# Riding Sunbeams

# Solar PV and Net Zero in Railways: Case of India

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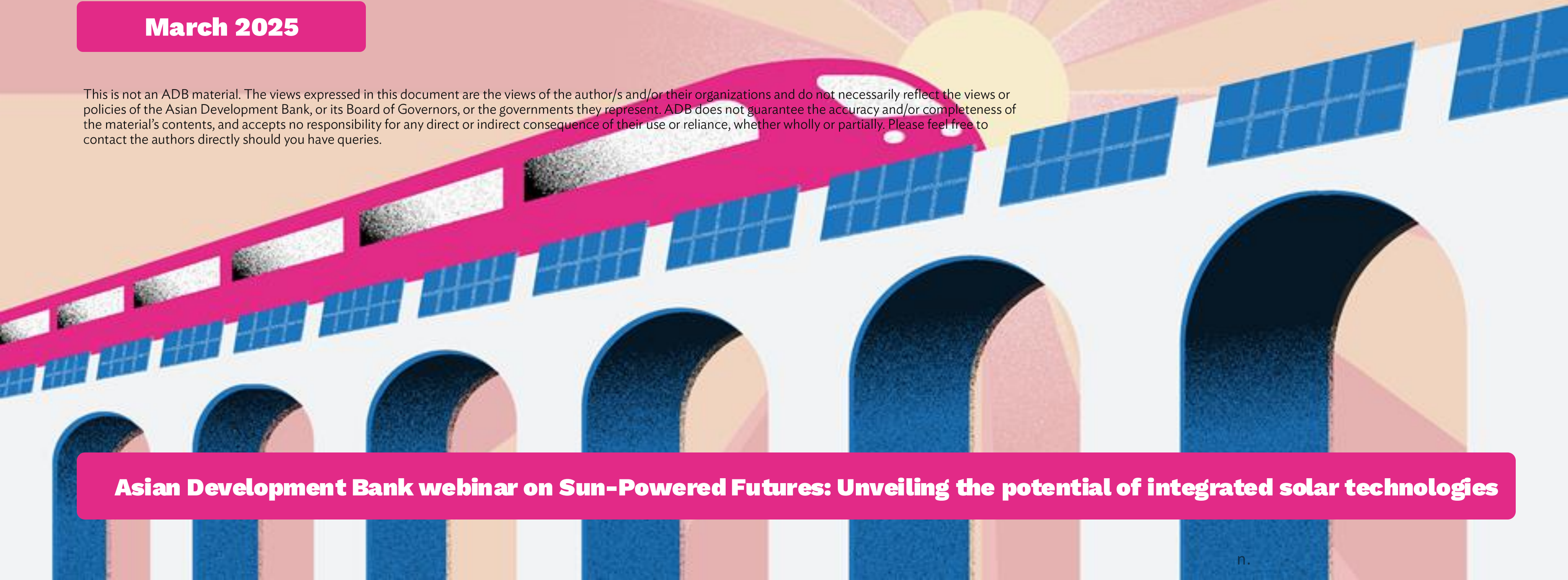



