Council on Energy, Environment & Water

GREENING THE TRACKS

Achieving the 1 gigawatt solar PV target of the Indian Railways

Policy Brief

ADITYA RAMJI

Council on Energy, Environment & Water

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CEEW Policy Brief

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A policy brief on 'Greening the tracks: Achieving the 1 gigawatt solar PV target of the Indian Railways'.

Disclaimer: The views expressed in this policy brief are those of the author and do not necessarily reflect the views and policies of CEEW.

Editor: Arunabha Ghosh

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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.

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सुरेश प्रभु
SURESH PRABHU

रेल मंत्री
भारत सरकार, नई दिल्ली
MINISTER OF RAILWAYS
GOVERNMENT OF INDIA
NEW DELHI

Foreword

The Indian Railways has been the lifeline of India for more than a century. As India's population grows and increasingly urbanises, and as the structure of the economy changes, public transportation, particularly Railways, will be the most preferred strategy for meeting rising transportation demands, in a sustainable and energy efficient way. The Indian Railways, with its increasing network and intensive resource utilisation, has to play a significant role for the ensuing transformation of the Indian economy, to achieve high growth combined with lower carbon energy use.

While such a vision would demand expansion of the Railways, it will also lead to an increasing dependence on resources, especially, energy. Indian Railways has taken various initiatives towards energy efficiency and better resource management over the last decade. A key vision, in this regard, is to have a greater deployment of renewable energy, for various requirements of the Railways.

In the Rail Budget 2015-16, the target to achieve one gigawatt of installed capacity of solar PV as part of the Solar Mission of Railways was announced. The Participative Policy document issued in December 2014, aimed at promoting public-private partnerships in the Railways also included non-conventional energy projects, in order to achieve this objective.

I compliment the Council on Energy, Environment and Water (CEEW), a leading think-tank, for coming forward to undertake this detailed study on the potential as well as way forward to achieve the one gigawatt solar PV target by Indian Railways. As the study indicates, we need to use our available resources, from the roof of loco-sheds & railway stations to the available railway land, in a strategic manner to achieve this target. I am sure that this report will provide the required insights for planning and execution of the Solar Mission of Indian Railways.

1 June 2015

Yours sincerely,

(Suresh Prabhu)

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About CEEW

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CEEW has been ranked as India's top climate change think-tank two years in a row (ICCG Climate Think Tank Ranking). The Global Go To Think Tank Index has ranked CEEW as

- 1st in India among 'Top Think Tanks with Annual Operating Budgets of Less Than $ 5 Million USD' (2013, 2014 also first in South Asia; 14th globally)
- Ist in India for 'Best Institutional Collaboration' involving two or more think tanks (2013, 2014 also first in South Asia)
- Ist in India for 'Best Policy Study/Report' for its study on India's National Water Resources Framework (2013)

In four years of operations, CEEW has engaged in more than 70 research projects, published more than 40 peer-reviewed policy reports and papers, advised governments around the world over 80 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 30 occasions, helped state governments with water and irrigation reforms, and organised more than 80 seminars and conferences.

CEEW's major completed projects: 584-page National Water Resources Framework Study for India's 12th Five Year Plan; India's first report on global governance, submitted to the National Security Adviser; foreign policy implications for resource security; India's power sector reforms; first independent assessment of India's solar mission; India's green industrial policy; resource nexus, and strategic industries and technologies for India's National Security Advisory Board; $125 million India-U.S. Joint Clean Energy R&D Centers; business case for phasing down HFCs; geoengineering governance (with UK's Royal Society and the IPCC); decentralised energy in India; energy storage technologies; Maharashtra-Guangdong partnership on sustainability; clean energy subsidies (for the Rio+20 Summit); reports on climate finance; financial instruments for energy access for the World Bank; irrigation reform for Bihar; multi-stakeholder initiative for urban water management; Swachh Bharat; environmental clearances; nuclear power and low-carbon pathways; and electric rail transport.

