private institutions, and engages with wider public.

In 2016, CEEW was ranked the best in South Asia in two categories three years running (Global Go To Think Tank Index); among the top 100 out of 6846 think-tanks in nine categories. This included CEEW being featured on a prestigious list of 'Best Managed Think Tanks' and 'Best Independent Think Tanks'. In 2016, CEEW was also ranked 2nd in India, 4th outside Europe and North America, and 20th globally out of 240 think tanks as per the ICCG Climate Think Tank's standardised rankings. In 2013 and 2014, CEEW was rated as India's top climate change think-tank as per the ICCG standardised rankings.

**In six years of operations,** CEEW has engaged in more than 130 research projects, published well over 70 peer-reviewed books, policy reports and papers, advised governments around the world over 260 times, engaged with industry to encourage investments in clean technologies and improve efficiency in resource use, promoted bilateral and multilateral initiatives between governments on more than 50 occasions, helped state governments with water and irrigation reforms, and organised more than 140 seminars and conferences.

**CEEW's major projects on energy policy include** India's largest energy access survey (ACCESS); the first independent assessment of India's solar mission; the Clean Energy Access Network (CLEAN) of hundreds of decentralised clean energy firms; India's green industrial policy; the $125 million India-U.S. Joint Clean Energy R&D Centers; developing the strategy for and supporting activities related to the International Solar Alliance; modelling long-term energy scenarios; energy subsidies reform; decentralised energy in India; energy storage technologies; India's 2030 renewable energy roadmap; solar roadmap for Indian Railways; clean energy subsidies (for the Rio+20 Summit); and renewable energy jobs, finance and skills.

**CEEW's major projects on climate, environment and resource security include** advising and contributing to climate negotiations (COP-21) in Paris; assessing global climate risks; assessing India's adaptation gap; low-carbon rural development; environmental clearances; modelling HFC emissions; business case for phasing down HFCs; assessing India's critical mineral resources; geoengineering governance; climate finance; nuclear power and low-carbon pathways; electric rail transport; monitoring air quality; business case for energy efficiency and emissions reductions; India's first report on global governance, submitted to the National Security Adviser; foreign policy implications for resource security; India's power sector reforms; resource nexus, and strategic industries and technologies for India's National Security Advisory Board; Maharashtra-Guangdong partnership on sustainability; and building Sustainable Cities.

**CEEW's major projects on water governance and security include** the 584-page National Water Resources Framework Study for India's 12th Five Year Plan; irrigation reform for Bihar; Swachh Bharat; supporting India's National Water Mission; collective action for water security; mapping India's traditional water bodies; modelling water-energy nexus; circular economy of water; and multi-stakeholder initiatives for urban water management.

# Acknowledgements

The authors would like to thank Mr K Swaminathan (Additional Member, Railway Board), Mr Abhay Bakre (Executive Director, Railway Board), and Mr Sudhir Garg (Executive Director, Railway Board) from the Ministry of Railways, Government of India, for their inputs and guidance towards making this analysis rigorous. We would like to thank Mr Sachin Sharma, Senior Professor, National Academy of Indian Railways (NAIR), Mr Daljit Singh, Consultant, and Mr Sunil Goyal, for reviewing the report. We would like to thank UNDP for its financial support, which facilitated the preparation of this policy report. The authors would also like to thank Dr Arunabha Ghosh, Mr Karthik Ganesan, Ms Shruti Nagbhushan, Mr Sumit Prasad and Mr Tirtha Biswas from CEEW, Mr Chinmaya Acharya from Shakti Foundation, Mr Anish De from KPMG in India and Mr Saba Kalam from UNDP, for providing the necessary institutional support and guidance.

# Contents


Acknowledgements vii
Foreword ix

**Executive Summary** 1

**1. Introduction** 2

**2. Need for Energy Policy and Low Carbon Action Plan** 5
- 2.1 Climate change commitment through INDCs 6
- 2.2 Barriers in implementing low carbon projects 7
- 2.3 Scope of the study 8

**3. Vision, Mission and Goals** 9
- 3.1 Vision statement 9
- 3.2 Mission statement 9
- 3.3 Energy policy goals 9

**4. Identifying and Prioritising Energy Efficiency Interventions** 10
- 4.1 Assessment of interventions 11
- 4.2 Assessment of potential savings 12
- 4.3 Cost benefit analysis and prioritization of interventions 13
- 4.4 Global good practices to improve efficiency in energy use 15

**5. Identifying and Prioritising Solar Energy Interventions** 20
- 5.1 Diesel locomotive sheds 22
- 5.2 Railway workshops 22
- 5.3 Car sheds and electric loco sheds 23
- 5.4 Production units 23
- 5.5 Railway stations 24
- 5.6 Proposed targets of Railways Energy Management Company Ltd. (REMCL) 24
- 5.7 Proposed solar PV projects of Indian railways at railway offices (Ministry of Railways) 25
- 5.8 Use of vacant land belonging to the Indian railways 25
- 5.9 Estimated solar potential and emission savings 26

**6. Achieving Net Zero Energy Status for Non-traction: Case Study** 28

**7. Future Technologies: Energy Storage and Clean Tech** 30
- 7.1 Renewable energy installations for non-traction applications 30
- 7.2 Traction application 31
- 7.3 Clean technology development: What is the future of solar? 32

**8. Traction Energy Efficiency and Integration of Renewables** 34

**9. Financing models for implementation** 35
- 9.1 Financing energy efficiency projects 35
- 9.2 Financing renewable energy projects 36

**10. Potential MRV Framework** 38

10.1 Evaluation types and approaches 38

10.2 Implementing the MRV mechanism 39

**11. Way Forward** 40

11.1 Key strategies for Indian railways 41

# Executive Summary

In view of rising energy demand and uncertainty in power tariffs, the Indian Railways has identified the need for an aggressive push towards alternate fuels in the Indian Railways as well as identify potential opportunities for energy savings and realise a cost-effective energy system with least environmental impact. As part of the efforts, the Indian Railways has also been taking steps towards mitigation on Climate Change and is strengthening the Rail Transport sector to increase its intermodal share in freight traffic from 36% to 45% in the next 15 years. Indian Railways' goal as part of its low carbon growth strategy is to reduce emission intensity by 33% in the year 2030 over the year 2005 by improving rail traction energy and fuel efficiency by 8 – 13% over 2013.

This report analyses the role of renewable energy and energy efficiency across the Indian Railways and their potential in reducing the emissions intensity of the rail transport sector in India. The report also sets out the vision for the railway energy policy with goals for renewable energy, particularly solar; energy efficiency and emissions reduction.

Non-traction energy constitutes about 15% of railways' total energy consumption. The solar potential is estimated to be about 2 GW across various railway operations, while energy efficiency interventions are expected to provide a cumulative savings of 6 billion units by 2030. These efforts along with traction efficiency could lead to a cumulative reduction of about 138 million tonnes of $CO_2$ equivalent.

While the Indian Railways is looking to increase its portfolio of renewable energy and scale energy efficiency investments, the risks associated with financing for such projects need to be recognised and evaluated.

Going forward, Measurement, Reporting and Verification (MRV) is a crucial post-implementation step, to assess the performance of planned interventions and ensure that desired results in the form of savings is achieved with greater certainty.

There exists a huge potential to accelerate these individual initiatives and bring them under a single flagship program and facilitate integrated planning at the zonal level, both inter-zone and intra-zone.

This study while focusing on non-traction operations, recognises the equal if not greater importance of traction energy efficiency. At the same time, it is expected that this study will set the tone for further discussions on the need for a comprehensive strategy around energy management in the Indian Railways.

# 1. Introduction

The Indian Railways is one of the world's largest rail networks and covers around 67,000 km under track length, of which nearly 30,000 km is electrified rail network, as of 2016[1]. Around 12,000 passenger trains and 7,500 freight trains operate daily in India, comprising mostly of electric and diesel locomotives[2]. With the large scale of operations across the country, the Indian Railways is the single largest consumer of electricity. In 2013-14, the railways consumed nearly 17.5 billion units of electricity corresponding to about 4000 MW, which was about 1.8% of India's total electricity generation that year[3].

Fuel expenditure in the railways constitutes a major portion of the Working Expenditure of the Indian Railways. The total expenditure on fuel during 2013-14 is estimated around 22.26% of the total Ordinary Working Expenses (O.W.E.), as compared to about 18.49% in 2010-11[4]. Electricity accounted for about 22% of the railways' total working expenses. Of the total fuel expenses, diesel accounted for about 70%[5]. Over time this cost has been escalating, prompting the ministry to respond with drastic measures. With the Union Minister of Railways, Shri Suresh Prabhu having set the target to save INR 5,000 crore in the energy bill by 2019[6], energy savings of INR 2500 crore are currently being achieved[7]. The procurement of low cost electricity with the recognition of the Railways as a Deemed Distribution Licensee will also help bring down the total energy costs[8].

Despite the high consumption in physical terms as well as costs due to diesel traction, 65% of the freight and 50% of the passenger traffic (as of 2013) is carried by electric locomotives[9]. Productivity analysis by the Railway Board suggests that diesel locomotives have been increasing the cost burden on the railways with increasing diesel prices, whereas the productivity of these diesel locomotives has not been improving at the same pace. This explains the move by the Railway Board to switch from diesel locomotives to electric locomotives with the progression of time. However, with increasing electric locomotives, the demand for electricity by the railways will also be seen growing rapidly. As the railways pursue higher electrification targets, its power requirements are expected to grow from 4000 MW in 2012 to around 15000 MW in 2032[10].

The Indian Railways, has distinguishing features with respect to its energy requirements, notably – the need for 24x7 reliable power supply and short term variations in power demand across its network requiring smart power scheduling and dispatch strategies. In view of rising energy demand and uncertainty in power tariffs, the Indian Railways has identified the need for an aggressive push towards alternate fuels in the Indian Railways[11] as well as ***identify potential opportunities for energy savings and realise a cost-effective energy system with least environmental impact***[12]**.**

1 http://www.core.indianrailways.gov.in
2 http://www.indianrailways.gov.in/railwayboard/uploads/directorate/finance_budget/2014-15_Final/English%20-%20Railway%20Budget%20Speech%202014-15.pdf
3 https://www.railsaver.gov.in/en_scenario.html#maincontent
4 Ministry of Railways, Railway Statistics (various issues), Ministry of Railways, Government of India
5 Singh S P (2015), Indian Railways gets cracking on environment protection, fuel bill, Business Standard (http://www.business-standard.com/article/economy-policy/railways-gets-cracking-on-environment-protection-fuel-bill-115012900178_1.html)
6 http://www.business-standard.com/article/economy-policy/prabhu-asks-indian-railways-to-save-rs-5-000-crore-by-2019-on-energy-bill-115110600317_1.html
7 http://www.irgreenri.gov.in/tile_led.html
8 http://economictimes.indiatimes.com/industry/transportation/railways/highlights-of-the-railway-budget-2016-17/articleshow/51137122.cms`
9 http://www.thehindubusinessline.com/economy/logistics/as-fuel-bill-soars-railways-to-fasttrack-electrification/article4375497.ece
10 http://indiainfrastructure.com/confpdf/brochure-energy-needs-of-indian-railways-april2016.pdf
11 Ministry of Railways (2015), White Paper - Indian Railways: Lifeline of the Nation, Ministry of Railways, Government of India
12 Public Accounts Committee (2014), Environment Management in the Indian Railways – Stations, Trains and Tracks, Third Report of the Public Accounts Committee (2014-15), Sixteenth Lok Sabha, Government of India

Energy consumption by the railways can be divided into two parts: traction and non-traction.

Traction energy is all the energy that goes into the running and operation of a locomotive, whereas non-traction energy is rest of the energy use by the railways – for manufacturing of coaches, lighting of stations and buildings, etc. Traction power consumes around 85% of the total railway energy. In the period 2007-08 to 2013-14, the average growth rate in traction power consumption was around 20%[13].

This growth in traction power consumption was supplemented with a 40% increase in freight traffic along with a 36% increase in passenger traffic in terms of kms travelled. This goes to show that the railways have been increasing their energy efficiency. This is well in keeping with the policy changes being made by the Ministry of Railways in the recent years.

While, efficiency and energy savings in traction operations can have significant benefits for the railways, it is also a sector which involves significant capital expenditure and longer term technology transitions. Thus, in the short and medium term, significant efforts can be made on the non-traction side. In recent years, focus has been given to non-traction energy efficiency through various efforts including the use of LED lighting for all buildings, separation of 70% and 30% lighting circuits on platforms, the Rail Saver initiative, among others.

Most of the focus is currently on non-traction energy and the railways has so far achieved 2% reduction in non-traction energy consumption through extensive audits, monitoring, and use of high star-rated appliances[14].

With energy efficiency improvements, renewable energy can play a significant role in helping the railways not only achieve lower energy costs, but also have a lower carbon footprint by way of sourcing clean energy. This will also have positive cost implications for the railways and promote energy security.

## 1.1 Railways and Sustainability

The Indian Railways' vision for sustainability states that it *'shall provide efficient, affordable, customer-focused and environmentally sustainable integrated transportation solutions[15].'* One of the key targets as per the Vision 2020 document was to ***'utilize at least 10% of its energy requirement from renewable sources'.*** In keeping with the spirit of the New Environment Policy (2006) and based on recommendations of the Public Accounts Committee report, the Railway Board established the Environment Directorate in 2015, taking a step further in its commitment towards environmental protection and resource conservation.

The last two Rail Budgets have also ***indicated an increased focus and thrust on energy and environment management within the Railways.*** With the Railways being a significant consumer of energy and other resources, the potential for substantial savings also exists. Identifying critical areas for ensuring comprehensive energy management, the Rail Minister also announced the following:

- **Renewable Energy:** 1GW of solar installations will be set up by developers on Railway/private land and on rooftop of Railway buildings at their own cost in the next five years.
- **Energy Efficiency:** No additional allocation to energy costs under the budget, with expectations on renewables and other initiatives resulting in savings.

