

# Riding Sunbeams in India

Indian Railways' net-zero commitment  
is key to India's decarbonisation



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Riding Sunbeams is a world-leading innovator on a mission to power the world's railways with direct supply from solar PV, while maximising social benefits for line-side communities.

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## Acknowledgements

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# Executive Summary

## Indian Railways (IR) set a target in 2020 to become the world's first net-zero emissions railway by 2030.<sup>1</sup>

In 2018, the government approved plans for 100% electrification of railways by 2023. In July 2020, IR stepped up its target to net-zero emissions by 2030. Achieving this target could lead to an annual emissions reduction of at least **15 million tonnes of CO<sub>2</sub>**, which could help meet 5% of India's NDC target.<sup>2,3</sup>

This report examines IR's net-zero plan in detail and presents the results from a groundbreaking study analyzing the total share of IR's traction load (the power required to move the trains in a railway network) that could be met with direct supply from solar PV arrays located alongside railway lines. The analysis examined two load profiles and found that:

- Converting all current diesel traction to electric would initially cause a **32% increase in CO<sub>2</sub> emissions** due to India's reliance on coal to produce electricity. The emissions intensity of the Indian electricity grid is 825 tCO<sub>2</sub>e / GWh, over three times higher than the emissions intensity from the UK, for example. To mitigate this, IR would need either to procure its own supply of clean electricity from solar and wind generators connected directly into the rail network, or develop new grid-connected renewable projects to match the traction energy supplied via the electricity grid.
- **Direct connection of solar PV is an attractive method for Indian Railways to meet the net-zero target.** IR plans to install 20 GW of solar for both traction and non-traction loads as part of its effort to reach net-zero by 2030. About 51,000 hectares of unproductive railway land has been identified as suitable for solar developments. IR and the Ministry of Railways have formed a joint venture (JV) Railway Energy Management Company to support the development of solar PV and wind energy projects to supply the railway's energy needs.
- To assess the share of Indian Railways' traction load that could be met with direct solar PV supply, the energy demand of 16 out of IR's 18 railway zones were studied. Two load profiles were considered – the flat profile assumed the traction demand was constant every day of the year between the hours of 04:00 and 23:00, while the commuter profile assumed a morning and evening peak, as observed on traction networks in the UK.

- The study found that for a fully-electrified IR traction network, **the amount of solar PV generation that could be connected is estimated to be 5,272 MW for the flat profile and 3,338 MW for the commuter profile.** This would supply **28%** of the traction demand for the flat profile and **18%** of the traction demand for the commuter profile. The energy output from connecting the solar PV generation is expected to be 8,296 GWh for the flat profile and 5,251 GWh for the commuter profile. **In the case of the flat profile, direct connection of 5,272 MW of solar PV generation is estimated to reduce emissions by 6.8 million tCO<sub>2</sub>, per year, contributing substantially to the overall reductions from electrification.**

#### **Achieving net-zero by 2030 will save INR 17,000**

**crore (USD 2.3bn) in fuel costs and other savings per year.**<sup>4</sup>

To move away from diesel and thermal power-based electricity consumption, IR is scaling up its renewable energy (RE) plan, including tendering 3GW of solar projects this year and commissioning 103MW of wind power, as well as **creating green jobs** and **lowering air pollution.**

Official estimates show that, if India deploys 100 GW of solar power, **IR could help meet 5% of India's NDC target.**<sup>5</sup> The approved electrification will generate direct employment of ~20.4 crore (204 million) man-days during the period of construction.<sup>6</sup>

## Part 1

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# Indian Railways is planning for a low-carbon future

Indian Railways (IR) is among the world's largest rail networks and employs more than a million people. IR transports nearly 2.3 crore (23 million) people daily and carries 1,160 million tonnes of goods annually. This requires enormous amounts of energy.<sup>7</sup> For example, IR is the largest electricity consumer and third largest diesel consumer in India – in 2018–19, IR used 17,682 TWh of electricity, 2,749 billion litres of diesel and one thousand tonnes of coal.<sup>8,9</sup> As a result, railways account for 4% of India's total greenhouse gas (GHG) emissions (the entire transport sector accounts for 12%), despite rail-based transport being more sustainable than other modes of transportation.<sup>10,11</sup>

In 2018, the government approved plans for 100% electrification of railways by 2023.<sup>12,13</sup> In July 2020, IR stepped up its target to achieve net-zero emissions by 2030.<sup>14</sup> IR has committed to an ambitious programme of decarbonisation, with the following key components:

- **Full electrification by 2023.**<sup>15</sup> As of March 2021, nearly 71% of India's conventional (broad gauge) railway tracks are electrified (more than 45,000 km), making it the third-largest electrified railway system in the world after Russia and China.<sup>16</sup> IR has just broken the record for annual rail electrification with over 6,000 route km wired in 12 months, and is set to be fully electrified by December 2023.<sup>17,18</sup>
- **Increasing investment in new infrastructure.** IR is replacing diesel locomotives with electric and building dedicated freight corridors (DFCs) and high-speed rail (HSR).<sup>19,20</sup> These projects could increase the share of rail in transportation,

moving it away from roads and benefiting the environment, while also making the traffic of freight and passengers faster.<sup>21</sup> This is because DFCs carry more goods over shorter time frames than roads, and HSR can respond quickly to growing passenger demand.<sup>22</sup>