CEEW's **current projects include**: the Clean Energy Access Network (CLEAN) of hundreds of decentralised clean energy firms; the Indian Alliance on Health and Pollution; low-carbon rural development; modelling long-term energy scenarios; modelling energy-water nexus; coal power technology upgradation; India's 2030 renewable energy roadmap; energy access surveys; energy subsidies reform; supporting India's National Water Mission; collective action for water security; business case for energy efficiency and emissions reductions; assessing climate risk; modelling HFC emissions; advising in the run up to climate negotiations (COP-21) in Paris.

About the Author

ADITYA RAMJI

Aditya Ramji is a Junior Research Associate with the Council on Energy, Environment and Water (CEEW), India. He is an energy and development economist by training with a specialisation in environmental and resource economics. His key areas of research have been development policy, energy access and energy policy, programme implementation and impact evaluation. Prior to joining CEEW, he worked with *The Energy and Resources Institute (TERI)*, New Delhi, as a Research Associate with the *Green Growth and Development Division*, dealing specifically with issues pertaining to green growth, sustainable development and energy security.

Most of his work has involved ***policy analysis*** with regard to energy and environment with a focus on quantitative modeling of energy-economy-environment linkages. He has extensive field experience across India. He has also published in leading academic journals including the Journal of Energy and Journal of Energy Policy (Elsevier Publications).

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The author would like to thank Dr Arunabha Ghosh, Mr Karthik Ganesan and Ms Shalu Agrawal, at CEEW, for their inputs and guidance towards making this analysis rigorous. The author also expresses his sincere gratitude to Mr K. Swaminathan, Adviser (Environment), Ministry of Railways and Mr Sachin Sharma, Director (Efficiency & Research), Ministry of Railways, for their support.

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“An investment in Indian Railways is an investment in our future. It is an investment in our sustainability. It is an investment for posterity.”

SHRI SURESH PRABHU
Union Minister for Railways, Government of India

Executive Summary

With the Indian Railways being a significant consumer of resources, especially energy, identifying cost-effective options and realising an energy system with minimal environmental impacts is essential. The Vision 2020 document of the Indian Railways states that a key target is to use at least 10% of its energy requirement from renewable sources. Further to this, the Rail Budget 2015-16 announced that the railways would aim to achieve an installed capacity of 1 gigawatt (GW) of solar by 2018-19. This initiative of the Indian Railways would be a significant contribution to India's 100 GW solar targets under the National Solar Mission.

This study uses techno-economic analysis to assess the potential of solar PV projects across various non-traction operations of the Indian Railways. The analysis includes diesel locomotive sheds, railway workshops, railway stations, railway offices, level crossing gates, and use of vacant railway land.

A conservative estimate indicates that the Indian Railways could achieve about 40% of the 1 GW target at an estimated cost of around ~INR 2,930 crore. In the 'Optimistic' scenario, the Indian Railways could achieve close to 1.37 GW of installed solar PV capacity.

It is estimated that cumulative emission savings of about 45 Mt CO_2 would accrue under the Optmistic scenario; under the Conservative scenario, emissions reduction would be about 12.5 Mt CO_2. The results indicate that the use of railway land for large solar PV along with installations at diesel loco-sheds and railway workshops have the highest potential in terms of emission savings over the lifecycle of the plant.

The study proposes that in the first year, the Railways should focus on developing solar PV projects in the three railway zones, namely, Northern Railway, Central Railway and South Central Railway. These three together will help the Indian Railways achieve about 25% of its 1 GW target.

In order to ensure that the Indian Railways achieves its 1 GW solar target, three key priority areas are: financing, modalities of land use for solar, and streamlining of institutional mechanisms. The Railways must explore the possibility of innovative PPP modes which would facilitate adequate financing for solar PV projects. With regard to use of vacant land, the Railways must map future expansion plans and, then, identify suitable tracts of land which could be diverted to large solar PV projects such that the opportunity cost of land is minimal. Coordination between the various line departments and Railway Board directorates, including the Environment Directorate, is essential for effective implementation of sustainability strategies.

1. Introduction

The Indian Railways, with a network of over 64,000 route-kilometres, is the fourth largest railway network in the world in terms of length, and the world's third largest in terms of traffic density, and commonly recognised as the *'lifeline to the nation'*.