13 http://www.irgreenri.gov.in/tile_led.html
14 http://indiainfrastructure.com/confpdf/brochure-energy-needs-of-indian-railways-april2016.pdf
15 Ministry of Railways (2009), Railway Vision 2020 Document, Ministry of Railways, Government of India

The railways in India have also made significant progress so far with regards to energy conservation. Some of the notable initiatives and targets include:

a. Commissioning and tendering about 150 MW of solar and another 150 MW of wind power plants

b. Energy audits being done in all large non-traction energy consumption centres for identifying areas with energy conservation potential. 85 energy audits carried out across various zones last year

c. Use of energy efficient appliances and equipments are being promoted across the Railways

d. Use of LEDs in all new passenger coaches and railway stations and buildings

e. Web portal railsaver.gov.in on Energy Efficiency Management System providing data on efficiency parameters across various railway operatios

f. Introduction of PAT (Perform, Achieve and Trade) scheme for the designated consumers of Indian Railways is being considered

g. Providing auxiliary power units in all new diesel locomotives

h. Target of 8% to 13% reduction in consumption of traction energy and fuel by the year 2030

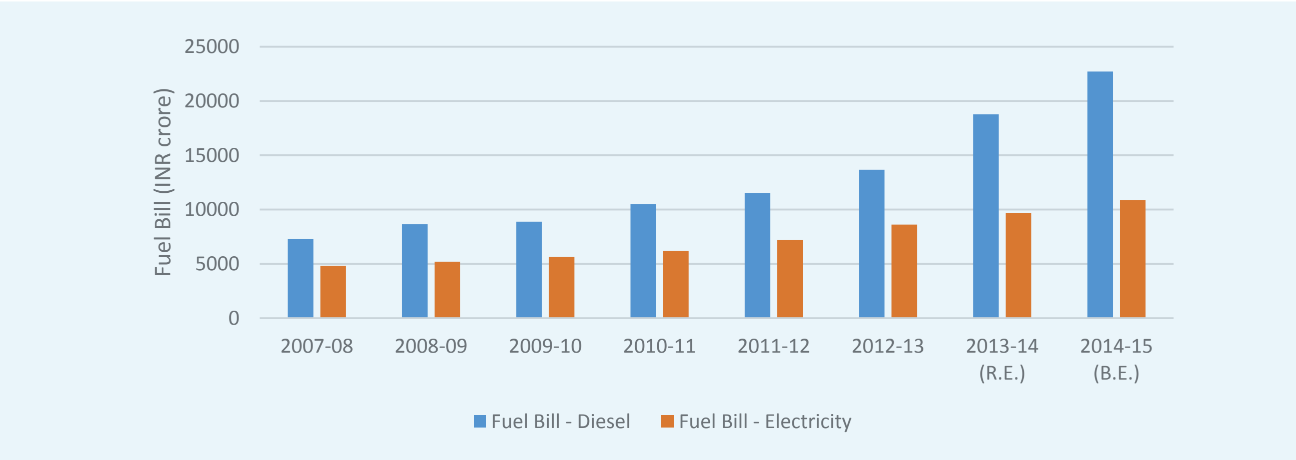
# 2. Need for Energy Policy and Low Carbon Action Plan

Railways is one of the key fossil fuel and electricity consumer in India and its energy bill accounts for one fifth of its total working expenses, which presents a challenge from both cost and demand side.

1. Electricity tariff has shown an increasing trend over the last 5 years (average annual growth rate of 8% for most states[16]). It is estimated that the traction electricity cost will likely reach INR 7.93/kWh by 2030 (CAGR of 3.8%), while non-traction electricity cost is estimated to reach INR 14.03/kWh by 2030 (CAGR of 3.7%)[17].

   In addition, the fluctuating diesel prices (which varied between INR 44.95 per litre to as high as INR 67.26 per litre in the last two years, i.e. 2013-2015[18]) also expose the Indian Railways to forex risks and it is difficult to predict and take mitigating action against this.

**Figure 1: Fuel bill of Indian Railways over the years**




*Source: Ministry of Railways, Government of India, 2016*

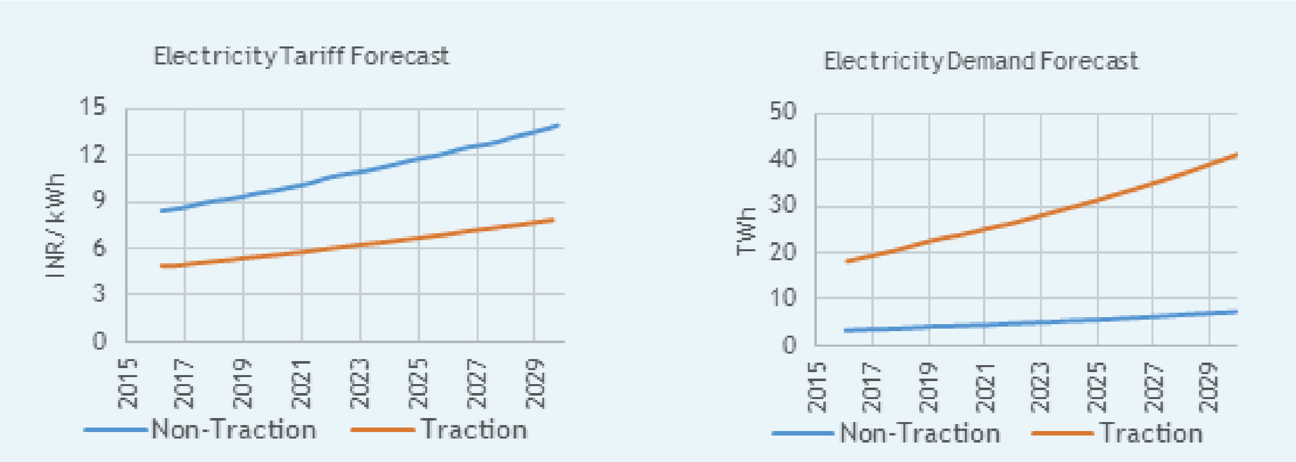
2. Energy demand has also seen a rising trend in the last 3 years (CAGR of diesel consumption was 1.8% and that of electricity consumption was 4.7% from 2012-2015[19]) and is expected to grow substantially in the coming years with expected growth in passenger and freight traffic, increased electrification of routes, growth in new stations and modernization of existing stations. On account of all this, it is estimated that the electricity consumption would grow at a compounded annual rate of 6% to reach 48.7 TWh by 2030[20]

This estimated increase in electricity tariff and demand could cost an additional INR 2200 crores annually (with about INR 500 crores from non-traction) to Indian Railways, in case business as usual scenario continues[21].

The energy demand forecast for Indian Railways till 2030 is presented in Figure 1.[22]

16 http://powermin.nic.in/pdf/Power_Sector_Reforms.pdf
17 Report on "Decarbonization of Indian Railways" – Climate Policy Initiative
18 https://iocl.com/Products/DieselDomesticPrices.aspx
19 KPMG Analysis
20 Report on "Decarbonization of Indian Railways" – Climate Policy Initiative
21 Report on "Decarbonization of Indian Railways" – Climate Policy Initiative, KPMG Analysis
22 Report on "Decarbonization of Indian Railways" – Climate Policy Initiative

**Figure 1: Energy Demand and Cost Outlook for Indian Railways**




*Source: Ministry of Railways, Government of India, 2016*

With this consideration, the Indian Railways has been making efforts to procure low cost energy in the recent past, and also scaling up efforts to conserve energy.

## 2.1 Climate Change commitment through INDCs

India is committed to transition towards a low carbon emission pathway, while simultaneously endeavouring to meet all the developmental challenges that the country faces today. As a part of the 2015 International Paris Agreement on Climate Change, India has pledged a reduction in emissions intensity of 33-35% by 2030 from 2005 levels. India has also set a target to transition to non-fossil fuel based energy for 40% of its cumulative electricity generation capacity by 2030. As part of the efforts, the Indian Railways has also been taking steps towards mitigation on Climate Change and is strengthening the Rail Transport sector to increase its intermodal share in freight traffic from 36% to 45% in the next 15 years. Indian Railways' goal as part of its low carbon growth strategy is to reduce emission intensity by 33% in the year 2030 over the year 2005 by improving rail traction energy and fuel efficiency by 8 – 13% over 2013.

Several other steps have already been taken by the Indian Railways in this respect. Railways has decided to formulate energy efficiency plans to reduce energy consumption and, thus, the energy bill by INR 5000 crores in the next five years[23]. Further, Railways has also been included under the Perform, Achieve and Trade (PAT) scheme of the Bureau of Energy Efficiency and have notified energy consumption standards for all their 16 zones across both traction and non-traction categories, for the various Designated Consumers of the Indian Railways. Energy audits have also been conducted at various stations, workshops and factories to identify potential interventions for energy conservation and efficiency improvement.

In addition to energy efficiency initiatives, other efforts to increase renewable energy capacity, which include solar power, wind energy, and waste to energy, to reduce energy cost as well as carbon emissions, are being taken up. So far, railways have set up 11 MW of solar power plants across various establishments, with other projects in the pipeline[24].

23 http://www.businesstoday.in/current/economy-politics/railways-plan-to-save-rs-5000-crore-on-energy-bill/story/225800.html
24 Environmental Sustainability – Role of Indian Railways, Annual Report 2015 – 16, Ministry of Railways, Government of India

## 2.2 Barriers in implementing low carbon projects[25]

Given the scale and sheer volume of operations, implementing energy efficiency initiatives as a dedicated and continuously monitored programme becomes a challenge when it comes to the Indian Railways. Having said that, there is enough evidence based on published reports, to show that the Railways intends to push forth the agenda of sustainable growth going forward and implement energy efficiency and renewable energy measures across both traction and non-traction categories. While they are aware of the pressing need to institutionalize some of these energy interventions and have been implementing various programmes at a zonal/division level, there is possibly a lack of a clear policy framework defining the implementation roadmap and governance mechanism for the same.

On the basis of past trends and various documented reports, it is suggested that key issues or barriers in implementing energy interventions fall in four broad buckets: institutional barriers, information and technology barriers, lack of incentives and most importantly, financial barriers. Some of the issues hindering the implementation of a consolidated effort towards energy efficiency and low carbon projects in the Indian Railways are highlighted below:

- ### Institutional barriers

  In the current structure of the Railways, having a unified and centrally driven policy framework is crucial. At the moment, for example, the procurement process is not on the basis of life cycle cost[26]. While there are directives on the subject, a policy level document would help bring in uniformity and accountability to the system. Having a structured institutional set-up to promote and drive energy-related initiatives is also needed to monitor progress and efficacy of the initiatives.

- ### Information and capacity barriers

  With large number of units under each of the non-traction categories - station, buildings, workshops, yards etc., and de-centralized procurement/inventory management systems, availability of baseline data is a key gap when it comes to energy initiatives. Availability of data on energy consumption at a unit level, types of equipment / appliances in use etc. will make a significant impact on assessment parameters and help design a robust monitoring framework.

  One of the critical success factors for energy efficiency and clean energy initiatives is to ensure sufficient information/awareness among railway officials and staff about measures, savings target and policy guidelines.

  Consequently, the existing training and testing facilities also need to be upgraded and benchmarked against global technology practices. The facilities should have suitable equipment/capacity to test energy technologies and also impart technical skills training among railway staff to assess, test and implement/install energy efficiency measures and technologies.[27]

- ### Lack of Incentives

  The existing regulatory framework within the Indian Railways is not very clear on the incentive mechanism (financial or non-financial) for the zones or divisions to implement such measures. There also needs to be a clear mechanism to plough back the savings from these measures into the system.

---

25 Improving Energy Efficiency in the Indian Railway system under Indian Railway – United Nations Development Programme (IR-UNDP) – 2015

26 Presentation on Energy Conservation on Indian Railways – 4th May 2016, Railway Board

27 Improving Energy Efficiency in the Indian Railways System, UNDP Report 2012

- **Financial barriers**

  Given the rapid growth in demand, infrastructure and maintenance typically get a priority when it comes to budget allocations. Resources for the implementation of energy efficiency and clean energy measures are therefore residual, and often inadequate.[28]

  At an overall level, the Railways is committed to focus on environment sustainability initiatives including use of alternate fuels and improving energy efficiency for both, traction and non-traction sides.[29] Environment Directorate has also been formed in the Railway Board to drive these initiatives and monitor at a zonal level, their performance on environmental issues including efficiency in consumption of energy. [30]

## 2.3 Scope of the study

This study was conceptualized to develop an energy policy and low carbon roadmap, with a focus on non-traction operations for the Indian Railways. The study analyses the following:

- Identification of energy efficiency and renewable energy potential
- Identification and prioritization of energy saving interventions
- Development of energy interventions and cost saving potential till 2030
- Evaluation of cost benefit analysis of identified interventions
- Document potential initiatives to promote energy efficiency, based on global good practices
- Development of potential financing models and monitoring, reporting framework

At the same time, the report largely considers energy conservation from an electricity perspective and does not make detailed assessments on avenues for reduction of other fossil fuels such as diesel and coal in non-traction operations, due to data limitations.

28 Improving Energy Efficiency in the Indian Railways System, UNDP Report 2012
29 Environmental Sustainability – Role of Indian Railways, Annual Report 2015-16
30 Railway Board Notice: Formation of Environment Directorate in Railway Board – 07/01/2015

# 3. Vision, Mission and Goals

## 3.1 Vision Statement

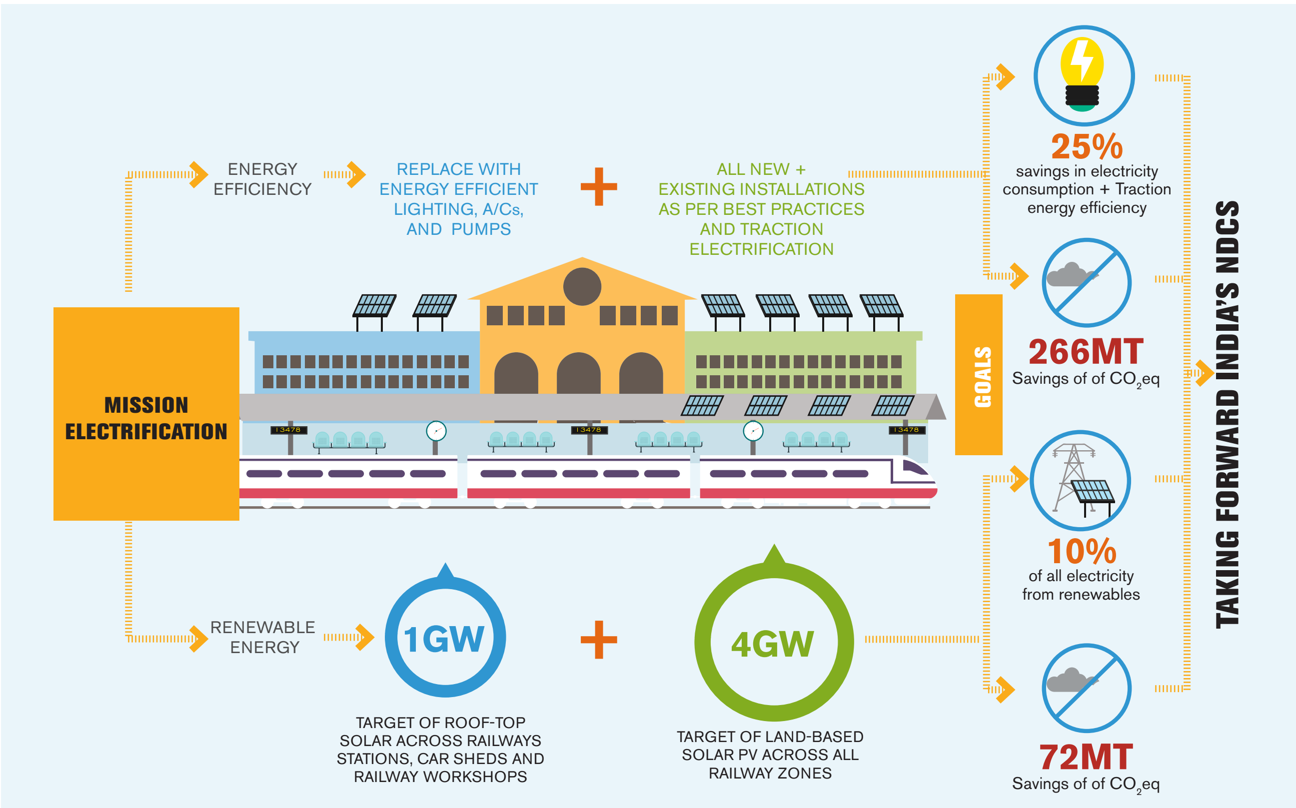
Leading sustainable mass transport innovations through the promotion of clean energy, energy conservation and environmental stewardship.