**Asian Development Bank webinar on Sun-Powered Futures: Unveiling the potential of integrated solar technologies**

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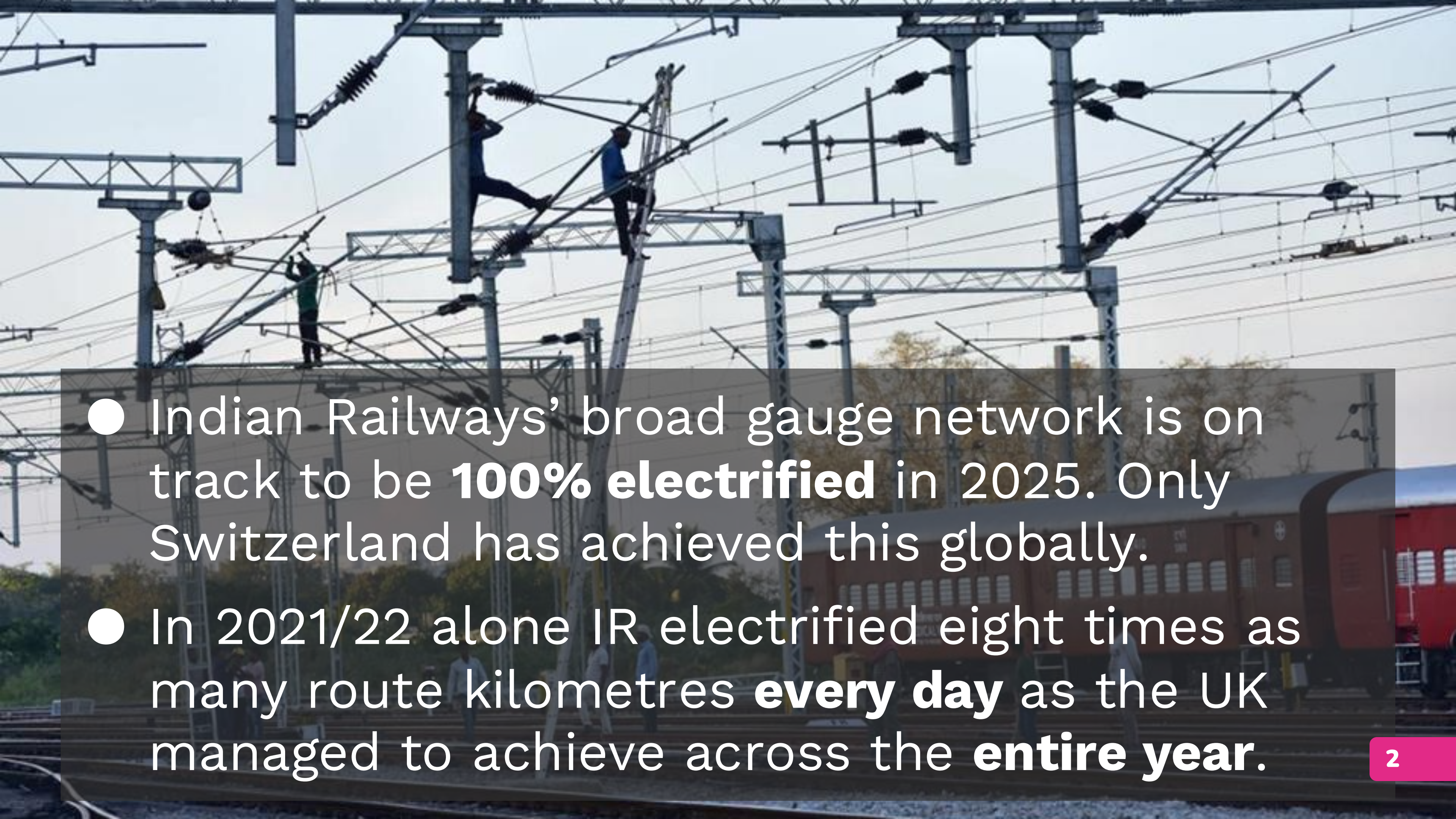
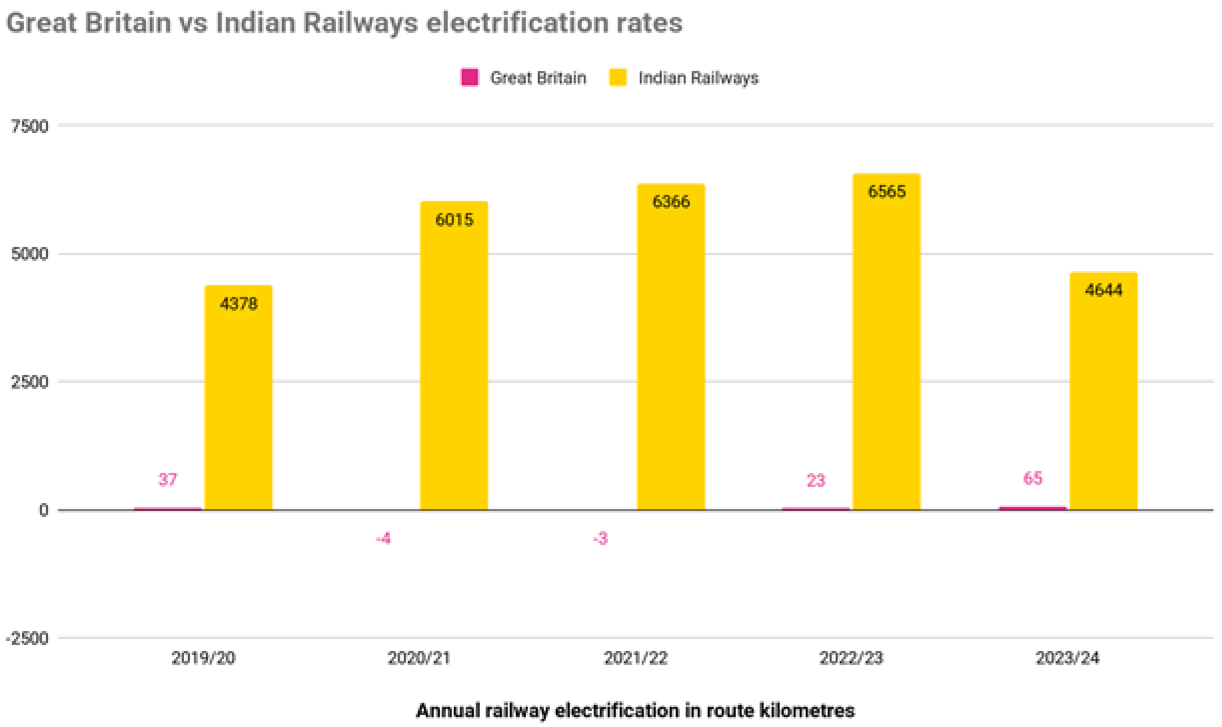