The Indian Railways consumed about 1.8% of the country's total power generation for its traction and non-traction applications in 2013-14 *(REMCL)*. 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[1]. Electricity accounted for about 22% of the railways' total working expenses. Of the total fuel expenses, diesel accounted for about 70%[2]. The CO_2 emissions from railway operations in India is currently around 4 million tonnes each year[3] and is estimated to increase to about 6.7 million tonnes per annum by 2020-21[4]. In view of rising energy demand and uncertainty in power tariffs, the Indian Railways identified the need for an aggressive push towards alternate fuels in the Indian Railways[5] as well as indentify ***potential opportunities for energy savings and realise a cost-effective energy system with least environmental impact***[6].

The Indian Railways' vision for sustainability states that it *'shall provide efficient, affordable, customer-focused and environmentally sustainable integrated transportation solutions*[7]*.'*

The railway network has been a boon in terms of transportation and mobility, but at the same time, it is also a significant consumer of resources, especially energy. Thus, measures towards resource efficiency and energy management in the Indian Railways would also have a significant impact on the environment.

The objective of this study is to carry out a techno-economic analysis to assess the potential of solar PV projects across various non-traction operations of the Indian Railways and how far it would get the railways in achieving the dual targets of 1GW of solar and use of 10% of its electricity from renewable energy.

1 Ministry of Railways, Railway Statistics (various issues), Ministry of Railways, Government of India
2 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)
3 International Energy Agency (IEA) and International Union of Railways (UIC) (2012), Railway Handbook 2012, Energy Consumption and CO_2 emissions, OECD/IEA
4 Singh S K (2006), CO_2 emissions from passenger transport in India, European Business and Technology Centre
5 Ministry of Railways (2015), White Paper - Indian Railways: Lifeline of the Nation, Ministry of Railways, Government of India
6 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
7 Ministry of Railways (2009), Railway Vision 2020 Document, Ministry of Railways, Government of India

2. Initiatives by Indian Railways towards Renewable Energy

A comprehensive roadmap would be one that aims to make overall railway operations environmentally benign such that infrastructure creation and railway operations would not put pressure on environmental resources. At the same time, it should attempt to compensate for the environmental damage caused by transport activities by adopting green technologies. Thus, there is a need to review every aspect of railway operations and infrastructure from the perspective of achieving resource efficiency. The last 5 years have been significant for the Indian Railways towards promoting renewable energy.

The Ministry of Railways' 'Vision 2020' document issued in 2009 was one of the first major steps towards addressing the challenge of reducing carbon emissions while ensuring expansion of the sector. The document highlighted various initiatives by the railways with regard to energy efficiency and emission reductions. One of the key targets as per the Vision 2020 document was to ***'utilize at least 10% of its energy requirement from renewable sources and institute a foolproof eco-friendly waste management system.'***

Subsequently, the Ministry of Railways (MoR) and RITES Ltd. formed a joint venture company, namely, Railway Energy Management Company Limited (REMCL), in the shareholding pattern of 49% and 51%, respectively. The main objectives being to undertake projects of the Indian Railways related to deployment of green energy like solar and wind power plants, power trading activities, and energy conservation initiatives, among various others.

In keeping with the spirit of the New Environment Policy (2006), the Public Accounts Committee (Sixteenth Lok Sabha, 2014-15) in its third report, *'Environmental Management in Indian Railways – Stations, Trains and Tracks'*, reviewed the processes of the Indian Railways towards ensuring environmental protection. One of its key recommendations was the need for a separate department within the railways which would coordinate and monitor environmental management initiatives across its various operations. With the establishment of the Environment Directorate, under the Railway Board, in January 2015, the Indian Railways has further established its commitment towards environmental protection and resource conservation.

The efforts of the railways in setting up renewable energy projects would contribute to Government of India's 100 GW of solar target under the National Solar Mission. *Given the large scale of operations and coverage of the Indian Railways, even sourcing a small percentage of its power requirements from renewable energy sources would have a substantial impact.* The Union Rail Budget 2015-16 stressed the need for harnessing solar energy and identified railway stations as one of the largest potentials for the same.