## 3.2 Mission Statement

- To promote energy efficiency measures
- To maximise the use of renewable energy
- To reduce the carbon footprint of the Indian Railways

## 3.3 Energy Policy Goals

- Renewable Energy – Increase installed solar capacity to 5000 MW so as to utilise about 25% of all electricity demand from renewable sources by 2030
- Energy Efficiency – Achieving 25% savings in electricity consumption from Energy Efficiency Interventions in non-traction and 10% in traction by 2030
- Emissions Reduction – Achieve a cumulative reduction of about 340 million tonnes of $CO_2$ equivalent[31] by 2030




31 Refer Annexure 1.2.8 for details

# 4. Identifying and Prioritising Energy Efficiency Interventions

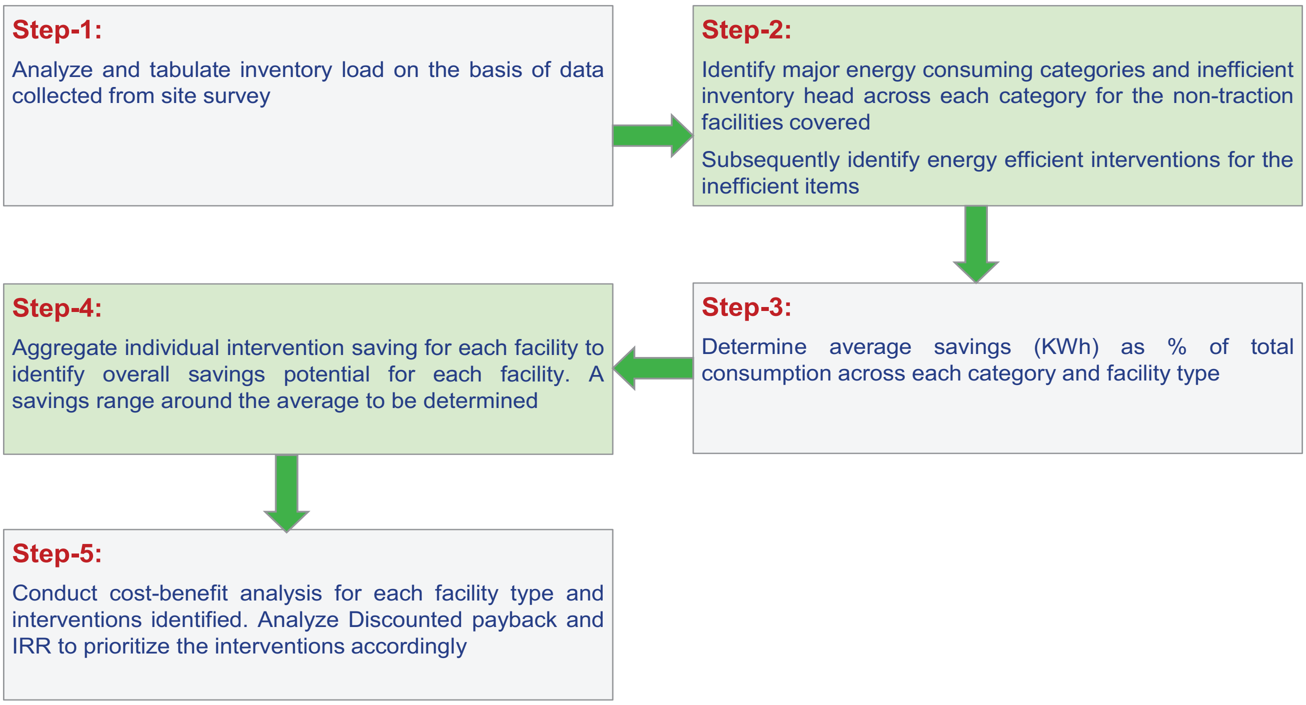
The objective of this section is to determine the overall energy efficiency saving potential for the Indian Railways and prioritize these interventions so that the railways can consider an implementation framework accordingly.

To arrive at the results, analysis was conducted on the current energy consuming inventory across select railway facilities in India. The data analysed included inventory details of key energy consuming units / equipment across stations, workshops, factories and office buildings[32]. Based on the available data the following railway facilities were covered:

- 6 A1 Category Stations
- 14 A Category Stations
- 9 B Category Stations
- 5 Railway Office Buildings
- 2 Factories
- 2 Workshops

The methodology for carrying out the energy efficiency analysis follows a five step process, which is described in Figure 2 below.

**Figure 2: Approach Methodology for Energy Efficiency Analysis**




*Source: KPMG Analysis*

32 Based on Indian Railway Audit Reports and Delhi Division Inventory Data. For details of sample surveyed station refer Annexure 1.2.3. The data available is for the year 2014 and due to unavailability of latest data, analysis assumes no change in inventory between 2014 and 2016.

## 4.1 Assessment of interventions

Analysis of percentage wise average connected load pattern of railways and buildings shows that the major electricity consuming equipment in railway stations and buildings typically are lighting, Air Conditioners (AC), pumps and fans. The breakup of average connected load for each category of non-traction facility is shown in Table 1.

**Table 1: Average Connected Load for Non-Traction**

| Type of Location | Lighting | Fans | Air Conditioning | Misc. Equip. | Pumps | Machine & Parts | Air Compressors | Cranes | Average Connected Load (KW) |
|---|---|---|---|---|---|---|---|---|---|
| Station A1 | 38% | 13% | 14% | 2% | 28% | 0% | 0% | 0% | 568 |
| Station A | 36% | 14% | 20% | 1% | 29% | 0% | 0% | 0% | 129 |
| Station B | 31% | 16% | 22% | 0% | 30% | 0% | 0% | 0% | 62 |
| Workshop | 13% | 3% | 6% | 0% | 1% | 27% | 18% | 31% | 2,715 |
| Factories | 10% | 6% | 0% | 0% | 1% | 68% | 15% | 0% | 1,425 |
| Buildings | 19% | 28% | 38% | 2% | 10% | 0% | 0% | 0% | 1,025 |

*Source: KPMG Analysis*

An analysis of existing load inventory of Indian Railways based on the sample data provides for a number of energy conservation opportunities as identified. Some of these specific programs through which the energy savings target can be achieved, include the following:

- Replacement of existing lighting with energy efficient LED on the basis of equivalent lumen values[33].
- Replacement of non-star rated AC inventory with BEE 5-star rated AC
- Replacement of old inefficient ceiling fans with super-efficient fans
- Replacement of current inefficient water pumps (30-40% efficiency) with BEE rated water pumps having higher efficiency and better performance

A list of some of these energy efficient interventions based on an analysis of current railway inventory is provided in Table 2. The detailed list can be referred to in Annexure 1.2 (Section 1.2.2).

33 Refer Annexure 1.2 (Section 1.2.4) for Lumen Comparison Chart

**Table 2: Energy efficiency interventions and potential savings based on current inventory analysis**

| Existing Inventory in Use (Conventional) | Equivalent Energy Efficient Intervention (Proposed Replacement) | Savings (in W) |
|---|---|---|
| | Lighting Inventory | |
| CFL 11 W | LED 5 W | 6 |
| CFL 18 W | LED 7 W | 11 |
| CFL 36 W | LED 20 W | 16 |
| FTL 36 W | LED 18 W Tube | 18 |
| Metal Halide Lamp 150 W | LED Lamp 70 W | 80 |
| Metal Halide Lamp 250 W | LED Lamp 120 W | 130 |
| Metal Halide Lamp 400 W | LED Lamp 200 W | 200 |
| Sodium Vapour Lamp 250 W | LED Lamp 120 W | 130 |
| Sodium Vapour Lamp 400 W | LED Lamp 200 W | 200 |
| T12 Tube Light 40 W | LED Tube Light 18 W | 22 |
| T8 Tube Light 36 W | LED Tube Light 18 W | 18 |
| | AC | |
| Low Efficient (Non-Star or 1-2 Star Rated) Window and Split AC's | Energy Efficient 5-Star Rated ACs | 450/ Tr. |
| | Water Pump | |
| 35-50% Inefficient Water Pumps | 70% Efficient, BEE 5-Star Rated Water Pumps | 7000 |
| | Fan | |
| Inefficient Ceiling Fans (Rated 60 W and above) | Super-efficient fans – 35 W | 25 |

*Source: KPMG Analysis*

*Note: All LED interventions suggested must be verified for compliance as per "Functional requirement specification for energy efficient led based luminaire unit for indoor lights to be used in Indian railway offices and buildings - RDSO"[34] or any other subsequent release of standards / guidelines issued for lighting by RDSO and should only then be considered for replacement or retrofitting.*

## 4.2 Assessment of Potential Savings

Based on the interventions identified, average energy savings potential has been determined for each facility across different electricity load categories. The overall savings potential range (as a percentage of total electricity consumption) on an average basis[35] is determined to be[36]:

- 15-37% for A1 category stations
- 26-36% for A category stations
- 24-36% for B category stations
- 35-39% for workshops
- 2-38% for buildings
- 43-51% for factories

The breakup of average savings potential across different interventions categories is as per Table 3[37] (for detailed analysis and assumption refer Annexure 1.2 (Section 1.2.7).

34 http://dfccil.gov.in/upload/RDSO_LED_Indoor_lighting_speci-EOI.pdf

35 This range is based on confidence interval for the mean of a population based on a sample size provided, with a 5% significance level and with standard deviation of sample assumed to be the standard deviation of population. This is based on a Student's t-distribution.

36 Source: KPMG Analysis. Refer Annexure 1.2 (Section 1.2.6) for savings breakup for the non-traction facilities analysed

37 Breakup of the savings potential across different load categories is provided in Annexure 1.2 (Section 1.2.7)

**Table 3: Energy Efficiency Savings Potential for Railway (Non-Traction)**

| Type of Building | Average Estimated Savings from EE Interventions | | | | Estimated Total Savings | | |
|---|---|---|---|---|---|---|---|
| | AC | Ceiling Fan | Lights | Water Pumps | Average | Min. | Max. |
| Station A1 | 1.2% | 3.4% | 16.8% | 2.5% | 24.1% | 14.8% | 36.5% |
| Station A | 3.8% | 7.5% | 15.4% | 4.1% | 30.9% | 26.1% | 36.3% |
| Station B | 5.7% | 7.4% | 13.6% | 3.4% | 30.0% | 24.4% | 36.5% |
| Workshop | 2.2% | 2.8% | 30.7% | 0% | 35.8% | 34.7% | 39.5% |
| Buildings | 7.8% | 1.6% | 7.5% | 0.3% | 17.1% | 2.4% | 38.0% |
| Factories | 0.8% | 3.0% | 43.3% | 0% | 47.1% | 43.3% | 50.8% |

*Source: KPMG Analysis*

If all the identified interventions are implemented, then it would lead to considerable savings for the Indian Railways. The potential of savings that can accrue to the railways is[38]:

1. 258 MU of annual energy savings
2. More than INR 170 crore of annual non-traction electricity bill savings[39]
3. Annual CO2 equivalent emissions reduction of 0.18 million tons

However, in order to consider a strategy to implement these interventions, it is critical to prioritize the same based on a cost-benefit analysis (CBA).

## 4.3 Cost Benefit Analysis and Prioritization of Interventions

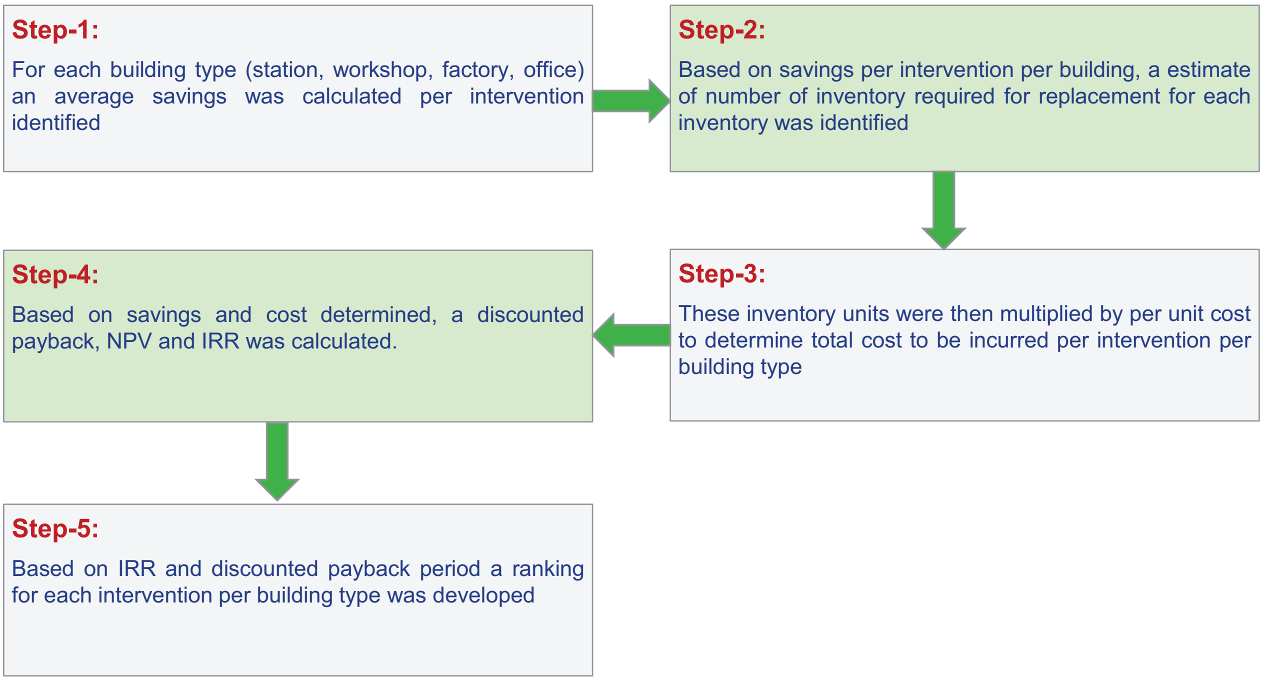
The priority rankings for the interventions has been determined based on discounted payback period, IRR calculated for each intervention. Some of the key assumptions considered for the cost-benefit analysis include:

- Discount rate of 11% has been assumed
- Average operating hour per interventions is assumed to be 12 hours
- Installation cost has been taken as 10% of unit replacement inventory cost[40]
- Baseline Non-Traction Tariff Rate is taken as INR 6.75/kWh[41]
- Growth in Non-Traction Tariff is taken to be 3% per annum
- Time period for IRR and NPV calculation has been considered as 5 years

38 These are base year (FY16) annual saving figures.
39 At tariff of 6.75 Rs/ KWh
40 For details of unit cost of interventions identified, refer to Annexure 1.2 (Section 1.2.5)
41 http://www.financialexpress.com/article/economy/indian-railways-to-buy-electricity-at-rs-3-69-per-unit-from-adani-power/151729/

The stepwise approach followed for developing a prioritized ranking is described in Figure 3.

**Figure 3: Approach Methodology for Energy Efficiency Analysis**




*Source: KPMG Analysis*

Based on the cost-benefit analysis, the interventions can be classified into three priority categories for the Indian Railways: short term, medium term and long term.

- **Short term interventions** are those which reap immediate returns to the railways (discounted payback of 1-2 years). These interventions could be taken up immediately by railways without much need of external financing. Given the short payback, these interventions also carry a low risk of technology advancements making the identified interventions obsolete.
- **Medium term interventions** are those which provide payback within 2-5 years. These interventions could be taken up in a phased approach with higher return interventions to be taken up first. Bulk procurement strategies could further pull down cost estimates and provide higher return. Further, PPP or ESCO financing models could be considered to drive these investments.
- **Long term interventions** are ones with payback period more than 5 years. With the prevalent cost structure, these interventions provide a negative return and are not economically viable. To make these projects viable, innovative financing models (including PPP) and procurement strategies need to be developed to drive down costs and increase returns.