- **Integration of renewable energy (RE).** IR's latest update showed that 3 GW of land-based solar was tendered in 2020, 103 MW of wind projects has been installed, with a further 187 MW of wind energy plants in the next two years.<sup>23,24</sup> 100 MW of rooftop solar is also being rolled out at 900 stations, with 400 MW under different stages of execution.<sup>25</sup> The target is for 7,000 railway stations plus trains to be fitted.<sup>26</sup> IR is also making 51,000 hectares of land (an area nearly the size of Mumbai) available for potentially 20 GW of land-based solar – one project of 1.7 MW at Bina (Madhya Pradesh) **is the first solar plant to directly power railway overhead lines in the world.**<sup>27,28</sup>
- **Further off-grid RE initiatives** are being implemented, including 100% LED lighting across its installations, utilising battery-powered shunting locomotives and deploying electric-vehicle charging infrastructure.<sup>29,30</sup>
- **Planting trees.** IR has committed to plant trees along its rail lines and station yards without transferring land ownership to the State Forest Department. IR has planted 1.1 crore (11 million) saplings in 2018-19.<sup>31</sup>

**Together, IR says these initiatives will make IR the first transport organisation to be energy self-sufficient.**<sup>32</sup> This means its future energy consumption (projected to increase from 21 billion KWh to 33 billion KWh by 2030) will be entirely supplied by renewable energy.

## What does Indian Railways' "net-zero by 2030" commitment mean?

In July 2020, IR stepped up its target from 100% electrification to achieve net-zero emissions by 2030.<sup>33,34</sup> This is a hugely significant development for India's decarbonisation.

**India's diesel consumption will go down and improve energy security.** India relies heavily on imported oil.<sup>35</sup> IR is the third largest diesel consumer in India (2.7 billion litres in 2018-19, equivalent to 7.45 million tonnes of CO<sub>2</sub>).<sup>36,37,38</sup> Thus, IR plans to be fully electric by 2023 (currently at 71%), which will reduce the use of imported fossil fuels, thereby improving energy security.<sup>39,40</sup> The total shift to electric will also **reduce high speed diesel oil consumption by 2.83 billion litres per year.**<sup>41</sup> Currently, a total of 505 pairs of trains have been converted to Head on Generation (HOG) technology, which taps power from overhead power lines, potentially saving ~70 million litres of diesel, or INR 450 crore (USD 60 million) per year, and improving energy efficiency by 15%.<sup>42</sup>

**The power sector's decarbonisation will speed up.** Becoming 100% electric means shifting emissions to the power sector, which is 76% powered by coal as of December 2020.<sup>43</sup> The net-zero target means IR will be pushing the power sector to provide renewable energy instead of coal-based electricity. Since IR is already the biggest single consumer of electricity nationally

(about 20 TWh in 2018–19, roughly 1.45% of the country’s total power generation), IR’s switch to fully electric will mean it can leverage its procurement power to accelerate power sector decarbonisation in the coming decade.<sup>44</sup>

**Switching to electric trains and renewable power will help improve air quality.** Electric trains do not directly generate air-pollutant emissions.<sup>45</sup> IEA’s estimates for an optimistic scenario show high railway use can avoid 6 kilo-tonnes of fine particulate (PM<sub>2.5</sub>) emissions in 2050.<sup>46</sup> In enclosed railway stations, exhaust emissions from diesel trains reduce air quality and endanger rail workers and passengers that spend considerable time commuting regularly.<sup>47</sup> The new HOG system in the South Central Zone, for example, cuts out diesel use altogether, reducing both air and noise pollution.<sup>48</sup>

**IR will become one of the biggest renewable investors in India.** IR has consistently raised the ambition of its targets over the years. In **2009**, it committed to source at least 10% of its energy from renewables, such as solar and biomass.<sup>49</sup> In **2015–16**, it planned to install 1000 MW of solar and 150 MW of wind energy by 2020.<sup>50</sup> **In 2020, it committed to** increase its land-based solar systems by installing 20 GW

of solar on vacant land by 2030, with most of the work tendered off to private partners, meaning IR does not have to incur capital expenditure.<sup>51,52</sup>

### **Job creation would occur along railway**

**lines.** The approved electrification will generate direct employment of about 20.4 crore man days during the period of construction.<sup>53</sup> **More rail means more jobs.** IR is the largest employer in India (1.4 million jobs).<sup>54,55</sup> Thus, increasing rail tracks and RE deployment can generate a large number of jobs, particularly in the solar sector.<sup>56</sup> Solar already creates the highest number of jobs in the power sector in India.<sup>57</sup> According to IRENA, grid-connected solar can generate 115,000 jobs, a number that could double if off-grid deployments – such as direct supply to the rail traction system – are included.<sup>58</sup>