Identifying critical areas for ensuring a comprehensive environmental management plan, the Union Rail Minister in the 2015-16 budget speech announced expanding and expediting the Solar Mission of the Railways with an additional capacity of 1000 MW to be set up by developers on railway or private land and on rooftops of railway buildings at their own cost with subsidy/Viability Gap Funding (VGF) support from MNRE[8] over the next five years.

8 Ministry of New and Renewable Energy, Government of India

Notable recent initiatives of the railways include the setting up of a solar power plant at the Katra Railway Station; a 26 MW wind farm in Jaisalmer district of Rajasthan[9]; commissioning of a 30 kW Solar Plant at the roof top of the Rail Bhawan at New Delhi; and installation of 2.1 MW of solar PV at the Rail Coach Factory (RCF), Rae Bareilly, Uttar Pradesh. Currently, the RCF at Rae Bareilly is functioning completely on solar power.

9 http://www.energynext.in/railway-minister-calls-ramping-re-generation

3. Assessing the Potential of Commercially Viable Solar PV Projects in Indian Railways for Non-traction Activities

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

All railway operations can be classified broadly into traction and non-traction activities. Traction includes running electric and diesel-based passenger and freight trains, whereas, non-traction 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[10] 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 1GW 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[11].

10 The tariff rate, at which, the Net Present Value (NPV) of the project equals zero.
11 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 con-

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.

Table 1: 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. Thus, in the case of variable tariff, most potential installations would be feasible. 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 2.

Table 2: 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 [12]	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	1% of vacant railway land to be diverted for installation of large solar PV
		• The land required for setting up 1 MW of large scale solar PV is 5 acres. • Cost is assumed to be INR 6.5 crore[13] for projects of sizes 1 – 10 MW. Given that land availability is not contiguous in nature, most projects will be in the range of 1 – 10 MW.	

Source: CEEW analysis, 2015

text *(http://www.cercind.gov.in/2011/Whats-New/PERFORMANCE%20OF%20SOLAR%20POWER%20PLANTS.pdf).*

12 Detailed assumptions on the use of railway land for installation of large solar PV are discussed in Section 3.6.

13 Based on discussions with various solar project developers.

3.1 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 3 provides the details.

Table 3: 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 – A)* 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 4 provides a summary of the variable tariff rate case.

Table 4: 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		

3.2 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 5 provides the details.

Table 5: 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 – B) 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 6 provides a summary of the variable tariff rate case.

Table 6: 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

3.3 Railway Stations

The Indian Railways has 8495 railway stations in India[14]. 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.

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

3.4.1 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[15].

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.

3.4.2 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.

14 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)

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

3.4.3 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.

3.5 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.

3.6 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[16]. 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[17]. 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 7210 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[18]. 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[19]. 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.

16 Land and Amenities Directorate, Ministry of Railways, Government of India
17 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
18 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
19 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

4. 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 7 summarises the estimated 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 about 40% of this target through solar energy at an estimated cost of around ~INR 2,930 crore.*** With the REMCL also taking up projects to tap into wind potential, the Indian Railways could realise its renewable energy targets of 1 GW.

In the 'Optimistic' scenario, the Indian Railways could achieve close to 1.37 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 9450 crore.