The comprehensive list of interventions under the above defined priority categories is presented in Table 4.

**Table 4: Classification of Prioritized Interventions[42]**

| Railway Building Category | Short Term Interventions (Payback Period <24 months; IRR>40%) | Medium Term Interventions (24 months< Payback Period <60 months; 15%<IRR<40%) | Long Term Interventions (60 months< Payback Period <120 months; IRR<10%) | Estimated Total Savings |
|---|---|---|---|---|
| A1 Category Station | • Old inefficient water pumps<br>• Inefficient reciprocating chillers<br>• CFL 18W, CFL 55W/60W, CFL 15W | • CFL 20W, CFL 11W, CFL 36W<br>• T12 40W, T8 36W<br>• MH 1000W<br>• Non-star or 1/2 Star rated ACs<br>• Ceiling Fans | • MH and HPSV, 75W, 150 W, 250W and 400 W<br>• T5 28W | 24% |
| A Category Station | • Old inefficient water pumps<br>• CFL 18W, CFL 55W/60W, CFL 15W | • CFL 20W, CFL 11W, CFL 36W, CFL 45W<br>• T12 40W, T8 36W<br>• Non-star or 1/2 Star rated ACs<br>• Ceiling Fans | • MH and HPSV, 75W, 150 W and 250W<br>• T5 28W | 31% |
| B Category Station | • Old inefficient water pumps<br>• CFL 15W | • CFL 20W<br>• T12 40W, T8 36W<br>• Non-star or 1/2 Star rated ACs<br>• Ceiling Fans | • MH and HPSV, 75W, 150 W and 250W<br>• T5 28W | 30% |
| Workshops | • Energy inefficient screw compressor<br>• CFL 85W, 18W | • CFL 36W<br>• T12 40W, T8 36W<br>• Non-star or 1/2 Star rated ACs<br>• Ceiling Fans | • MH and HPSV, 75W, 150 W and 250W<br>• T5 28W | 36% |
| Factories | • Old inefficient water pumps<br>• CFL 18W, 60W | • CFL 36W, 11W<br>• T12 40W, T8 36W<br>• Non-star or 1/2 Star rated ACs<br>• Ceiling Fans | • MH and HPSV, 75W, 150 W and 250W<br>• T5 28W<br>• T5 14W | 17% |
| Office Buildings | • CFL 15W | • CFL 20W,<br>• T12 40W<br>• T8 36W<br>• Non-star or 1/2 Star rated ACs<br>• Ceiling Fans | • MH and HPSV, 75W, 150 W and 250W<br>• T5 28W | 47% |

*Source: KPMG Analysis*

## 4.4 Global good practices to improve efficiency in energy use

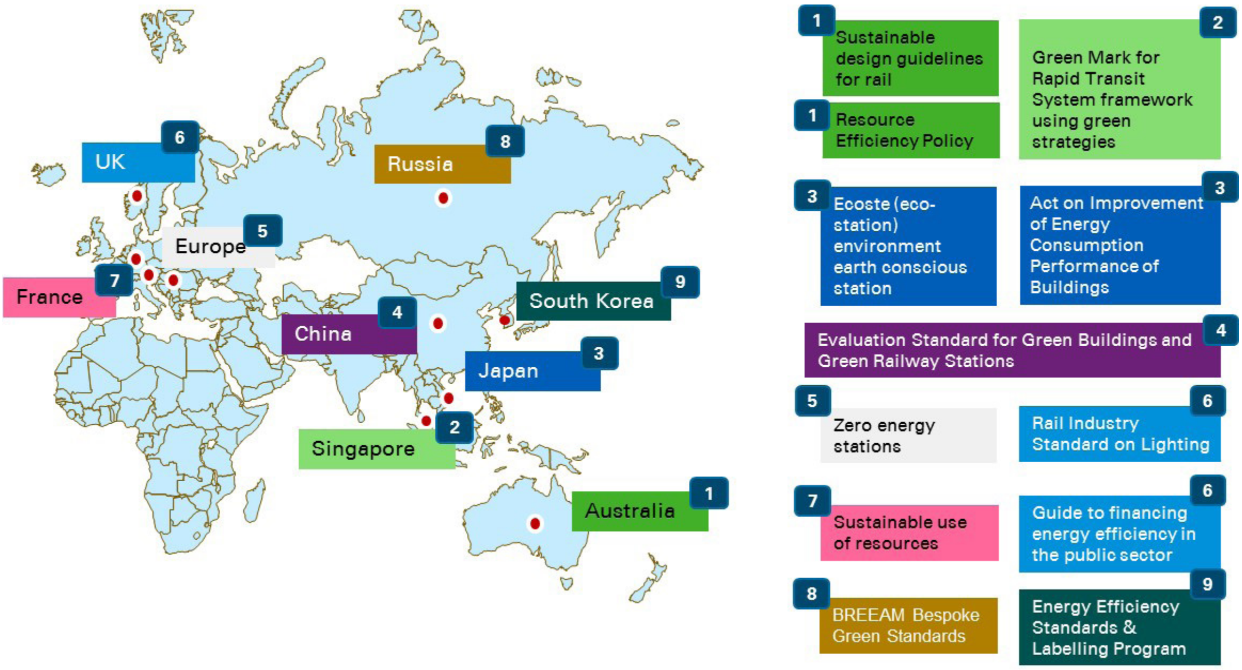
The Indian Railways in the recent years have issued various guidelines for energy efficiency practices across various operations[43]. Similarly, railway operations across the world have been effectively following leading practices and measures towards increasing energy efficiency and achieving energy conservation. It is therefore, important to examine successful, international best practices in energy-saving across railway buildings, with a view to adopt some of these initiatives for Indian Railways.

The Indian Railways has the opportunity to consider multiple initiatives which on one hand can help bring in standardization such as in building design, equipment deployed etc., and on the other hand can incentivize adoption of innovative energy efficiency measures. Following section details out some of the successful international good practices in energy-saving policies and interventions across railway building. These initiatives can be suitably adopted/implemented by the Indian Railways in its endeavor to meet the goals set forth in this document.

42 Detailed results of intervention Cost-Benefit Analysis are presented in Annexure 1.2 (Section 1.2.2). This table represents the current inventory of IR which needs to be replaced by equivalent EE interventions.

43 https://beeindia.gov.in/sites/default/files/Energy%20Efficiency%20Initiatives%20by%20Railways_Mr.Kishore%20kumar.pdf

**Figure 4: Summary of Global Good Practices Policies and Initiatives for Railway Non-Traction Energy Efficiency**




*Source: KPMG Analysis, 2016*

## 1. Green Building Standards

Mandatory compliance to Green Building Standards for all upcoming ventures and upgrading existing facilities to meet the criteria could be a starting step to meeting the energy efficiency goals of Indian Railways. Further, Green Building Evaluation Standards can enable design of incentive schemes around it. Singapore, for example follows an incentive mechanism to co-fund energy efficiency projects for buildings which meet the prescribed criteria as per the Green Mark Standard (refer details in the table below).

Similar 'Green Railway Station Evaluation Standards' are being followed in other countries like China, Japan and Russia.

The Railways has already announced adoption of Energy Conservation Building Code (ECBC) for construction of Green Buildings in all upcoming projects[44] and energy audits have been initiated for railway buildings starting with Rail Bhavan. Further, existing green building rating system in India like GRIHA (Green Rating for Integrated Habitat Assessment) or IGBC (India Green Building Council) Ratings can be developed in the context of railway stations for providing incentive/compliance schemes around these ratings/certifications.

44 Environmental Sustainability – Role of Indian Railways, Annual Report 2015-16 (Indian Railways)

**BCA-LTA Green Mark for RTS[44] (Singapore)**

Under the sustainable Singapore Blueprint 2009, a green framework for rail systems was proposed for improving resource efficiency. The BCA and LTA (Building and Construction Authority - Land Transport Authority) have jointly developed the Green Mark benchmark for RTS (Rapid Transit System) for improving the energy efficiency of railway stations.

This framework is based on three pillars: Effective Use of Energy, Environmental Protection & Sustainable Development and Water Conservation.

The Green Mark Scheme is a rating system to evaluate the environmental impact and performance of buildings. Every year buildings are evaluated on the criteria specified in Green Mark Scheme and certified accordingly.

The $100 million Green Mark Incentive Scheme for Existing Buildings (GMIS-EB)[45] further aims to encourage developers and/or building owners to adopt energy efficient retrofitting design, technologies and practices in their existing building to achieve a significant improvement in the building energy efficiency and thereby entitle themselves for co-funding of the costs for future initiatives.

## 2. Eco Station Concept

For the on-going Station Redevelopment Programme, Indian Railways can potentially consider development of 'eco-stations' by incorporating energy efficiency initiatives at the planning stage itself. Therefore, design guidelines, covering themes like energy conservation, passive building design and renewable energy initiatives can be included in the tender stages itself.

Eco-Station concept is in place in Japan, which provides for initiatives to equip railway stations with a variety of environmental conservation technologies. Three "Ecoste" (Eco stations) have already been renovated based on this model during 2012 and 2013. In a similar initiative, Transport authority of New South Wales, Australia has implemented sustainable design guidelines for railways.

**"Ecoste" (Eco station) concept for railway station development [46] (Japan)**

JR East (Japan Railways East Company) has an "ecoste" (Eco station) concept for railway station development. It is an initiative to equip railway stations with a variety of environmental conservation technologies. "Ecoste" aims to advance eco-friendly development practices based on four pillars which are as following:

- Energy Conservation: Promoting practices that include initiatives directly reducing energy use, such as high-efficiency lighting and climate control
- Energy Creation: Actively implementing renewable energy initiatives (e.g., solar energy)
- Eco-Awareness: Preparing facilities that make users eco-aware. These activities promote usage of natural resources to reduce energy consumption.
- Environmental Harmonization: Creating vitality by harmonizing people with their environment. It includes initiatives that emphasize the relationship between nature and the local area, for example through green spaces on station buildings, etc.

45 Building and Construction Authority – Press Release 20 October 2010
46 http://www.nextstation2015.com/IMG/pdf/presentation_yuko_ando.pdf
47 http://www.nextstation2015.com/IMG/pdf/presentation_yuko_ando.pdf

## 3. Net Zero Guidelines

To provide impetus towards developing Net Zero Energy Buildings (NZEB), a comprehensive strategy framework/ guidelines covering design and construction principles for NZEB along with setting targets at zonal/divisional level could be taken up for the stations considered for redevelopment and for upcoming new stations planned. Further, these policy measures would need to be augmented by capacity building exercises and possible undertaking of 4-5 pilot to demonstrate the commitment of Indian railways towards NZEB path, and consequently acquire valuable first-hand experience of developing and managing NZEBs.
European Union and a few other countries have already taken political and policy decisions to go for NZEBs in the coming years, which also include railway stations in its ambit.

**Directive on Energy Performance of Buildings (European Union)[47]**

By 2020, the EU aims to reduce its greenhouse gas emissions by at least 20%, increase the share of renewable energy to at least 20% of consumption, and achieve energy savings of 20% or more. Consequently, the directive requires all new buildings, including railway stations, must be nearly zero energy buildings by 31 December 2020 and Member States are expected to set minimum energy performance requirements for buildings in the coming year.

Member states have to set their own interim and final targets, and a host of strategies to accomplish these targets. Member States are also required to draw up national plans reporting on their plans for increasing the number of NZEB, definition of NZEB, policies/measures in order to stimulate the transformation of buildings that are refurbished into NZEB and interim steps towards NZEB.

A detailed review of international experience and initiatives undertaken globally to improve efficiency in energy use is presented in Annexure 1.5.

Apart from the interventions discussed above, additional interventions, based on international good practices, which can be considered by the Indian Railways depending on resources available and overall feasibility[49] are indicated below:

48 https://ec.europa.eu/energy/en/topics/energy-strategy/2020-energy-strategy
49 Detailed section on global best practices is included in Annexure 1.5

### Table 5: Advanced energy efficiency interventions based on international good practices

| Additional EE Interventions | Key Features |
|---|---|
| Use of adaptive lighting technology | Lighting systems are connected to sensors which help in automatically dimming or turn off lights on pedestrian or railway carriage movement. The sensors also help in luminaires increase illumination levels during peak hours. |
| Energy Efficient air-conditioning and HVAC systems | Involves use of technology as well as design based interventions to make the air conditioning or HVAC systems more efficient<br>• **Smart Glass or Glazing** - Installing energy saving window films or glazing on concourse windows helps create climate adaptive building shells (reduces heat gain and minimizes air conditioning losses) thereby reducing the energy consumption for HVAC as well lighting[49]<br>• **Automatic sliding doors and air curtains** at critical points in building exposed to ambient temperatures, to reduce air-conditioning loss[50]<br>• **Floor-mounted jet nozzles for air conditioning** in large area such as ticket booking offices or waiting rooms are more efficient compared to ceiling-mounted systems and improve the overall HVAC performance[51] |
| Building Management System (BMS) for energy efficiency | BMS helps operate a building's mechanical and electrical equipment such as HVAC, lighting, fire and security systems etc. through logic-based centrally controlled system. Systems linked to a BMS typically represent 40% of a building's energy usage and if lighting is included, this number approaches to 70%. It is therefore a powerful tool to control, monitor and optimize energy consuming equipment[52]<br>• Scheduling: turn equipment on or off depending on time/day, or other variables such as outdoor air conditions<br>• Helps identify predictive maintenance through monitoring power consumption profile of various machinery & equipment<br>• Diagnostics: to monitor information such as temperatures, flows, pressures etc. to determine whether equipment is operating inefficiently |
| Energy efficient building design | Modern building design and architecture to improve energy efficiency focus on aspects of using natural lighting and at the same time, creating an efficient building envelope[53]<br>• These designs feature large open spaces with abundant natural light / effective day lighting, large, cavernous indoor spaces with tall ceilings facilitating natural ventilation, commonly using steel structures enhancing overall thermal performance of building envelope to minimize heat gain.<br>• The design, however, needs to avoid glare and increasing heat load in summer months, possibly by using low-emissivity glass and roof shading, and should seek a balance between lighting and air-conditioning energy consumption. |

50 National Institute of Building Designs, Washington DC. https://www.wbdg.org/resources/windows.php
51 Air Curtains: A Proven Alternative to Vestibule Design - http://cdn.thomasnet.com/ccp/00164277/35841.pdf
52 The Hindu, http://www.thehindu.com/features/homes-and-gardens/are-our-airports-built-right/article7137900.ece
53 Automated Buildings - http://www.automatedbuildings.com/news/apr07/articles/esource/070322105430kamm.htm
54 ADB Report - http://www.adb.org/sites/default/files/publication/173696/energy-intelligent-railway-station.pdf

# 5. Identifying and Prioritising Solar Energy Interventions

In line with the Indian Railways' vision and mission for environmentally benign operations, this section assesses the potential of commercially viable solar PV projects across its various non-traction activities.

Non-traction operations include railways sheds, workshops, stations, and offices among others. The viability, particularly from the perspective of technology, has been debated with regards to the use of solar PV for traction purposes, whereas non-traction purposes provide a feasible opportunity for large scale deployment of solar PV projects and, thus, result in significant benefits, both in terms of energy savings as well as emission reductions.