### **India would be one step closer to achieving its national climate goals.**

IR’s net-zero commitment is key to reducing overall emissions from transportation and from India as a nation. The commitment means IR will need to rapidly reduce CO<sub>2</sub> emissions from its current level of 15 million tonnes per year, which could help meet 5% of India’s NDC target in the process.<sup>59,60</sup> Electrification of tracks, improvements in energy efficiency and deployment of renewable energy will diminish demand for coal and diesel, catalyzing power sector decarbonisation, centralization and efficiency.<sup>61</sup> Together, these will help India reach its renewable energy target and its National Solar Mission (an initiative by the Indian Government to promote solar power).<sup>62,63</sup> Shifting freight from roads to railways (the target is to go from 36% rail freight in 2015 to 45% by 2030) will further enable the country to reduce emissions from road transportation as railways are much more efficient.<sup>64</sup> CO<sub>2</sub> emissions could be reduced by about 450 million tonnes over 30 years.<sup>65</sup>



## Net-zero by 2030 makes business sense for Indian Railways

### **Electrification will reduce fuel and maintenance costs for IR.**

Complete electrification can save INR13,000 crore (USD 1.8bn) per year in fuel bills.<sup>66</sup> Switching to HOC technology, for example, has already led to a total net saving of INR313.8 crore per year by reducing diesel consumption.<sup>67,68</sup> Electrification will also help IR reduce expenditure on locomotive maintenance. The maintenance costs for electric locomotives are half those for diesel locomotives – INR16.45 per thousand gross tonne km (GTKM) compared to INR32.84 per thousand GTKM.<sup>69</sup>

### **Increasing renewable energy production can also reduce costs.**

Instead of buying electricity from the grid, IR would produce it. For example, solar PV installed along electrified tracks in ten states could generate solar power to replace 4 GW of coal-fired electricity currently consumed by the railways, saving 20% of IR's annual energy bill in the first year, and 40% thereafter.<sup>70</sup> Leveraging regulatory support for open access procurement could also help drive down power procurement costs, with potential savings of INR41,000 crore over 10 years.<sup>71,72</sup>

### **Changes will attract investment and new partnerships.**

To achieve the 20 GW renewable energy target, IR and the Railway Minister are holding talks with strategic partners in the solar power sector to set up solar projects along IR's railway tracks.<sup>73</sup> Companies participating in the talks held in August 2020 included Adani, ACME, NTPC, Renew Power, Hero Future Energies, Greenko Group, Azure Power and Tata Power.<sup>74</sup> Given its scale, the company's purchases of solar and wind power would provide a unique opportunity for solar developers and other providers.<sup>75,76</sup> Estimates show that moving to renewables could attract USD 4 billion in private investment.<sup>77</sup>

## Part 2

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# Riding sunbeams in India

## Meeting Indian Railways' net-zero commitment with direct solar PV

To assess how much solar PV IR would need to meet its traction demand, Riding Sunbeams commissioned Ricardo Energy & Environment, a global energy and climate change consultancy, to conduct a modelling study.

The power required to move the trains in a railway network is known as traction load. To assess the share of the traction load that could be met by a direct solar PV supply, the energy demand of 16 out of IR's 18 railway zones were considered in the study. The two zones not considered were the Metro zone and the new South Coast railway management zone, as the annual consumption data for these two regions was not available.