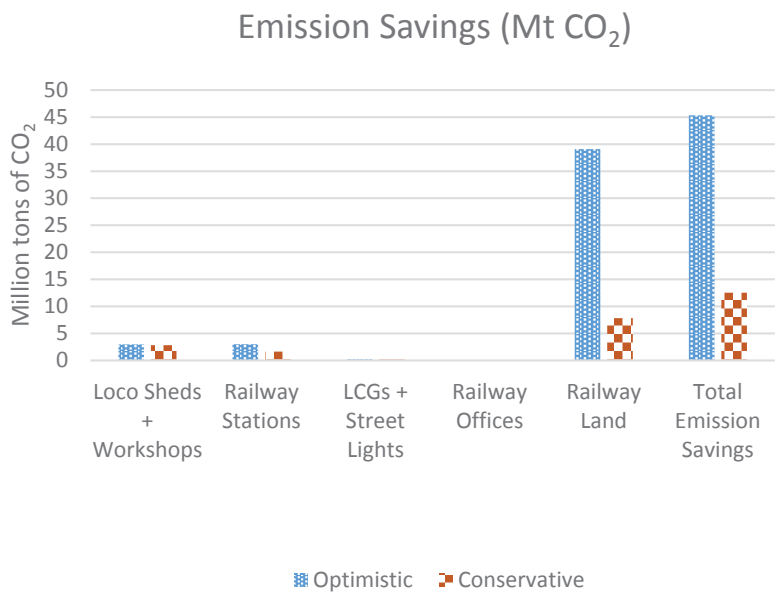
If the railways were to own all projects except the large solar PV projects on vacant railway land, under both scenarios, they would incur a cost of INR 150 – 200 crore each year towards servicing debt payments for a period of 10 years.

The cumulative emission savings accruing over a 25 year period have been estimated for the various railway operations included in the assessment of solar PV potential in this analysis. It is estimated that a cumulative emission savings of about 45 Mt CO_2 and about 12.5 Mt CO_2 could be achieved in the 'Optimistic' and 'Conservative' scenarios, respectively (Figure 1).

The use of railway land for large solar PV along with solar PV installations at diesel loco-sheds and railway workshops have the largest potential in terms of emission savings over the lifecycle of the plant.

Table 7: Estimated solar PV potential across various identified railway operations (at constant tariff)					
	Railway Unit	Optimistic		Conservative	
		Capacity (MW)	Costs (INR crore)	Capacity (MW)	Costs (INR crore)
1	Diesel Loco Sheds	16.33	122.45	11.66	87.46
2	Railway Workshops	67.82	508.62	48.44	363.30
3	Railway Stations	84.14	631.06	60.10	450.76
3.1	Already proposed (REMCL)	5.25	52.50	5.25	52.50
3.2	Additional potential	79.70	797.00	41.58	415.80
4	Level Crossing Gates (LCGs)	6.10	97.60	6.10	97.60
5	Street Lights	0.22	0.44	0.22	0.44
6	Railway Offices (Proposed by Ministry of Railways)	0.76	23.73	0.76	23.73
7	Total (1-7)	260.32	2237.40	174.11	1491.59
8	Large PV potential				
8.1	5% land utilization	1109.35	7210.80		
8.2	1% land utilization			221.87	1441.16
9	TOTAL (7-8)	1369.67	9444.20	395.98	2933.75
Source: CEEW analysis, 2015					

Figure 1: Emission savings (million tones of CO_2) across railway operations with solar PV installations



Source: CEEW analysis, 2015

5. Achieving Targets: The Way Forward

In conclusion, taking into account availability of budgetary resources and various other constraints as highlighted earlier in the report, it is recommended that the Indian Railways pursue the 'Conservative' scenario in a planned manner. The assessment indicates that this could lead to a return of 7% - 9% over the life time of the projects being undertaken[20]. The Indian Railways has set 2018-19 as the target for achieving 1 GW installed capacity of solar PV[21]. It is proposed that, in the first year, the railways focus on development of solar PV projects in the three railway zones, namely, Northern Railway, Central Railway and South Central Railway. These three together will help the Indian Railways achieve 25% of its 1 GW target.

Unleashing finance through a participative approach

While no specific funds have been earmarked towards energy conservation measures in the Railway Budget 2015-16, so far energy conservation efforts have been covered through works sanctioned in the Pink Book Budget[22], while day-to-day energy efficiency efforts were covered through revenue grants. The Ministry of Railways, while recognising that energy conservation is an important thrust area, has integrated various such measures within its range of operating activities. Most of these measures form part of the Ordinary Working Expenses (O.W.E.) where adequate funds are provided[23].

While the Zonal Railways had, on their own, fixed their Internal Action Plan targets for energy conservation, these were achieved partially or wholly subject to the availability of funds. Such projects were being planned and implemented under revenue grants or under the lump sum grants allocated to the Zonal Railways each year. Availability of adequate financing has been a major hindrance in meeting these targets.