For the purposes of this analysis, we have included diesel locomotive sheds, railway workshops, railway stations, railway offices, level crossing gates, and use of vacant railway land. Across its sixteen zones, the Indian Railways has close to 50 diesel sheds, 40 railway workshops, over 8000 stations and about 43000 hectares of vacant land. The analysis does not include electric locomotive sheds and the carriage and wagon depots for which the necessary data were not available.

A preliminary analysis based on available data from railway statistics indicates that the average project size for most operations would be about 100kW. Thus, a Cost-Benefit Analysis (CBA) has been carried out for a prototype 100kWp solar plant and the minimum tariff rate[55] at which the plant would be commercially viable was determined. While electricity tariffs are periodically increasing, the CBA considered two scenarios:

a. ***Constant electricity tariff over 25 years:*** With the railways planning to achieve the 1 GW solar target by 2018-19, and some states having taken up power sector reforms to a large extent, may not result in significant electricity tariff hikes.
b. ***5% year-on-year increase in electricity tariff over 25 years:*** This case has been considered to provide an overview of the solar potential if there were a tariff hike across various railway zones.

The following assumptions were made for the CBA:

i. Cost of 100 kWp plant using crystalline PV panels was estimated at INR 75 lakh, i.e. INR 75,000 / kWp.
ii. A 70:30 Debt-Equity scenario has been considered, where in, 70% of the capital cost is raised through debt while the Railways would invest 30% as equity.
iii. Debt financing has been considered at a 12% interest rate with a 10-year payback period.
iv. A discount rate of 11% has been assumed.
v. Power output has been assumed to decrease by 0.5% each year from Year 3 onwards[56].
vi. The life of each plant has been assumed to be 25 years.
vii. Operation and Maintenance (O&M) costs would increase by 5.72% each year from Year 1 onwards.
viii. No subsidy or Viability Gap Funding (VGF) from MNRE has been considered.

55 The tariff rate, at which, the Net Present Value (NPV) of the project equals zero.

56 While studies by NREL and IFC indicate a degradation rate of 0.5% per annum, these have been based on studies in Europe and North America. A report submitted to the CERC indicates the assumption taken for this study based on studies in the Indian context (http://www.cercind.gov.in/2011/Whats-New/PERFORMANCE%20OF%20SOLAR%20POWER%20PLANTS.pdf).

**Table 6: Cost Benefit Analysis results of 100 kWp solar PV installation**

| | Minimum tariff rate for project to be viable |
|---|---|
| At constant tariff | INR 5.51 |
| At variable tariff | INR 3.75 |

*Source: CEEW Analysis, 2015*

Based on the CBA for a 100 kWp system, it is observed that in the constant tariff case, the minimum tariff rate over which all plants are financially viable, with a payback period of 10 years, is INR 5.51. Assuming an increase in tariff rates at 5% each year over a 25-year period, it is found that the minimum tariff rate above which all plants would be financially viable is INR 3.75. The electricity tariffs for railway operations across various states in India range from INR 3.15 (Goa and Jammu & Kashmir) to INR 7.65 (Maharashtra), with the median tariff being around INR 4.93 (as of 2014-15). Thus, in the case of variable tariff, most potential installations would be feasible[57]. But, this would come at a significant upfront capital cost.

Based on the CBA estimates, two scenarios have been developed, which take differing assumptions with regards to availability of rooftop area, coverage of railway stations and use of vacant railway land. The two scenarios are summarised in Table 7.

**Table 7: Overview of scenarios considered for the analysis**

| Assumption | Comments | Scenario 1 (Optimistic) | Scenario 2 (Conservative) |
|---|---|---|---|
| Availability of rooftop area in diesel sheds and workshops | Not enough data is available on the roof type. | 70% of total covered area | 50% of total covered area |
| Railway stations | With no data available on the roof top area available across railway stations, it has been assumed that each station could potentially have a 10kWp system (based on various pilot projects of the railways and REMCL targets). Actual assessment based on data availability could lead to higher estimates. | All railway stations (over 8000) would have a 10kWp system, at a cost of INR 1,25,000 per kWp, including battery based storage | All Class-E railway stations (about 4000) would have a 10kWp system, at a cost of INR 1,25,000 per kWp, including battery based storage |
| Use of vacant railway land [57] | With about 43000 hectares of railway land lying vacant, use of a small proportion could add significant potential to installed solar PV capacity. | 5% of vacant railway land to be diverted for installation of large solar PV<br>• The land required for setting up 1 MW of large scale solar PV is 5 acres.<br>• Cost is assumed to be INR 6.5 crore[58] for projects of sizes 1 – 10 MW. Given th at land availability is not contiguous in nature, most projects will be in the range of 1 – 10 MW. | 1% of vacant railway land to be diverted for installation of large solar PV |

*Source: CEEW Analysis, 2015*

57 It should be noted that
58 Detailed assumptions on the use of railway land for installation of large solar PV are discussed in Section 5.8.
59 Based on discussions with various solar project developers.

## 5.1 Diesel Locomotive Sheds

A total of 49 Diesel Locomotive Sheds across all Railway Zones were considered for the analysis. In order to estimate the potential of solar PV in each of the diesel loco-sheds and workshops, two cases were considered, first, where 70% of the total covered area is available for rooftop installations, and, secondly, where 50% of the total covered area is available for rooftop solar. In cases where the system size is greater than the average monthly power consumption of the unit under consideration, it is assumed that any excess power would be sold to the grid via a net-metering system.

The feasibility assessment *(assuming constant tariff)* indicated that solar PV installations would be commercially feasible in 21 of the 49 loco-sheds analysed. Table 8 provides the details.

**Table 8: Assessment of feasible solar PV projects at constant electricity tariff – Diesel Loco-sheds**

| Constant Tariff (INR 5.518) | Viable Projects | |
|---|---|---|
| | Scenario 1 (70%) | Scenario 2 (50%) |
| Capacity (MW) | 16.33 | 11.66 |
| Costs (INR crore) | 122.45 | 87.46 |

*Source: CEEW Analysis, 2015*

The analysis indicates that, cumulatively, the 21 viable projects *(Annexure – 2.1.1)* could lead to a total installed capacity of 16.33 MW in an 'Optimistic' scenario at a cost of INR 122.45 crore while in a 'Conservative' scenario, a total installed capacity of 11.66 MW could be achieved at an investment of INR 87.46 crore.

Under the variable tariff rate assumption, all 49 diesel sheds could contribute to a cumulative installed capacity of 26 – 36 MW, at an investment of INR 197-277 crore. Table 9 provides a summary of the variable tariff rate case.

**Table 9: Assessment of feasible solar PV projects at variable electricity tariff – Diesel Loco-sheds**

| Variable Tariff (INR 3.751) | Viable Projects | |
|---|---|---|
| | Scenario 1 (70%) | Scenario 2 (50%) |
| Capacity (MW) | 36.87 | 26.34 |
| Costs (INR crore) | 276.54 | 197.53 |

*Source: CEEW Analysis, 2015*

## 5.2 Railway Workshops

A total of 40 railway workshops across all railway zones in India were considered for the analysis. The feasibility assessment *(assuming constant tariff)* indicated that 17 of the 40 railway workshops analysed had the potential for commercially feasible solar PV installations. Table 10 provides the details.

**Table 10: Assessment of feasible solar PV projects at constant electricity tariff – Railway Workshops**

| Constant Tariff (INR 5.518) | Viable Projects | |
|---|---|---|
| | Scenario 1 (70%) | Scenario 2 (50%) |
| Capacity (MW) | 67.82 | 48.44 |
| Costs (INR crore) | 508.62 | 363.30 |

*Source: CEEW Analysis, 2015*

The analysis indicates that, cumulatively, the 17 viable projects *(Annexure – 2.1.2)* could lead to a total installed capacity of 67.82 MW in an aggressive scenario at a cost of INR 508.62 crore, while in a conservative scenario, a total installed capacity of 48.44 MW could be achieved at an investment of INR 363.30 crore.
Under the variable tariff rate assumption, cumulatively all 40 railway workshops could contribute to a total installed capacity in the range of 175-245 MW, at an investment of INR 1313-1838 crore. Table 11 provides a summary of the variable tariff rate case.

**Table 11: Assessment of feasible solar PV projects at variable electricity tariff – Railway Workshops**

| Variable Tariff (INR 3.751) | Viable Projects | |
|---|---|---|
| | Scenario 1 (70%) | Scenario 2 (50%) |
| Capacity (MW) | 245.13 | 175.09 |
| Costs (INR crore) | 1838.46 | 1313.18 |

*Source: CEEW Analysis, 2015*

## 5.3 Car Sheds and Electric Loco Sheds

Of about 30 Car sheds, about 12 car sheds are of similar holding size, while, there are about 8-10 smaller sheds. Similarly, there are about 30 Electric Loco Sheds, of which 27 are of similar holding capacity. For the purposes of this estimation, the solar PV system size was estimated for the Ghaziabad Car Shed and the Ghaziabad Electric Loco Shed, as a prototype. A similar potential has then been assumed for the remaining 12 car sheds and 27 electric loco sheds.

In the case of car sheds, in an 'Optimistic' scenario (Case 1), at an investment of about INR 2210 crore, a total capacity of 221 MW (gross potential) of solar PV can be installed across 12 car sheds under the Indian Railways, while under a 'Conservative' scenario (Case 2), a total installed capacity of 158 MW of solar PV can be achieved at an investment of INR 1578 crore.

In the case of electric loco sheds, in an 'Optimistic' scenario (Case 1), at an investment of about INR 342 crore, a total capacity of 34 MW (gross potential) of solar PV can be installed across 27 electric loco sheds under the Indian Railways, while under a 'Conservative' scenario (Case 2), a total installed capacity of 24 MW of solar PV can be achieved at an investment of INR 244 crore.

## 5.4 Production Units

The Indian Railways has seven Production Units which include the Chittaranjan Loco Works – Chittaranjan, Diesel Loco Works – Varanasi, Rail Coach Factory – Kapurthala, Integral Coach Factory – Chennai, Rail Wheel Factory – Bangalore, Diesel Loco Modernisation Works – Patiala and Rail Coach Factory – Rae Bareilly.

Among these, there is area available both in the form of rooftop and open land within the complex of these units. While the rooftop estimation has been done similar to all other similar railway establishments, in the case of the open land, it has been assumed that only 10% of this land is available for solar PV installations.

Across the seven Production Units, in an 'Optimistic' scenario (Case 1), at an investment of about INR 3586 crore, a total capacity of 358 MW (gross potential) of solar PV can be installed, while under a 'Conservative' scenario (Case 2), a total installed capacity of 219 MW of solar PV can be achieved at an investment of INR 2187 crore.

## 5.5 Railway Stations

The Indian Railways has 8495 railway stations in India[60]. The REMCL has set a target of covering 525 stations with a total capacity of 5.25 MW of solar PV. Thus, a total of 7970 stations remain as potential for solar PV projects, apart from the REMCL target. Two cases have been considered. The first case assumed that all the 7970 stations would get a 10 kWp solar PV plant each, while the second case assumes that each of the 4158 Class-E stations would get a 10 kWp solar PV plant. In both cases, it is assumed that each station meets the necessary requirements for setting up a 10 kWp solar PV plant at a cost of INR 1,00,000 per kW without any storage.

In an 'Optimistic' scenario (Case 1), at an investment of INR 797 crore, a total capacity of 79.7 MW of solar PV can be installed across 7970 railway stations under the Indian Railways, while under a 'Conservative' scenario (Case 2), a total installed capacity of 41.58 MW of solar PV can be achieved at an investment of INR 415.8 crore across the 4158 Class-E railway stations.

## 5.6 Proposed targets of Railways Energy Management Company Ltd. (REMCL)

### 5.6.1 Level Crossing Gates (LCGs)

The REMCL has also decided to install solar PV at level crossing gates (LCGs). This shall also ensure safety at unmanned level crossing gates as flashing LED lights could give sufficient warning for vehicles and others to refrain from crossing the LCG before a train passes through.

A total of 6100 LCGs have been identified to be installed with solar PV each with a capacity of 1 kWp. The notification by the Indian Railways states the cost for an off-grid 1 kWp solar PV plant with battery based storage for a LCG has been assumed to be INR 1,60,000[61].

Thus, at an investment of INR 97.6 crore, a total capacity of 6.1 MW of solar PV can be achieved across the identified LCGs.

### 5.6.2 Street Lights

The REMCL has also set a target of installing 600 street lights powered by solar PV, each with a capacity of 0.37 kWp. The cost per street light is INR 20,000. Thus, at an investment of INR 0.44 crore, a total capacity of 0.22 MW can be achieved through 600 solar powered street lights.

### 5.6.3 Railway Stations

The REMCL has also targeted covering 525 stations with a total capacity of 5.25 MW, in addition to those identified in Section 3.3. The cost assumption is the same as in Section 3.3. Thus, at an investment of INR 52.5 crore, a total capacity of 5.25 MW would be installed.

---

60 Notification No. '2012/TG-IV/10/PA/Category of Stns', Ministry of Railways (http://www.indianrailways.gov.in/railwayboard/uploads/directorate/traffic_comm/Comm-cir-2k13/Number_050713.pdf)

61 The Energy and Resources Institute (2015), Rooftop Solar PV Experience in India, TERI; Notification No. 2002/Elect.(G)/150/9, Ministry of Railways

## 5.7 Proposed solar PV projects of Indian Railways at Railway Offices (Ministry of Railways)

The Ministry of Railways has also proposed a total of 61 solar PV projects across various offices under the Ministry at a total investment of INR 23.73 crore, resulting in a total installed capacity of 0.76 MW of solar PV.

## 5.8 Use of vacant land belonging to the Indian Railways

The Indian Railways has a large amount of land spread across the various zones. As per the Ministry of Railways, a total of 110935 acres (about 44894 hectares) is currently lying vacant[62]. It is possible that some of this land could be diverted for purposes of setting up solar PV. The Rail Budget 2015-16 indicates that use of railway land is possible for solar PV installations.

While data on land holding distribution across the railway zones was available, information on whether this land was contiguous was not clear. Thus, for this analysis, it is assumed that the land holdings are fragmented and the optimum size of large solar PV projects would be in the range of 1 – 10 MWp. For large solar PV projects, the efficiency of the plant, apart from other factors such as wind velocity and temperature, is dependent on solar irradiation in that region. With India being a vast country, the Direct Natural Irradiance (DNI) ranges from below 3 kWh/$m^2$/day to 6.5 kWh/$m^2$/day, with the median DNI being around 4.5 kWh/m2/day[63]. In this analysis, the total estimated potential of large solar PV using railway land includes all railway zones.

The solar PV potential, which can be achieved in Scenario-1 (Optimistic), is estimated to be about 1.11 GW, while in Scenario-2 (Conservative), it is about 0.22 GW, at a cost of ~INR 7211 crore and ~INR 1442 crore, respectively *(Annexure – C)*. If zones with DNI < 4.5 kWh/m2/day were excluded, then the large solar PV potential in the Optimistic and Conservative scenario are estimated to be around 0.75 GW (~INR 4864 crore) and 0.15 GW (~ INR 973 crore), respectively.