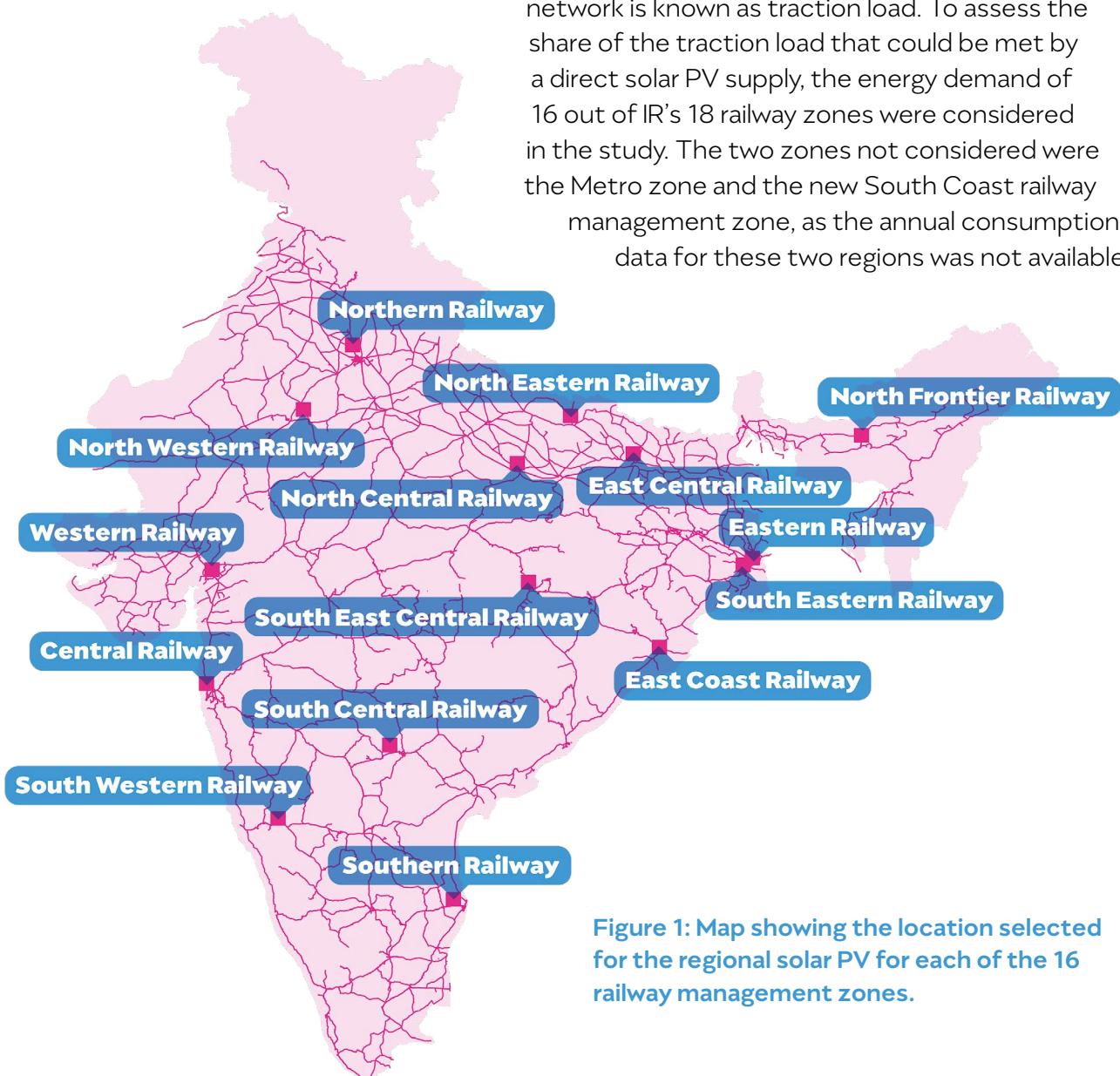
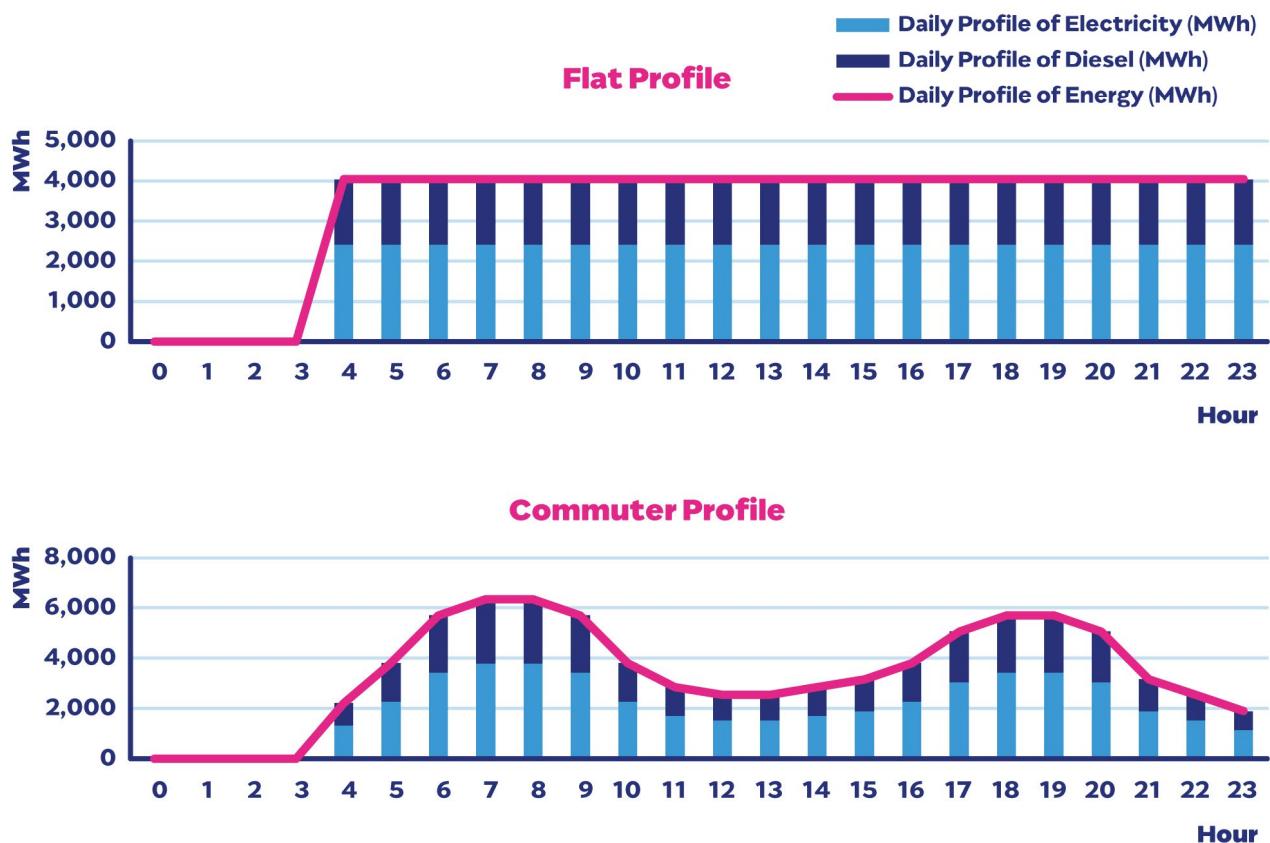


Figure 1: Map showing the location selected for the regional solar PV for each of the 16 railway management zones.