Keeping this in consideration, the Railways has proposed the setting up of solar plants of 1000 MWp in the next 5 years with subsidy support of MNRE through the PPP mechanism. Under the PPP mechanism, the 'Plug and Play' PPP model could be explored, wherein 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. 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 such a case, 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 power generation to the grid.

As power tariffs increase in states such as Haryana and Maharashtra, the incremental benefits to the railways from installation of solar PV projects would be higher if they were to engage the services of a developer to install the project, while the ownership is retained with the railways. With the Railways already having sufficient expertise

20 The average Railway tariff across India is INR 4.95/kWh. The potential IRR that could be achieved is in the range of 17 – 20% (with a Discount Rate of 11%).
21 Union Rail Budget 2015-16, Ministry of Railways, Government of India
22 The Pink Book provides a detailed programme of the 'Work, Machinery and Rolling Stock Programme' of the Railways for each financial year.
23 Public Accounts Committee, Sixteenth Report, November 2014

with its various departments (Electrical, Mechanical and others) to operate and maintain these plants, it could save on Operations and Maintenance (O&M) costs, apart from added benefits of ensuring security of railway premises, as it would restrict the free movement of any non-railway staff.

With the 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.

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.

Use of railway land: Asset or liability?

The use of railway land could, in theory, lead to significant capacity addition of solar PV and has also been proposed in the Railway Budget 2015-16 as a possible option. Large scale PV deployment on railway land has the advantage of zero-risk in terms of land acquisition and could see greater ease in raising debt given the sovereign guarantee of railway bonds. Land under the Railways is an asset and is used for various competing purposes which include expansion of railway networks, housing for staff, new workshops and sheds, as well as exchange for land acquired from private owners. Thus, the use of railway land for large solar PV projects could potentially have a significant opportunity cost attached to it.

This issue has been addressed to an extent by the Ministry of Railways in its proposal to lease land at INR 1 per annum to solar PV developers for large projects. With the land holdings distributed across various geographic locations, the assessment of whether a share of this land holding should be diverted to solar PV projects should be taken up on a case-by-case basis as future plans of railway network expansion and production need to be considered. This would help reduce the risk of land becoming a liability for railway operations as the competing uses of land, both in the present and the near-future, would be accounted for.

Streamlining institutional mechanisms

While, the Indian Railways should in a phased manner carry out a detailed audit of potential energy saving measures including renewable energy deployment, all future construction including stations and other railway buildings could be designed in a way such that renewable energy deployment is integrated. Including use of solar PV within the criteria for an *Adarsh* Station or Model Station under the Adarsh Station Scheme could be an incentive for planned deployment of solar PV at basic functional units within railway operations.

A monitoring system to document the performance of implemented projects and for quantification of benefits accrued to railways as a result of deployment of solar panels/hybrid systems would go a long way in facilitating detailed energy conservation plans.

In order to ensure that the guidelines and policies are effectively implemented, it is critical that the nodal staff incharge of the railway units or zones take the necessary proactive steps and processes to execute renewable energy projects. While the role of nodal departments within the Ministry of Railways, such as the Environment Directorate, is to provide the necessary policy and institutional support, adequate training programmes should be provided to those responsible for environment management at the zonal levels.

The 1 GW Solar Mission of the Railways is a step in the right direction. Along with various other initiatives in the areas of water management, waste management and energy efficiency, these would take the Indian Railways close to realising the broader goals of environment management and become one of the largest rail networks with a focused sustainability strategy.

Annexures

ANNEXURE – A

The following table provides a summary of all the 21 projects across Diesel Loco-sheds that are located in states with railway electricity tariff above INR 5.518.