- Indian Railways’ broad gauge network is on track to be **100% electrified** in 2025. Only Switzerland has achieved this globally.
- In 2021/22 alone IR electrified eight times as many route kilometres **every day** as the UK managed to achieve across the entire year.




- For three years running Indian Railways electrified more new route kilometres each year than the UK's entire electrified network put together.



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- However, converting all current diesel traction to electric will initially cause a **32% increase in CO2 emissions** due to India’s ongoing reliance on coal to produce electricity.

In 2020 Indian Railways set a target to become the world's first **net zero railway by 2030.** To achieve this target the Rail Ministry estimates IR needs around **30GW of solar and wind** capacity.

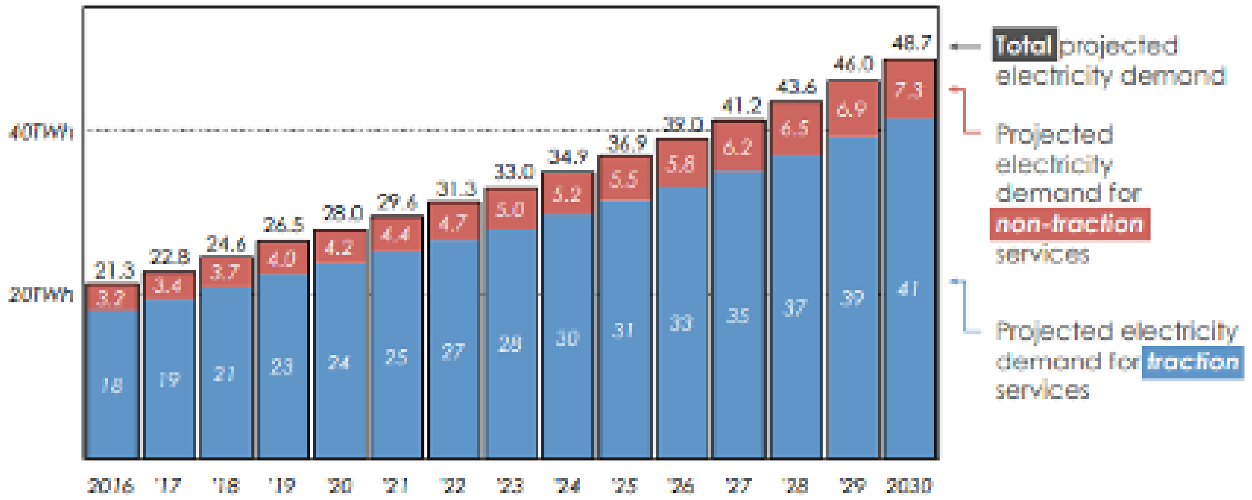


*Figure 3: Projected energy consumption of IR*

IR's projected electricity consumption is set to increase from 21.3 TWh in 2016 to 48.7 TWh by 2030, with traction power forming the bulk of this growth as network electrification and new high speed rail and dedicated freight corridor routes come online. Meeting IR's 2030 electricity demand will require a roughly 1% increase in India's electricity generation.


Electrification and self supply are not only driven by Net Zero: Prime Minister Modi's wider national 'Atmanirbhar Bharat' or 'self-reliant' India economic mission aims to make India energy independent by 2047. India currently imports almost 90% of its oil, and Indian Railways is the country's biggest energy user.