The use of railway land for commercial and other purposes is monitored by the Railway Land Development Authority (RLDA). The RLDA identifies land for various purposes and is responsible for processing the change in land use type in coordination with the respective State Governments if the need arises. The Ministry of Railways in a recent report has notified that 100% FDI will be permissible for all solar PV projects installed on railway land[64]. As mentioned earlier, the railways could explore the possibility of leasing land to project developers for construction, operation and maintenance of solar projects. In order to make this an attractive model for developers, the Ministry of Railways has proposed that the land lease would be at INR 1 per annum if the power produced is for use within the railways[65]. If that were not the case, then the land lease would be at commercial rates. This indicates that for land identified for solar PV projects, the opportunity cost of land could be negligible if the power generated were consumed wholly by the railways.

62 Land and Amenities Directorate, Ministry of Railways, Government of India

63 Ministry of New and Renewable Energy, Indian Solar Resource Maps, National Renewable Energy Laboratory, Department of Energy, Government of USA / Solar Energy Centre, Ministry of New and Renewable Energy, Government of India

64 Ministry of Railways (2014), Overview of Framework for Participative Models of Rail Connectivity and Domestic & Foreign Investment, PPP Cell, Infrastructure Directorate, Ministry of Railways, Government of India

65 Ministry of Railways (2014), Overview of Framework for Participative Models of Rail Connectivity and Domestic & Foreign Investment, PPP Cell, Infrastructure Directorate, Ministry of Railways, Government of India

## 5.9 Estimated solar potential and emission savings

Given the challenges involved in implementing small PV projects over a hundreds of touch points situated in different geographies, it might be useful to implement solar PV projects of larger sizes first, so as to achieve targets within an established time frame. The REMCL has proposed to achieve a target of about 5.25 MW through solar PV projects by covering about 525 stations. It is found that the diesel locomotive sheds and railway workshops, even as per conservative estimates, have a cumulative potential of about 60 MW, which could be achieved by implementing 41 projects as compared to spreading 5.25 MW across 525 stations. It would be useful to identify such low-hanging fruits for implementation of solar PV projects in the Indian Railways, which could help to propel the commitment of the Railways to transition towards a greener transportation system.

Table 12 summarises the estimated gross potential of solar PV for non-traction activities across all identified establishments of the Indian Railways, analysed in the above sections. Based on the Vision 2020 targets of 10% renewables, it would require the railways to consume about ~ 0.4 GW from renewable energy, while the 1 GW target set under the Rail Budget 2015-16 for solar PV aims to go beyond this. ***The 'Conservative' scenario will help the Indian Railways achieve this target and go beyond, through solar energy at an estimated cost of around ~INR 8728 crore.*** With the REMCL also taking up projects to tap into wind potential, the Indian Railways could realise greater renewable energy targets.

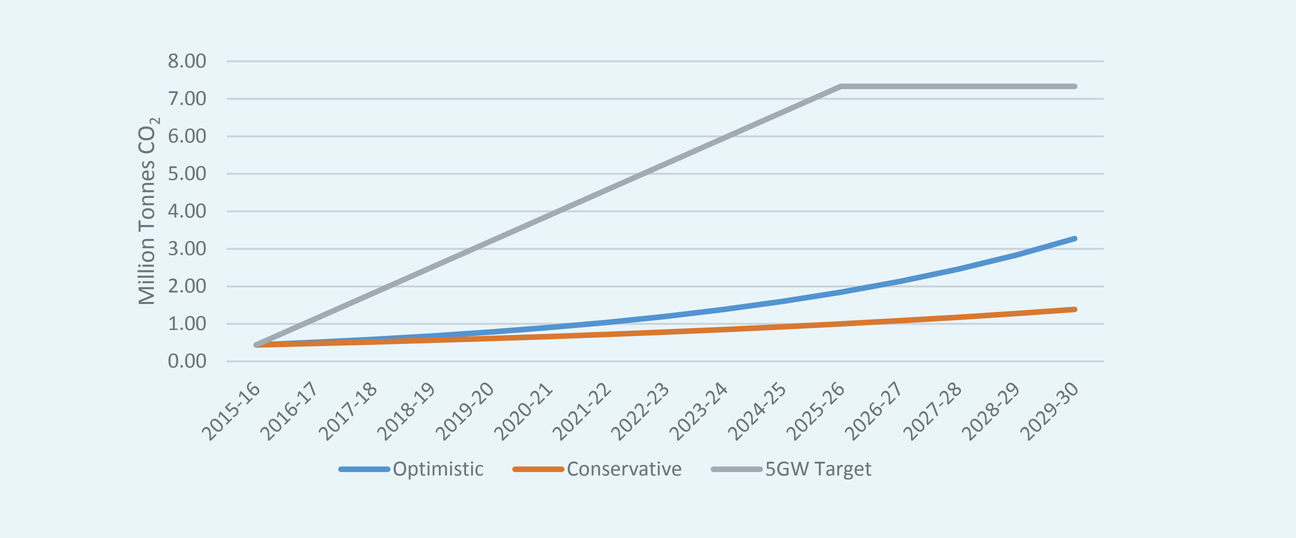
In the 'Optimistic' scenario, the Indian Railways could achieve close to 2.23 GW of installed capacity of solar PV, which would be greater than the set target, though this would come at a cumulative investment of ~INR 18,487 crore.

If the railways were to own all projects except the large solar PV projects on vacant railway land, under both scenarios, they would incur a cost of INR 150 – 200 crore each year towards servicing debt payments for a period of 10 years.

The cumulative emission savings accruing over a 15-year period have been estimated for the various railway operations included in the assessment of solar PV potential in this analysis (Figure 5). It is estimated that a cumulative emission savings of about 21.6 Mt $CO_2$ and about 12.5 Mt $CO_2$ could be achieved in the 'Optimistic' and 'Conservative' scenarios, respectively, by 2030. If the Indian Railways were to achieve its 5 GW renewable energy target, the emissions savings could go up to about 72 Mt CO2.

The use of railway land for large solar PV along with rooftop solar PV installations at railway workshops, car sheds and Production Units have the largest potential in terms of emission savings over the lifecycle of the solar PV systems.

**Figure 5: Emission savings (million tonnes of $CO_2$) across railway operations with solar PV installations**




*Source: CEEW Analysis, 2016*

**Table 12: Estimated Gross Solar PV potential across various identified railway operations**

| | Railway Unit | Optimistic | | Conservative | |
|---|---|---|---|---|---|
| | | Capacity (MW) | Costs (INR crore) | Capacity (MW) | Costs (INR crore) |
| **1** | **Diesel Loco Sheds** | 36.87 | 368 | 26.34 | 263 |
| **2** | **Railway Workshops** | | | | |
| *2.1* | *Rooftop PV* | 245.13 | 2451 | 175.10 | 1751 |
| *2.2* | *Workshop Land* | *135.06* | *1350* | *67.53* | *675* |
| **3** | **Car Sheds** | 220.96 | 2210 | 157.83 | 1578 |
| **4** | **Electric Loco Sheds** | 34.21 | 342 | 24.44 | 244 |
| **5** | **Production Units** | | | | |
| *5.1* | *Rooftop PV* | 184.06 | 1840 | 131.47 | 1315 |
| *5.2* | *PU Land* | 174.54 | 1745 | 87.27 | 872 |
| **6** | **Railway Stations** | | | | |
| *6.1* | *Already proposed (REMCL)* | 5.25 | 52 | 5.25 | 52 |
| *6.2* | *Additional potential* | 79.70 | 797 | 41.58 | 416 |
| **7** | **Level Crossing Gates (LCGs)** | 6.10 | 97 | 6.10 | 97 |
| **8** | **Street Lights** | 0.22 | 0.44 | 0.22 | 0.44 |
| **9** | **Railway Offices (Proposed by Ministry of Railways)** | 0.76 | 24 | 0.76 | 24 |
| **10** | **Total (1-9)** | **1122.86** | **11276.44** | **723.89** | **7287.44** |
| **11** | **Large PV potential** | | | | |
| *11.1* | *5% land utilization* | 1109.35 | 7211 | | |
| *11.2* | *1% land utilization* | | | 221.87 | 1441 |
| **12** | **TOTAL (10-11)** | **2232.21** | **18487.44** | **945.76** | **8728.44** |

*Source: CEEW Analysis, 2016*

# 6. Achieving net zero energy status for non-traction: Case Study

With the Union Ministry of Power emphasizing the need for Net Zero Energy Buildings (NZEB)[66], the Indian Railways have an opportunity to consider developing net zero station buildings as a part of the on-going Station Redevelopment Programme.

The net zero energy building concept is based on the principle that buildings should ideally meet all their energy requirements from low-cost, locally available, non-polluting, and renewable sources. From an implementation standpoint however, an NZEB basically generates enough renewable energy on-site so as to equal or exceed its annual energy use.[67]

Rapid strides taken by the Railways in the area of promoting sustainable and clean energy over the last two years indicate a positive movement in the direction of achieving the Net Zero Energy goal in the long run. Over 10 MW solar plants have been installed in the last two years including a 30 KW roof top installation on the Rail Bhawan, New Delhi.[68]

Railways can consider adopting global NZEB best practices in terms of using energy efficient lighting and equipment, integration of renewable energy technologies, and design strategies for the 400 stations selected for redevelopment. Indira Paryavaran Bhavan in New Delhi, which also hosts the Union Ministry of Environment, Forest and Climate Change (MoEFCC), one of the first NZEB building in India, stands testimony to the fact that such buildings are no longer a futuristic dream.

Designing of a NZEB would require successful integration and optimization of several architectural concepts and strategies such as building orientation with respect to sun path, natural ventilation, solar shading, day-lighting, solar heat gains, thermal comfort as well as deployment of well proven insulation practices, energy efficient glazing, air conditioning and lighting systems, and incorporation of renewable energy technologies for on-site power generation. The schematic in Figure 6 provides the overall framework for designing of a NZEB.

Based on the net-zero design path, an analysis on sample data of 3 railway stations (one A-category and two A1-category stations) presents an illustrative case on how net zero energy can be achieved by the Indian Railways.[69]

---

66 http://timesofindia.indiatimes.com/city/goa/USAID-and-ministry-of-power-launch-portal-to-promote-net-zero-energy-buildings/articleshow/52468985.cms

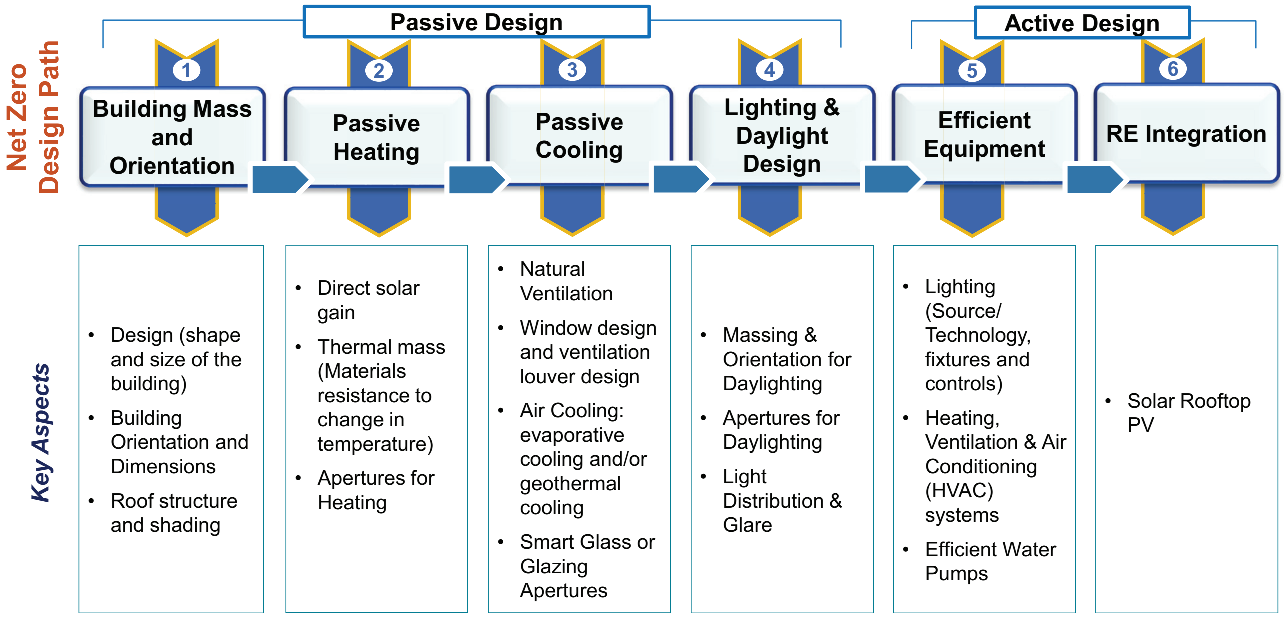
67 Zero Energy Buildings: A Critical Look at the Definition – NREL, US Department of Energy

68 Two Year Performance Report – Indian Railways

69 Following are assumptions for net-zero calculations:

- For calculation of net zero energy, data for Kota (A), Jaipur (A1) and Lucknow (A1) have been analysed. The source of data are the energy audit reports (FY14) of the respective station provided by Indian Railways.
- All calculations for A1 stations are average of the two sample data.
- The calculations for net-zero energy do not factor in any increase in demand due to redevelopment of existing stations.

**Figure 6: Net Zero Design Path**




*Source: KPMG Analysis*

**Table 13: Illustrative Case for Net Zero Energy Station[70]**

| Station Category | Current Consumption (MWh) | Annual Savings (MWh) | | | | | Annual Solar Generation (MWh) | Net Consumption (MWh) |
|---|---|---|---|---|---|---|---|---|
| | | Passive Building Design | LED Lighting | Occupancy Sensor | Other EE Measures | Building Mgt. System | | |
| A | **409** | 61 | 688 | 25 | 77 | 17 | 86 | **14** |
| A1 | **3411** | 512 | 512 | 25 | 121 | 299 | 136 | **1557** |

*Source: KPMG Analysis*

The case example (Table 13) highlights the potential of railway stations to achieve NZEB status through the adoption of active and passive design strategies.

In the current sample set, the A-category station has the potential to achieve near net-zero energy and with an additional roof-top area of 161 m$^2$ it can reach NZEB status.

However, for A1-category stations in this example, the present roof-top area is inadequate to achieve net zero status. But if the Railways were to make available additional area (by way of including open railway land around the station complex) of about 17,000 square meter on average for captive solar PV installation, then it can enable these stations to also achieve the status of a net-zero energy building.

70 Detailed calculation and assumptions are referred to in Annexure 1.4

# 7. Future Technologies: Energy Storage and Clean Tech

Energy storage and application of batteries has always been a critical component of Indian Railway system with applications in train coaches, signalling, locomotive starting and communication etc. Further, Indian Railways is planning to deploy solar PV systems at the stations and remote locations to utilise solar potential in a big way. Advance battery technologies with better performance, higher efficiencies and longer life will enable Indian Railways to utilise solar energy even during night hours while ensuring economic viability of such technologies.

As the railways embarks on large scale efforts towards energy efficiency and renewable energy, the role of energy storage applications would play a greater role in facilitating railway operations and associated energy requirements. Large un-electrified routes and technical non-compliance of overhead electric supply for non-traction electric applications requires the installation of batteries in coaches and for signalling applications. As a result, the Indian Railways, currently, is the largest consumer of lead-acid batteries in the Indian market. The battery market in 2015 for Indian Railways, including replacement demand, stands at INR ~5.3 billion (USD 80 million) which constitutes ~3.6% of overall market. The demand for batteries is primarily for coach and signalling & telecommunication applications (~90%), while locomotive applications are only a small fraction.