Table A: Feasible solar PV projects across Diesel Loco-sheds at constant electricity tariff

Railway Zone	Unit	Scenario 1		Scenario 2	
		Capacity (MW)	Costs (INR crore)	Capacity (MW)	Costs (INR crore)
CR	Kurla	0.24	1.81	0.17	1.29
CR	Kalyan	0.17	1.31	0.12	0.94
CR	Pune	0.86	6.44	0.61	4.60
WR	Bandra	0.34	2.59	0.25	1.85
ER	Andal	0.78	5.87	0.56	4.19
ER	Bardhaman	0.84	6.30	0.60	4.50
NEF	Siliguri	0.99	7.39	0.70	5.28
NE	Gonda	0.88	6.61	0.63	4.72
NE	Izzatnagar	0.30	2.27	0.22	1.62
SEC	Motibagh	0.39	2.90	0.28	2.07
EC	Vishakhapatnam	1.47	11.03	1.05	7.88
SC	Gooty	0.81	6.04	0.58	4.31
SC	Guntakal	0.63	4.73	0.45	3.38
SC	Maula Ali	1.06	7.97	0.76	5.69
SC	Vijaywada	0.30	2.28	0.22	1.63
SE	Kharagpur	1.02	7.61	0.73	5.44
N	Tughlakabad	0.76	5.70	0.54	4.07
N	Shakurbasti	1.22	9.14	0.87	6.53
N	Alambagh	2.07	15.55	1.48	11.11
N	Ludhiana	0.97	7.29	0.69	5.20
EC	Mugal Sarai	0.22	1.63	0.16	1.16
	TOTAL	16.33	122.45	11.67	87.46

Source: CEEW Analysis, 2015

ANNEXURE – B

The following table provides a summary of all the 17 projects across Railway Workshops that are located in states with railway electricity tariff above INR 5.518.

Table B: Feasible solar PV projects across Railway Workshops at constant electricity tariff

Railway Zone	Unit	Scenario 1		Scenario 2	
		Capacity (MW)	Costs (INR crore)	Capacity (MW)	Costs (INR crore)
CR	Kurduwadi	0.25	1.91	0.18	1.37
CR	Matunga	3.97	29.74	2.83	21.25
CR	Parel	2.30	17.26	1.64	12.33
ER	Kanchrapara	9.45	70.86	6.75	50.61
ER	Lilluah	0.03	0.22	0.02	0.16
NR	Alambagh	5.08	38.11	3.63	27.22
NR	Amritsar	3.90	29.24	2.78	20.88
NR	Charbagh	4.03	30.19	2.88	21.56
NCR	Jhansi	4.58	34.34	3.27	24.53
NER	Gorakhpur	3.57	26.77	2.55	19.12
NER	Izatnagar	2.04	15.32	1.46	10.94
NEFR	Tindharia	0.27	2.00	0.19	1.43
SCR	Lallaguda	1.20	9.03	0.86	6.45
SCR	Tirupati	2.52	18.90	1.80	13.50
SCR	Guntapalli	1.53	11.47	1.09	8.19
SER	Kharagpur	19.60	147.00	14.00	105.00
WR	Mahalaxmi	3.50	26.25	2.50	18.75
	TOTAL	67.82	508.62	48.43	363.30

Source: CEEW Analysis, 2015

ANNEXURE – C

The following table provides a summary of railway land lying vacant currently and the potential of large solar PV that can be achieved under the two scenarios.

Table C: Use of railway land for large solar PV

Railway Zone	Scenario 1 (Optimistic)			Scenario 2 (Conservative)		
	5% of land	Capacity (MW)	Cost (INR crore)	1% of land	Capacity (MW)	Cost (INR crore)
Central	306	61	398	61	12	80
Eastern	191	38	248	38	8	50
East Central	713	143	927	143	29	185
East Coast	167	33	218	33	7	44
Northern	361	72	469	72	14	94
North Central	91	18	119	18	4	24
North Eastern	732	146	951	146	29	190
Northeast Frontier	301	60	391	60	12	78
North Western	119	24	155	24	5	31
Southern	284	57	369	57	11	74
South Central	525	105	682	105	21	136
South Eastern	10	2	13	2	0	3
South Western	355	71	461	71	14	92
South East Central	419	84	545	84	17	109
Western	912	182	1186	182	36	237
West Central	60	12	78	12	2	16
		1109.35	7210.80		221.87	1442.16

Source: Lok Sabha, Starred Question No. 383 (as on 30.07.2009)
Rajya Sabha, Starred Question No. 1698 (as on 07.12.2012)
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