India has an excellent solar PV resource of between 1400 kWh/m<sup>2</sup> and 1800 kWh/m<sup>2</sup> per year. Higher generation and utilisation rates should greatly improve the economics of direct solar traction supply.

Two electricity demand profiles (load profiles) were considered. The flat profile assumed the traction demand was constant every day of the year between the hours of 04:00 and 23:00. The commuter profile assumed a morning and evening peak, as observed on traction networks in the UK.

IR primarily uses electricity and diesel to provide its traction energy. For the purpose of the study, diesel consumption was converted to an equivalent kWh electricity usage in order to model full electrification of the IR network.

The analysis found:

- Converting all diesel traction to grid electricity will initially cause a **32% increase in IR's CO<sub>2</sub> emissions** due to India's current reliance on coal to produce electricity, over three times higher than the grid carbon intensity in the UK grid, for example, because of the high percentage of coal in the generation mix. To mitigate this, IR will need either to procure its own supply of clean electricity from solar and wind generators connected directly into the rail network, or develop grid-connected renewable projects to decarbonise the traction

**Figure 2: Modelled daily profiles for the Indian Railway network. The top shows a flat profile and the bottom shows a typical profile where commuting is driving the demand for train services.**

Source: Indian Railways Opportunity for Connecting Solar PV Generation by Ricardo Energy & Environment.

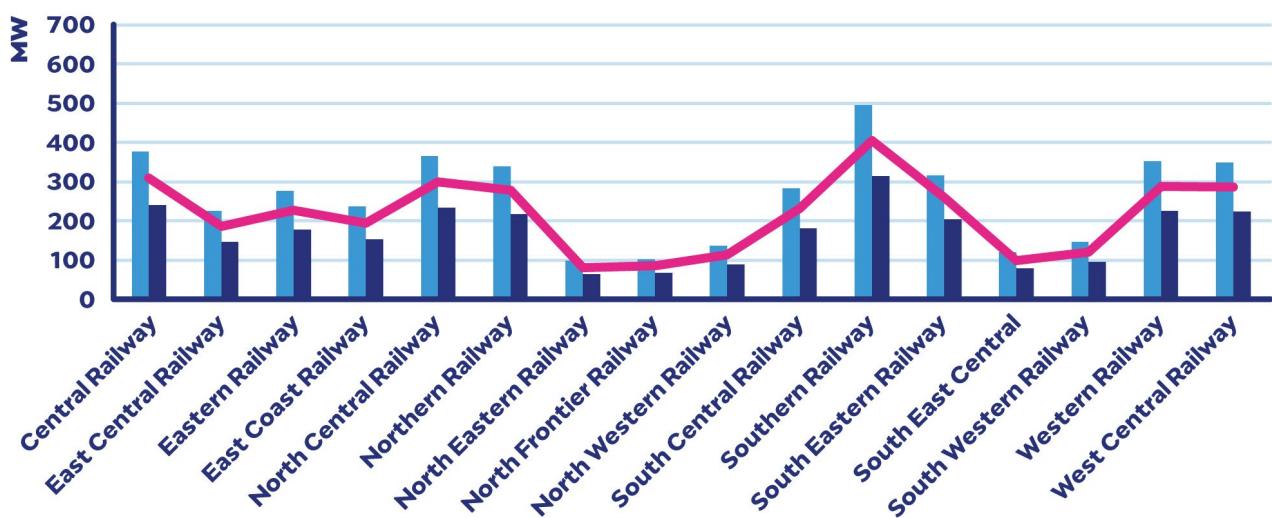
energy supplied via the electricity grid. The emissions intensity of the Indian electricity grid is projected to fall in the future, as coal plants are decommissioned and more renewable capacity comes onstream. As India's largest electricity consumer, IR is ideally placed to accelerate this transition by using its procurement power to bring forward new solar and wind generation.

- For a fully-electrified IR network, up to **28%** of the traction demand could be supplied with the direct connection of solar PV generation, based on current levels of energy demand. **The amount of solar PV generation that can be directly connected is estimated at 5,272 MW for the flat profile and 3,338 MW for the commuter profile.** This would supply **28%** of the traction demand for the flat profile and **18%** of the traction demand for the commuter profile. The energy output from directly connecting solar PV generation is expected to be 8,296 GWh for the flat profile and 5,251 GWh for the commuter profile. **In the case of the flat profile, direct connection of 5,272 MW of solar PV generation is estimated to reduce emissions by 6.8 million tCO<sub>2</sub> per year.**

**Figure 3: Estimated connection of solar PV generation for each of the 16 railway management zones.**

Source: Indian Railways Opportunity for Connecting Solar PV Generation by Ricardo Energy & Environment.

█ Flat Profile  
█ Commuter Profile  
█ Median



- The estimated theoretical total generation for each of the 16 railway zones is shown in Figure 3. The South Central Railway is able to connect the most solar PV generation at 625 MW, due to having the highest traction energy demand. The North Eastern Railway has the smallest traction energy demand and, therefore, is only able to connect 117 MW of solar PV generation.