Batteries for the Indian Railways are primarily used for the following applications:

- Traction Applications
  - Train lighting and air-conditioning
  - Locomotive Starting
  - Signalling and telecommunication
- Renewable Applications for non-traction applications
  - Renewable energy installations (particularly, solar, as per the Indian Railways' Solar Mission)

The Research Design and Standards Organisation (RDSO) defines the battery parameters and the performance standards of batteries for the Indian Railways. Previously, flooded lead-acid batteries were used and these are now being replaced by VRLA batteries primarily due to maintenance free operations.

## 7.1 Renewable Energy Installations for non-traction applications

The Indian Railways is now harnessing solar energy at a significant scale and has also announced in the Rail Budget 2015-16 to setup 1 GW of solar power by 2018-19. These will be mostly located at railway stations, factories and workshops. Currently, the Railways consume 2.5% of the total electricity consumption in India. With increasing renewable share, batteries will be required for reliability and maximum utilisation of the power generated from these systems.

For the purposes of this analysis, we have included diesel locomotive sheds, railway workshops, railway stations, railway offices, level crossing gates, car and loco sheds. Across its sixteen zones, the Indian Railways has close to 50 diesel sheds, 40 railway workshops, and over 8000 stations.

The total solar PV potential for the Indian Railways across its various non-traction operations ranges between about 1 GW to 2 GW (CEEW, 2015). The battery storage potential has accordingly been calculated assuming the use of 12V batteries. Depending on the use of different batteries, the number of batteries required may change.

The analysis indicates that about 261 million AH is the battery storage potential for solar PV installations across the Indian Railways. Table 14 provides the details of the same.

**Table 14: Storage potential across various railway operations with solar PV installations**

| | Solar PV Potential (MW) | 12 V Battery potential (million AH) |
|---|---|---|
| Diesel Loco Sheds | 26.338 | 9.481 |
| Railway Workshops | | |
| Rooftop PV | 175.091 | 63.032 |
| Workshop land | 67.531 | 24.311 |
| Production Units | | |
| Rooftop PV | 131.474 | 47.330 |
| PU Land | 87.27 | 31.417 |
| Car Sheds | 157.828 | 56.818 |
| Electric Loco Sheds | 24.442 | 8.799 |
| Railway Stations | | |
| Already proposed (REMCL) | 5.25 | 1.890 |
| Additional potential | 41.58 | 14.968 |
| Level Crossing Gates (LCGs) | 6.1 | 2.196 |
| Street Lights | 0.22 | 0.079 |
| Railway Offices (Proposed by Ministry of Railways) | 0.76 | 0.273 |
| Total | 723.884 | 260.596 |

*Source: CEEW Analysis, 2016*

## 7.2 Traction Application

Traction applications comprise locomotive starting, electric need of coaches (including lighting, fan, charging etc.), air-conditioning of AC coaches and signalling and telecommunication along the tracks. Batteries used for traction applications need to be robust and reliable to withstand outer atmosphere, vibrations, varying temperatures, continuous discharge and low maintenance.

### 7.2.1 Train Coaches

The Indian Railways uses different types of coaches primarily categorised as air-conditioned and non-air-conditioned coaches. Currently, there are close to 50,000 coaches, of which 10,000 are air-conditioned (1$^{st}$ Class, 2$^{nd}$ AC, 3$^{rd}$ AC, AC chair car etc.) and 40,000 are non-air-conditioned (sleeper, 2$^{nd}$ sitting, general coaches etc.). The Indian Railways owned coach manufacturing companies - Rail Coach Factory at Kapurthala and Integral Coach Factory at Perambur produce approximately 3,200 coaches every year.

As per RDSO standards, power is supplied at 110V DC current from batteries in both AC and non-AC coaches. For air-conditioned coaches, higher capacity batteries (1100Ah) are used due to air-conditioning load, while, in non-AC coaches, lower capacity batteries (120Ah) are used. More variants of different battery models used in coaches are provided in previous section. The standard replacement cycle for batteries has been defined at four years by RDSO.

Batteries are a primary source of electricity in self-generating (SG) coaches while in the case of End-ON Generation (EOG) coaches, batteries are only for backup and emergency power. End-ON Generation mechanism is primarily used in fully air-conditioned trains such as Rajdhani, GaribRath, Duranto etc.

RDSO and IRIEEN (Indian Railway Institute of Electrical Engineering) are also developing Head-ON generation (HOG), which will directly supply electricity from overhead electrical cables to coach applications apart from traction. Although, it has not been deployed yet, this could reduce the requirement of batteries in coaches.

### 7.2.2 Locomotive Starting

The Indian Railways currently has 5,633 diesel locomotives for non-electrified routes and 4,823 electric locomotives for electrified routes. A total of 250 electric and 320 diesel locomotives were produced in 2015 by the Chittaranjan Locomotive Works and Diesel Locomotive Works respectively.

Batteries are used to provide power to perform several pre-start functions of diesel engines such as powering up hydraulic pumps, air compressors and brake systems, which are mandatorily required for smooth starting of the engine without any damage to its components.

The Electric Multiple Units (EMUs) requires batteries to lift and connect the pantograph to the overhead electric line to start the operations from a disconnected situation. Batteries are also used for emergency backup power and breaking. With increasing electrification of India Railways, the demand from this segment is expected to grow steadily.

### 7.2.3 Signalling and telecommunication

Batteries are provided for backup power in signalling infrastructure to maintain fool proof communication in case of any interruption in main power for safety of railway operations. Batteries used for this have low self-discharge and should be maintenance free.

## 7.3 Clean Technology Development: What is the future of solar?

With the global push towards greater renewable energy deployment, especially solar, in countries like India, the International Solar Alliance (ISA), led by India and France, could be the inflexion point for the solar sector. With its primary objectives including access to finance and technology transfer, India would benefit significantly with its ambitious goal of 100 GW of solar by 2022. In line with the National Solar Mission (NSM), the Indian Railways has also announced solar targets, wherein, they could also leverage the benefits from the ISA and other initiatives being taken under the NSM.

While the railways continue to add solar capacity, the primary technology driving this is Solar Photo-Voltaic (PV). With rapid developments in technology, this section looks at the ongoing R&D in the solar PV sector which the railways could benefit from in the post-2030 regime.

### Signalling and communications in remote railway operations

For small, wireless systems where regular battery changes are not practical, bio solar panels could become permanent power sources. Bio solar panels use photosynthesis and the respiratory activities of cyanobacteria to generate electricity. While this may not yet be feasible as traditional rooftop solar yet, there is scope for further R&D.

## Optimising Land Use and Panel Sizes

As railway operations expand, and competing uses for land increase, large scale solar plants could face hindrances in terms of land availability. In order to cut down land costs, which make up a bulk of the cost of installing a solar panel, solar cells need to start generating more power for the same surface area, so that smaller panels can be built. Researchers in California have found a solution also termed as High Powered Cells, by combining inorganic semiconductor nanocrystals with organic molecules, to generate electricity from the light that would normally not get absorbed by solar photovoltaics.

Another solution to cutting land costs for solar panel installations, being developed by a French Company since 2011, is a large-scale Hydrelio Floating PV, which allows standard 60-cell PVs to be installed on large bodies of water. It's a great alternative to ground mounted PVs, and can also facilitate use of waste wetlands for solar installations.

IBM researchers have found a way to make solar PV cells that can absorb up to 10 times more light without melting, so that solar concentrators can be used to improve efficiency of the panel and build relatively smaller panels. IBM has plans of introducing this technology at an affordable cost by 2017.

The above-mentioned technologies, are example of the potential direction of technology development. If deployed at an affordable cost in the market, they have the potential to make solar PV more sustainable and economically feasible. Most of these futuristic technologies are focussing on reducing the land requirement in setting up solar panels, which is work in the right direction especially for India where land is limited and contested.

# 8. Traction Energy Efficiency and Integration of Renewables

Most of the focus is currently on non-traction energy and has led the Indian Railways to achieve a 2% reduction in non-traction energy consumption through extensive audits, monitoring, and use of high star-rated appliances.[71] Even renewable energy currently finds use in the non-traction energy domain. However, given the share of energy consumed for traction and non-traction, the interventions on reducing traction energy consumption would lead to significant energy savings.

In order to meet the growing requirements, the railways have been upgrading even their electrical infrastructure including dedicated transmission lines, better quality transformers, etc. The Indian Railways has electrified about 28,000 RKM so far, which is about 40% of the total. Some additional measures like introduction of three phase electric locomotive technology, use of power factor correction capacitors at Traction Sub Station TSS and regenerative braking have led to significant savings as far as electric traction consumption is concerned.[72] With electrification of track routes, IR is expected to save about INR 3250 crore between 2015-17.

Some key strategies for reducing the cost of power procurement for the railways include: (i) migration from DISCOMs; (ii) captive power plants; (iii) improving the railway transmission network; (iv) efficiency of power utilisation; and, (v) increased integration of renewable energy. The railways has now started purchasing power as a deemed distribution licensee under the new amendments of the Electricity Act, 2003, which were effected in April 2016. Under this arrangement, Railways has tied up close to 1800 MW of power across the country to feed to its transmission network and result in significant cost savings. The Railways' first captive power plant at Nabinagar, Bihar, which is a 1000 MW plant, is expected to provide power at INR 4/unit, with the entire plant expected to be commissioned by March 2018. In its efforts to improve its own transmission network, the railways has begun construction of transmission lines on routes such as Allahabad-Mughalsarai, Mughalsarai-Howrah, Delhi-Chennai, and Howrah-Mumbai to name a few, which would cover a route of about 7,000 kilometres. The railways has a plan to electrifiy 90% of the broad gauge network by 2020-21 and increase the rate of electrification of tracks to 4000 km/year.

The Railways have adopted energy efficient technology for AC tap changer electric locomotive, DC-DC Converter for head lights, air dryers, DBRs, etc. The Indian Railways has also introduced energy efficient state-of-the-art 6000 HP, 3-phase electric locomotives with regenerative braking.[73] Similarly, they have also adopted 3 phase IGBT Technology for EMUs in the Mumbai Suburban Rail, expected to reduce 600 tonnes of CO2 each year due to regenerative braking. There is also a move to fit 1000 KVA hotel load converters to supply to utilities in trains. The provision of Energy-cum-Speed Monitoring system (ESMON) will facilitate monitoring of driver performance on electric locomotives leading to energy conservation. Efforts in improving energy efficiency in diesel traction include the provision of Auxiliary Power Units (APUs), Common Rail Electronic Direct Injection (CReDI) system, multi-genset locomotives, and Miller Cycle Turbochargers.[74]

The Railways is also now taking up the Dedicated Freight Corridor (DFC) project with its primary objectives being to reduce the unit cost of transportation, to increase rail infrastructure to carry higher throughput per train, to increase the railways' share in the freight market, and to improve the overall efficiency of the national rail network. The Eastern and Western Corridor under the DFC project will have a capacity of 1975 BTKM and 3241 BTKM respectively.

71 http://indiainfrastructure.com/confpdf/brochure-energy-needs-of-indian-railways-april2016.pdf
72 http://www.irgreenri.gov.in/tile_led.html
73 http://www.indianrailways.gov.in/railwayboard/uploads/directorate/stat_econ/annual-rep-0607/managing-environment.pdf
74 http://www.indianrailways.gov.in/railwayboard/uploads/directorate/Environment_Management/Environment_Annual_Report.pdf

While using renewable energy for traction requires high voltages to be supplied for long durations, the setting up of utility scale solar PV projects can help the railways source a certain share of its traction electricity consumption from renewable sources. Under the UNDP-GEF Framework, efforts are on to increase the installed capacity of solar across Indian Railways to 5 GW by 2025. Innovative solutions such as smart grids will also help the railways in the long run. The current challenges in terms of electrification and associated infrastructure relate to the integration of renewables and distributed generation, limited capacity of power generation and the grid, old infrastructure and cost and emissions of supply. The smart grid solution could facilitate the balance of generation and demand, load management and quality of power, reliability through better monitoring and troubleshooting, and enhanced efficiency in generation, transmission, distribution and consumption. This will go a long way in facilitating better energy management as the railways expands its track network under electrification.

So far, the Indian Railways is on a path towards 3.3% of year-on-year saving in electric traction and a 2% year-on-year saving While it is recognised that locomotive technology is a long-term intervention and has significant cost-implications, the efforts of the railways so far along with the fast pace of electrifying tracks, the railways could accrue significant energy savings and emissions reductions of about 110 MT of CO2eq by 2030. If the emissions reductions from the DFC project were also to be included, then it is expected to add a further reduction of 150 MT of CO2eq by 2030.[75]

75 The Eastern Corridor is expected to reduce emissions by about 2.5 times while the Western Corridor by about 6 times.

# 9. Financing models for implementation

Investment in the rail infrastructure is considered green investment. It is more energy efficient in the case of both, passenger and freight, as compared to road transport. Increasingly, large investors are moving to green investments as a priority, with indicative pledges being made by institutional investors for about USD 11.2 trillion for green investments, insurance companies planning a 10-fold increase in green investments by 2020 and an increasing number of investors increasing their commitment to green instruments. The Indian Railways provides an opportunity to the market for promoting its plans of energy efficiency and renewable energy integration.

## 9.1 Financing Energy Efficiency Projects

There are several financing strategies for energy efficiency projects like On-Bill Financing (OBF), Property Assessed Clean Energy (PACE) Financing, Energy Service Companies (ESCOs), Lease Financing and Energy Service Agreements. However, some of these models are only suitable for residential projects. In view of the background for Indian Railways, different possible business models are examined below:[76]

### 9.1.1 Energy Service Company (ESCO) Model

**Shared Savings ESCO**

An Energy Service Company (ESCO) under a shared savings business model offers an entire solution from project design, equipment selection, project implementation, and post-commissioning testing to verify savings. As per the model, the developer provides funds (all or part) and agree with Indian Railways on terms of repayment. The type of fee arrangement generally depends on the agreed tasks, the degree of difficulty and also the risks involved.

Key Features of an ESCO model:

- Project financing is typically arranged by the ESCO.
- The ESCO would be responsible for procurement, installation, operation and maintenance of the project facility and would be paid service fees as agreed in the service agreement.
- If the savings do not reach the agreed minimum, ESCO would cover the difference; and if the savings exceeds the given limits then the Indian Railways would share the savings with the ESCO.
- In the case of a Guaranteed Savings ESCO model, two key differences would be: (i) the project financing would be typically arranged by the railways; and, (ii) ESCO would be paid a performance based fees on the energy savings guaranteed.

### 9.1.2 On-Bill Financing

Under an On-Bill Financing (OBF) model, the user leverages the existing utility's capabilities to access investments for developing energy efficient systems. OBF encourages utilities to invest in energy efficiency improvements and allows flexibility to the users to repay the funds through additional charges on their utility bills.

76 Each of these models are further discussed in Annexure 1.3

Key Features of an OBF model:

- Project financing is typically arranged by the utility
- On-bill programs can be structured as loans or tariffs

In case of India, since the state utilities have very low financing capabilities, scaling and sustainability of on-bill programs would be critical to availability of third-party financing for the utilities.

### 9.1.3 Energy Service Agreements

Energy service agreements are similar to energy savings performance contracts (ESPCs) in an ESCO model where a third-party company provides energy savings for a fee. The key difference is the model's structure, wherein the third party/developer in this case will also pay the owner's utility bill directly. Key Features of an ESA model:

- Indian Railways would finance the project by borrowing funds from a financial institution/bank or finance the project out of its budget. Indian Railways would cover the debt service and pay a service fee to the developer. With the developer taking the utility bill, the performance risk of the project is with the developer.

## 9.2 Financing Renewable Energy Projects

While the different models highlighted in the previous section on energy efficiency financing are also applicable for renewable energy projects, some of the issues specific to the renewables sector are discussed further.

While the Indian Railways is looking to increase its portfolio of renewable energy, particularly solar, the risks associated with financing for such projects need to be recognised and evaluated. With India already having a 100 GW solar target, the set of risks the railways would face in achieving its solar mission, would be of a similar nature to a large extent.

**Financing Energy Efficiency Projects under the ESCO Model: An initiative by Ministry of Railways and Energy Efficiency Services Limited (EESL)**

The Ministry of Railways has entered into an MoU with EESL with the primary objective of implementing energy efficiency projects across zonal railways which will result in potential energy savings. EESL will take up projects on a case-to-case basis wherein the upfront capital investment will be made by EESL under the ESCO model. These projects will be supported by the Railway Energy Management Company Limited (REMCL), whose primary objective is to procure power at economical tariffs for the railways, in addition to promoting energy efficiency. The MoU between the Ministry of Railways and EESL covers the following under the ambit of the ESCO model:

- Energy audits of railway establishments and identify techno-economically feasible interventions
- Benchmarking technical specifications for various equipment such water pumps, ceiling fans, Air conditioners, compressors, etc.

This model will have significant benefit to the Indian Railways as the burden of upfront capital will not be borne by it. This would allow the railways to continue investing in priority areas such as traction electrification and infrastructure upgradation, while the energy efficiency investments are financed externally with the energy savings resulting in effective payback to the financiers of these interventions.

Keeping this in consideration, the railways has proposed the setting up of solar plants with subsidy support of MNRE through the PPP mechanism. Under the PPP mechanism, the 'Plug and Play' PPP model could be explored, where in the railways provides the land or rooftop area for solar PV installation and then along with private entities, develops a part of the infrastructure required. After which, the developer(s) would operate autonomously with the railways getting first access to the power generated. The asset ownership in this case would lie with the project developer.

As suggested earlier in the analysis, financing projects through maintaining a Debt-Equity ratio of 70:30 would be a feasible option with the equity coming from the railways. In such a case, the developer would only execute the project and then transfer the ownership to the railways, which will maintain and operate the plant. In this scenario, the Railways would have to raise debt from domestic or international financial institutions via long term loans or bonds. Once the solar PV plant is set up, the railways could sign a Power Purchase Agreement (PPA) with the power utility or distribution company (DISCOM) to feed any additional generation to the grid.

In a detailed study of financing risks in the solar sector, Chawla (2016)[77] also identifies construction and regulatory risk as a significant concern for both debt and equity investment. Creating institutional processes for land acquisition (where railway land is not involved), obtaining grid connection and other necessary clearances could mitigate this risk.

With railways being a guaranteed consumer of the power generated, the risks to project developers are very low with assured returns on the project. A potential risk could be the non-compliance of Power Purchase Agreements (PPA) due to the poor health of Distribution Companies (DISCOMs), which could be a factor in determining the geographic location and size of PV deployment (CEEW 2015[78]).

The study by Chawla (2016) also finds that bankers were of the view that the availability of finance could increase with better technology data. The MRV framework, detailed in the next section, thus, will play an important role, not only from a climate mitigation perspective, but also in better availability of finance for solar projects.

The Railways has also called for a subsidy towards large PV deployment on railway land via the National Clean Energy Fund (NCEF). A model, where in the railways could lease land to a solar project developer and then purchase the power generated from them, could be explored in the case where vacant railway land is used.

## 9.3 Green Instruments

Recent estimates indicate the availability of close to USD 93 trillion for green investments by 2030.[79] While the market is looking for large scale investment, long-term investors, and low cost of finance, the railways provides an interesting opportunity. So far the Railways has received positive results in its procurement bids, however, some of them have higher financing costs than what the Railways can avail. Cost of debt has already reduced from 11% to 8%, while, the cost of equity has come down from 16% to 14%. A focused approach can help bring the costs further down by 18% – 20% or correspondingly bring energy costs down by INR 1 – 1.1 kWh.

77 Chawla, K (2016). Money Talks? Risks and Responses in India's Solar Sector. Council on Energy, Environment and Water; April 2016.

78 Ramji, A (2015). Greening the tracks: Achieving the 1 GW solar target of the Indian Railways. Council on Energy, Environment and Water; June 2015.

79 2016 State of the Market Report, Climate Bonds Initiative

### 9.3.1 Infrastructure Debt Funds (IDF)

The investments made using the IDF instrument will have a minimum of 90% in debt securities or securitised debt instrument, with the balance in listed equity shares, convertibles, etc. The investment maturity is expected over 15 years. The come with a fixed return of about 7-8%. In the case of IDF instruments, the credit risk associated with the projects is to be borne by the investor, in this case, given that the projects would have an indirect sovereign guarantee by virtue of being a government (Railways) commissioned project, it may be a barrier that could be overcome.

### 9.3.2 Green Bonds

Green bonds can be of different kinds which include Corporate Bonds, Use of Proceeds Revenue Bonds, Green Project Bond and Asset-backed Securitised Bond. In the recent years, green bonds have taken off as an instrument in rail sector financing, with the China Railway Corporation being the largest issuer (about USD 194 billion, including unlabelled bonds). The UK Network Rail and the National Rail Company of France are other large issuers. Most of the bonds issued are over 10-year maturity periods, with the possibility of utilities such as Railways issuing even longer term bonds, above 30 years.

# 10. Potential MRV Framework

Measurement, Reporting and Verification (MRV) is a crucial post-implementation step, especially in case of energy efficiency and renewable energy projects to assess the performance of planned interventions and ensure that desired results in the form of savings is achieved with greater certainty. Providing evidence of tangible and reliable savings is essential for the Railways to assure continued funding and support for the on-going programs and also, further improve the implementation process of these interventions. In the context of climate change mitigation, the Paris Agreement will require India to have a robust sectoral MRV framework. The implementation of an MRV framework for the railways, will allow for better reporting of emissions reductions and energy savings for the rail sector and thus, benefit, the overall transport sector in India.

Designing a robust, continuous and structured MRV mechanism will help the Railways run the overall energy efficiency and renewable energy program effectively and will typically provide inputs on following aspects:

- Documentation of benefits (i.e. impacts / savings) from a program, and determining whether it has met/ is on track to achieving its goals
- Identify ways and means to improve current and future programs
- Support energy demand forecasting and resource planning

## 10.1 Evaluation Types and Approaches

As in a typical MRV design, the evaluation should determine direct benefits (i.e. energy and demand savings) and co-benefits (i.e. avoided emissions) that directly result from an energy efficiency programme.
Evaluation can be expressed in terms of gross energy savings which can be determined by comparing energy use and demand after implementation of the energy efficiency programme (i.e. the reporting period) with the energy use and demand before implementation of the programme (i.e. the baseline period). The following formula can be used to determine the energy and demand savings from the energy efficiency programme:

**Energy Savings = (Baseline Energy Use) - (Reporting Period Energy Use) ± Adjustments**

*Wherein, adjustments refer to suitable modification to the baseline when post- implementation conditions in energy use have changed in relation to the pre installation conditions.*

To undertake the process of energy efficiency savings evaluation, any one of the following three approaches can be adopted:

- **Deemed Savings Approach**: This approach can be used when value of savings for energy efficiency measures is available based on historical savings data of previous energy efficiency programmes. This approach shall be used for programmes having simple energy efficiency measures with well understood savings mechanism (i.e. energy consumption usage pattern), similar operating conditions (i.e. operating hours) and are also not subject to significant variation in savings due to changes in independent variables. This approach does not require onsite measurement or metering but requires field inspection for all or a sample of projects in order to ensure its proper installation and operations.
- **Measurement & Verification Approach:** Any one or a combination of the four International Performance Measurement & Verification Protocol (IPMVP)[80] options can be used to estimate the gross savings

80 International Performance Measurement and Verification Protocol prepared by EVO, June 2014

through implementation of energy efficiency programmes.[81] Options can be chosen based on the specific features such as type and complexity, uncertainty of the project savings, potential for changes in key factors between baseline and reporting period and value of project savings of the particular energy efficiency programme.

- **Large Scale Data Analysis Approach:** Under this approach, a variety of statistical methods can be employed to measure facility energy consumption meter data (almost always whole facility utility meter billing data) and independent variable data to estimate gross energy and demand savings. This approach can be most suitable for programmes that involve large scale retrofit programmes with many participants.

## 10.2 Implementing the MRV Mechanism

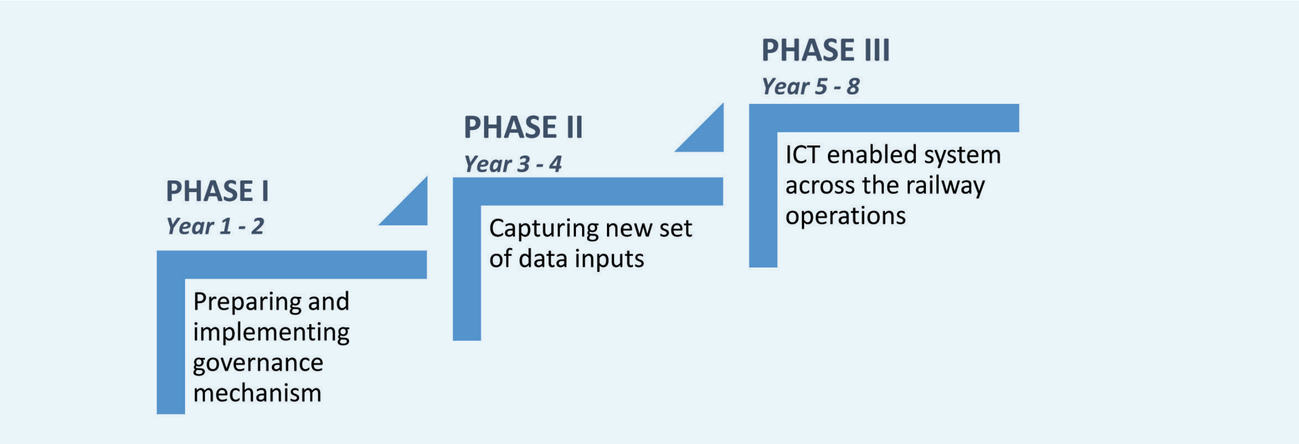
For implementing a robust MRV framework, data is required on the number of passengers and freight that are being transported, the distance across which they are moving, the fuel use per passenger-km or kWh per ton-km, and the quantum of GHGs being released per unit of energy consumed. There are two basic approaches for the MRV:

Top-down accounting provides a snapshot of GHG emissions during a specified time period based on statistical data aggregated at a certain geographical level (e.g. the total energy consumption in a year)

Bottom-up calculations are applied to estimate emissions in more detail and allow the identification of the causes of the emissions

While the Indian Railways is taking various initiatives such as traction electrification, active role in the PAT scheme, and the Dedicated Freight Corridor (DFC), which will not only enhance the efficiency of the system but also mitigate GHG emissions from its operations, a phased approach is essential for accounting for the emissions savings.

**Figure 7: Phased implementation of MRV Framework**




*Source: CEEW Analysis, 2016*

81 Refer Annexure 1.6 for the M&V options as detailed in International Performance Measurement & Verification Protocol

# 11. Way Forward

The Indian Railways has been constantly engaged in the past years, in implementing energy management measures across its sixteen zones. There exists a huge potential to accelerate these individual initiatives and bring them under a single flagship program and facilitate integrated planning at the zonal level, both inter-zone and intra-zone. Based on the cost-benefit analysis of the identified interventions and having prioritized them accordingly, it is now crucial to adopt a structured implementation plan with well-defined milestones.

It is necessary for the Railways to adopt an implementation roadmap towards improved energy management through three key imperatives: Strategic, Functional and Operational.

Strategic imperatives should lay down the broad policy for energy management in terms of compliance to standards, sourcing / procurement and design aspects. The functional and operational imperatives on the other hand, should focus on implementing and institutionalizing the policy at a zonal level and detail out the MRV mechanism to monitor the performance of the energy management measures.

The Railways must also set out appropriate guidelines for energy efficiency and management on its stations, yards, workshops, and operations in coordination with Zonal railways and other coordinating agencies at the Central and state level. In this regard, the high energy consuming railway station (Category A and A1) which are being taken up for modernization as part of station redevelopment project[82], can be looked as priority candidates for taking up energy efficiency initiatives and suitable measures should be included in the planning stage. In addition, B and C category stations, which are expected to see higher traffic in the coming years should also be considered for retrofitting and other energy efficiency measures.

Along with its significant efforts towards energy efficiency and renewable energy, it is also recommended that the Indian Railways should consider the adoption of advanced storage technologies in a strategic manner in the future, which will not only help them harness renewable energy to their full potential but will also help to achieve better efficiencies and improved reliability of the system.

Last but not the least, securing finance for implementing energy management initiatives at scale, is critical. There is a need for the railways to look towards innovative financing instruments to mobilise resources. At the same time, mitigating risks for financiers and developers is essential to give the necessary impetus for scaling energy management interventions.

This study while focusing on non-traction operations, recognises the equal if not greater importance of traction energy efficiency. At the same time, it is expected that this study will set the tone for further discussions on the need for a comprehensive strategy around energy management in the Indian Railways.

82 http://www.indianrailways.gov.in/StationRedevelopment/index.html

## 11.1 Key strategies for Indian Railways

*Institutional*

- Planning should be centralised in the near future to make the implementation of such initiatives effective given the varied expertise across zonal railways, while capacity building at the zonal level could be seen as a long-term goal
- Aligning its energy management programme with similar national programmes such as in the case of the National Solar Mission to leverage technical knowledge and financial avenues available to the Government and other stakeholders
- Centralised procurement processes and handholding for all zonal railways, as the internal capacity to implement such projects for each zone will vary
- Use the Innovation Council 'Kayakalp' in the Indian Railways to promote new ideas towards energy management
- Leverage the technology portal developed by National Academy of Indian Railways (NAIR) to promote R&D for energy conservation and efficiency

*Finance*

- Coordinate and engage closely with State Governments for resource mobilisation for energy management
- Identify low hanging solutions and their respective investment requirements which can then facilitate exploring innovative financing models under the Financing Cell instituted under the Railway Board, Ministry of Railways
- Exploring long-term institutional investors as alternate financing sources
- Leveraging the International Solar Alliance for access to international finance and technology transfer for renewable energy
- Investment in energy conservation and other related rail infrastructure, such as electric transmission and OHE, should be termed as green finance
- Explore partnerships with financing institutions such as IREDA, REMC, IRFC, Nationalised Banks such as SBI and PNB

*Operational*

- Enhance skills of railway staff under the MoU with the Ministry of Skill Development and Entrepreneurship which could potentially transform the implementation of energy management initiatives across the railways
- Build on its MoU with EESL to benchmark minimum performance standards in terms of energy efficiency for various railway operations

Council on Energy, Environment and Water,
Thapar House, 124, Janpath, New Delhi 110001, India

Tel: +91 407 333 00 | Fax: +91 407 333 99

OUR WEB RESOURCES

- ceew.in/publications
- ceew.in/blog
- ceew.in/news
- ceew.in/events
- ceew.in/videos
- ceew.in/images
- ceew.in/annualreport

OUR SOCIAL MEDIA RESOURCES

CEEWIndia

@CEEWIndia

company/council-on-energy-environment-and-water

CEEWIndia