- These headline figures assume 99.9% of the connected solar PV yield is consumed by trains on the network, as high utilisation rates are needed to ensure the unit price of energy for IR is lower than that for grid-supplied power, and the capital investment in solar is able to generate an adequate return.
- To help understand how connecting solar PV generation impacts both the utilisation of solar PV and the percentage of traction demand supplied, another simulation was performed. In Riding Sunbeams' model, solar generating capacity is sized to match the load as closely as possible, so that almost all of the energy generated by the solar PV is used to move trains on the network. Connecting more solar PV generation is possible, but this would reduce the percentage of solar PV generation that

can be used to meet traction demand. It means some surplus would be wasted ('curtailed') unless it is also possible to export to the grid from the rail

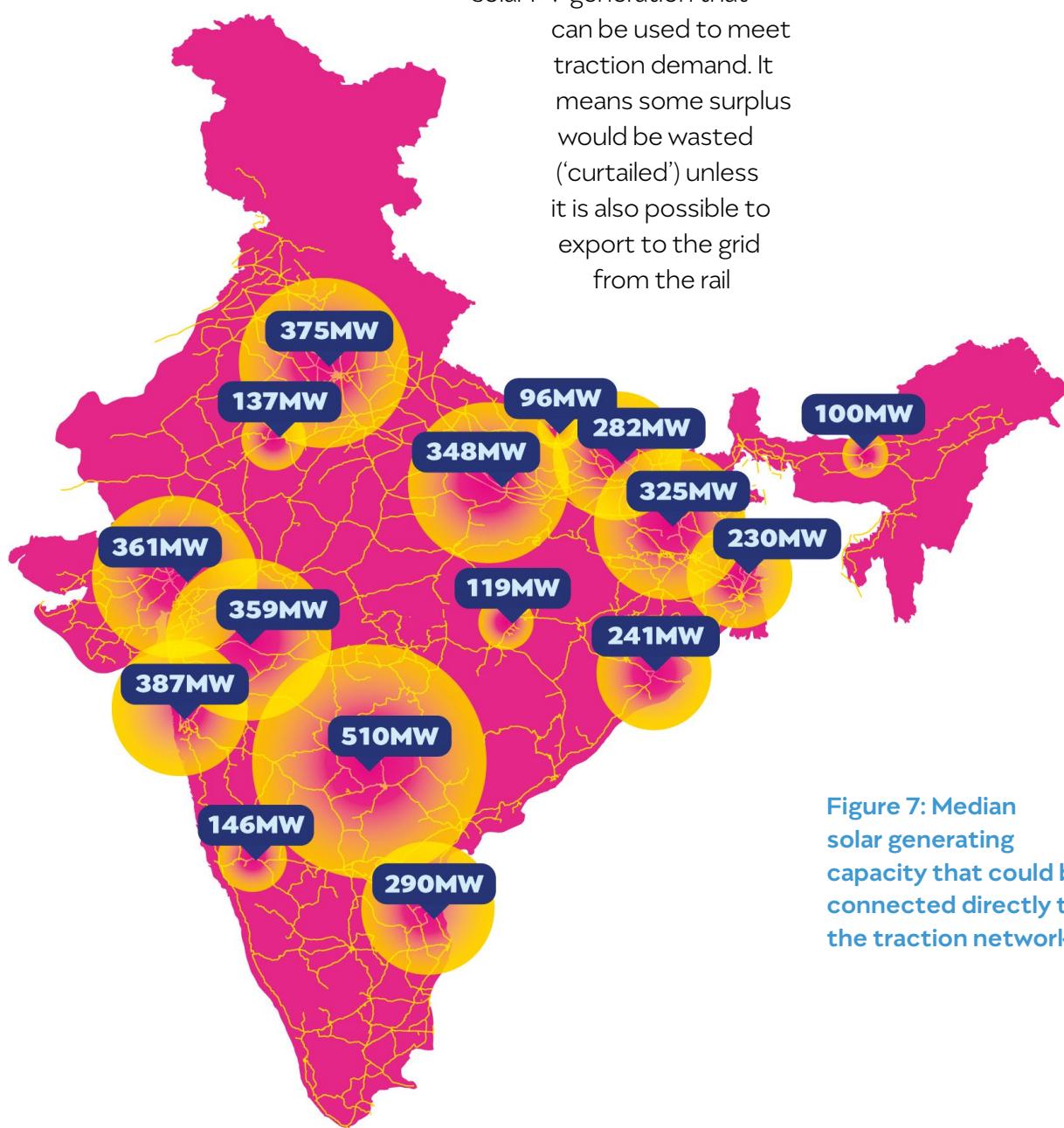


Figure 7: Median solar generating capacity that could be connected directly to the traction network.

traction system, but this would also allow a greater share of the total demand to be met. Riding Sunbeams' UK financial models estimate that less than 80% self-consumption by the railway is unlikely to be commercially viable for solar developers (although the higher PV capacity factors available in India mean this is a conservative estimate). Curtailment of up to 20% is likely to still be commercially viable in India, which could increase the share of the rail traction load met by directly connected solar PV to **42%** without the use of storage technologies.

- **The study considered the effect of connecting 20 GW of solar PV generation directly to the rail network**, meeting IR's solar deployment target of 20 GW fully. This report does not consider the non-traction demand. If 20,000 MW of solar PV generation were connected to directly supply traction demand, approximately **49%** of the traction demand could be supplied at a solar PV utilisation of 47% for the flat profile. For the commuter profile, the traction demand supplied reduces to **45%** with a solar PV utilisation of 43%. The excess generation would either be exported back to the Indian electricity network, or it would need to be curtailed, or used to charge energy storage devices.
- **Connecting solar PV generation with battery storage will increase solar PV utilisation and the percentage of traction demand that can be supplied.** Any surplus electricity generated by the solar PV installations could be stored in lineside energy storage facilities, increasing the share of the traction load which could be met via this method by providing more traction energy in the evenings when solar radiation has tailed off – while some could potentially be exported back to the grid via rail grid supply points (CSPs).
- **Overall, direct connection of solar PV is an attractive method to allow IR to meet its net-zero target.** IR plans to install 20 GW of solar for both traction and non-traction loads as part of their effort to reach net-zero by 2030. About 51,000 hectares of unproductive railway land has been identified as suitable for solar developments. IR and the Ministry of Railways have formed a joint venture (JV) Railway Energy Management Company to support the development of solar PV and wind energy projects to supply the railway's energy needs. Up to a quarter of this total solar PV generating capacity could be directly connected to the rail traction system on commercially attractive terms, rather than connecting to the grid. If lineside storage facilities can be integrated, an even higher proportion of IR's planned solar generating capacity could be viably connected to the traction network rather than the grid.

## Part 3

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### Going beyond net-zero

#### Shifting freight from road to rail is key to India's decarbonisation

Despite the rise in carbon emissions due to the rapid growth in railways that currently rely heavily on fossil fuels for energy, rail is still more sustainable than other modes of transport in terms of both energy use and carbon emissions.<sup>78,79</sup> As such, **IR's low-carbon growth strategy can help India achieve its 2030 emissions reduction goals** (33–35% decarbonisation of its economy by 2030 from 2005 levels).<sup>80</sup> Official estimates show that if IR deploys 100 GW of solar power, it would help meet 5% of India's NDC target.<sup>81</sup> Similarly, the reduced carbon footprint expressed as environmental cost per tonne km is 1.5 paisa for electric traction and 5.1 paisa for diesel traction.<sup>82</sup>

#### A High Rail Future – focus on India

In 2019, the International Energy Agency (IEA) published the Future of Rail report examining the role of rail in global transport, with a special chapter on India.<sup>83</sup> The energy and emissions intensity of rail in India is low, meaning that rail services always save energy and emissions compared to other transport modes. The modelling study confirms that decarbonisation can substantially lower emissions and improve air quality. **In the High Rail Scenario, 315 Mt CO<sub>2</sub> eq emissions and 6 kilotonnes of PM2.5 emissions can be avoided per year by 2050**, with rail replacing more carbon intensive transport.<sup>84,85,86</sup> Since this estimate was released before the net-zero by 2030 target was announced, IR is likely to deliver even more GHG reductions when it becomes a net-zero emitter.

To achieve this, IEA analysis shows that it would require **strategic commitment by IR and the government to further enhance the role of rail**, including investing to address infrastructure bottlenecks for conventional rail, meeting power demand with renewables-based generation, and investing in urban and intercity high-speed rail (e.g. completion of Mumbai-Ahmedabad corridor, or MAHSR) in order to make high-speed rail competitive with aviation.

**Dedicated freight corridors (DFCs) and high-speed rail (HSR) can improve connectivity across the country and reduce travel time.** The MAHSR, for example, will connect many areas of the country and reduce travel time from ~nine hours (by bus) or six hours (by conventional rail) to two hours when it becomes operational in 2023.<sup>87</sup> Since it provides a rapid connection between cities not currently served by air travel, MAHSR can also displace air travel, as it is faster and operates more reliably in all weather conditions.<sup>88</sup> Furthermore, DFCs will carry longer freight trains with higher loads and higher speeds, reducing freight traffic on existing lines, making way for more passenger train traffic and improving passenger train reliability while allowing passenger trains to achieve higher speeds.<sup>89</sup> Currently, rail is the preferred mode of transport (the world's second largest passenger traffic) carrying ~8.4 billion passengers in 2018–19.<sup>90,91</sup>

## IR's business model is poised to shift as coal transport prospects look uncertain

**The future of coal in India is uncertain.** Coal demand is declining in the country's power sector – by 2.3 million tonnes between April and October 2019 compared to the same period in 2018.<sup>92</sup> Growing use of renewable energy and the rise of high-voltage DC power lines – a type of electricity transmission – are also displacing coal as they are cheaper and more efficient.<sup>93</sup> This in turn is increasing the risk of stranded assets.<sup>94</sup>

**The COVID-19 pandemic has accelerated these trends, particularly the decrease in coal supply and demand.** India's lockdown reduced power demand by 30%, forcing nearly 65 GW of coal-fired plants to close and increasing stocks of coal stored at power stations.<sup>95,96</sup> India's electricity demand is projected to remain low for the next five years, meaning low coal demand.<sup>97</sup> The pandemic also affected demand for both freight and passenger trains.<sup>98</sup> As a result, IR predicts a revenue loss of INR 350 billion (USD 4.68 billion) in the 2020–21 financial year.<sup>99,100</sup>

**The uncertainty of coal is a problem for IR as it depends on the coal industry for revenue.** Coal is the main commodity transported by IR, representing ~46% of IR's freight revenues, or 30% of total revenue in 2018–19.<sup>101</sup> In the future, coal transportation as a revenue stream may become unreliable, as coal plants become increasingly uncompetitive against renewables.<sup>102</sup>

### **IR's business model is based on passengers**

**underpaying and freight overpaying.** IR depends on the revenues earned from its freight trains, which demand ~31% higher fares than passenger fares to keep prices lower for consumers and to avoid losing revenues.<sup>103</sup> This has significant implications on retail electricity prices since ~63% of total Indian coal production was transported via railways, with railways accounting for over 85% of costs for transporting coal to thermal power plants in 2018–19.<sup>104,105</sup> In 2017, this ‘overcharge’ raised the cost of power by about 10 paisa per kWh on average – a number that can be three times higher when coal is transported to distant states.<sup>106</sup> As the distance travelled by coal via railways is declining, IR must keep raising coal fares at a faster pace than other commodities.<sup>107,108</sup>

Given coal’s uncertain future, sustaining this model will be increasingly difficult.<sup>109</sup>

### **IR needs to proactively shift its business model away from interdependency with the coal industry toward a net-zero, high-freight volume future.**

There are signs that IR is trying to diversify its freight customers and reduce dependence on coal transport in the most recent National Rail Plan, although the coal transport projections drew heavy criticism as they included a doubling in volume by 2031, before declining.<sup>110,111</sup>

# Conclusion & recommendations

The COVID-19 outbreak has already caused economic problems for IR, but the company can use the pandemic as an opportunity to rethink its business model and accelerate its decarbonisation. The net-zero commitment has positioned Indian Railways to deliver everything India would want from the COVID-19 economic recovery – job creation, decarbonisation of both the transport and power sectors, huge cost savings and reductions in energy imports, plus long-term emissions reductions and air quality improvements. It is a massive undertaking, and the government would do well to boost investment and policy support for IR to speed up the transition.

IR becoming a net-zero emitter is a significant development. As India considers a national 2050 net-zero target, there is a great opportunity to carve a bigger role for IR in the national decarbonisation action plan.<sup>112</sup> Shifting freight transport from road to railways would be a game changer for India's emissions and would bring about cleaner air and better health. IR's solar power ambition is crucial for delivering a just energy transition in India, as it can create renewable energy jobs all over the country.<sup>113</sup>

## Recommendations

Minister Ashwini Vaishnaw can consider these actions to ensure IR fulfil its net-zero commitment:

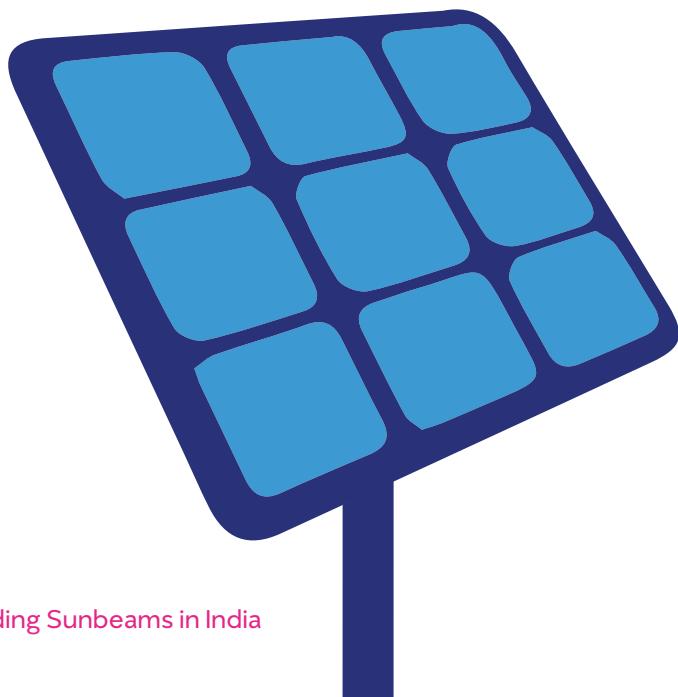
1. Invest in solar-to-rail pilot projects to test whether private wire traction energy supply, via direct feeds from solar generators through specially designed inverter technology into the 25kV AC overhead lines, is a technically viable and commercially attractive option for retrofitting throughout IR's national traction network.
2. Investigate the use of energy storage in combination with solar PV to increase the share of traction demand that can be met by renewable energy.
3. Proactively shift IR's business model away from the interdependency with the coal industry toward a net-zero, high rail future. For example, it can diversify its freight traffic by shipping goods previously moved by road and increasing transportation of other commodities that are being

transported during the pandemic.<sup>114,115,116</sup> Expanding the freight transport will allow IR to make full use of the planned 20CW of solar capacity.

4. With its timely delivery, IR can also expand its e-commerce targets, as online sales are rising due to lockdowns.<sup>117,118,119</sup> These moves will not only help IR financially, but could have a cascading impact on the economic recovery as companies benefit from lower costs and emissions compared to road transport.

As the Indian government considers a national 2050 net-zero target, the plan of national action will need to include:<sup>120</sup>

1. A significant shift of freight transport from road to railway.
2. Speedy decarbonisation of the electricity sector to make the shift to electric transport (passenger vehicles, public transport, and railways) meaningful for emissions reduction.



# Endnotes

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