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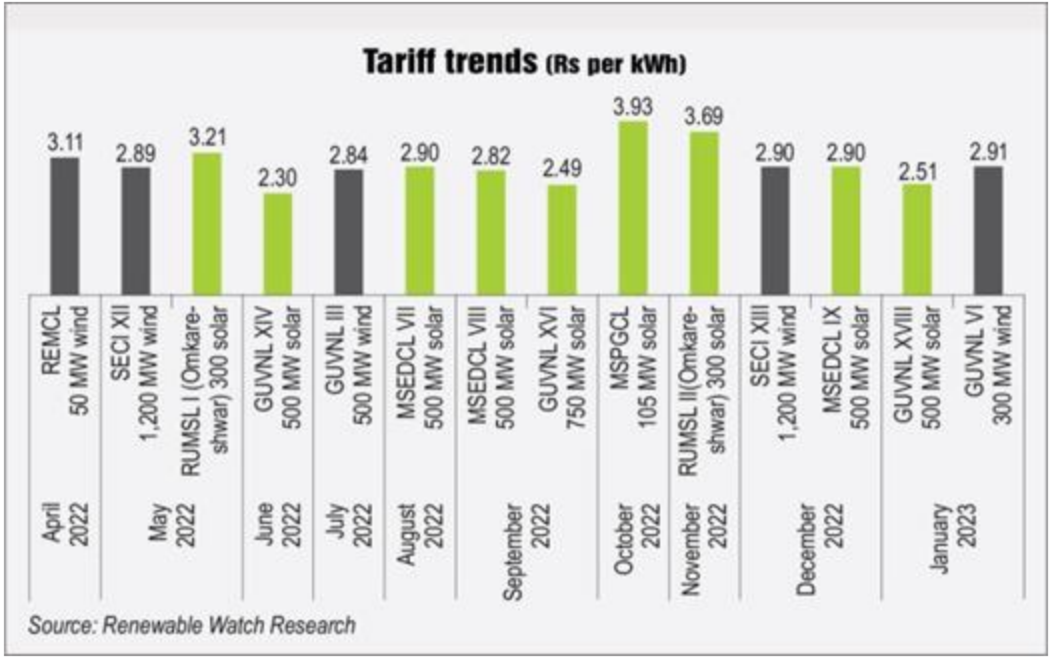


https://renewablewatch.in/2025/01/29/solar-growth-key-developments-and-policy-initiatives-across-segments/

Since 2015 solar and wind energy prices have fallen dramatically in India, making renewables a viable and cost-competitive alternative to traditional electricity sources. The lowest tariff observed in 2023/24 was Rs 2.15 per kWh.

Power procurement for IR is led by the Railway Energy Management Company (REMC), a joint vehicle of the Rail Ministry and RITES set up with the sole purpose of sourcing energy for Indian Railways, and now largely responsible for meeting IR's 2030 net zero target through sourcing of RE.

REMC BOUNDLESS ENERGY

REMC's renewable procurement strategy has three key workstreams:

- Station rooftop solarization
- Corporate sleeved power purchase agreements (PPAs)
- Direct wire traction supply



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As of January 2025, Indian Railways has installed 500 MW of rooftop solar capacity, covering over 1,000 stations - with plans for 6000 more, and 1GW of installed rooftop capacity by 2027.

Corporate sleeved PPAs enable energy to be procured directly from remote generators, and transmitted to IR via the grid. For instance, 195MW of the 1500MW Rewa Ultra Mega Solar project is contracted to supply Indian Railways. These PPAs are expected to be the principal method by which IR meets their renewable energy targets.

The structured approach to corporate PPAs is categorized into three primary segments:

- **Solar PPAs:** IR has prioritized solar power procurement due to its declining costs and widespread availability. Several long-term solar PPAs have been executed, allowing IR to procure energy at competitive tariffs through direct agreements with developers. This model has enabled IR to secure a reliable supply while benefiting from lower tariffs driven by reverse bidding auctions.
- **Wind PPAs:** wind energy procurement has been integrated into IR's renewable energy portfolio to complement solar power, particularly during non-daylight hours. Wind PPAs offer the advantage of higher capacity utilization factors (CUF) in specific geographies, balancing seasonal variations in solar generation. IR is strategically engaging with wind power developers in states with favorable wind energy policies and infrastructure.
- **Round-the-Clock (RTC) PPAs:** to ensure a continuous and stable power supply, IR is transitioning towards RTC PPAs, which combine solar, wind, and energy storage solutions. These agreements, each of which brings in excess of 100MW of capacity, are structured to maintain a minimum guaranteed power availability, optimizing the share of RE supply to meet IR's traction and non-traction energy needs. RTC contracts also mitigate the intermittency challenges of standalone renewable sources, improving grid stability and reliability. Per kWh prices returned for these huge tenders have been as low as Rs 3.5.



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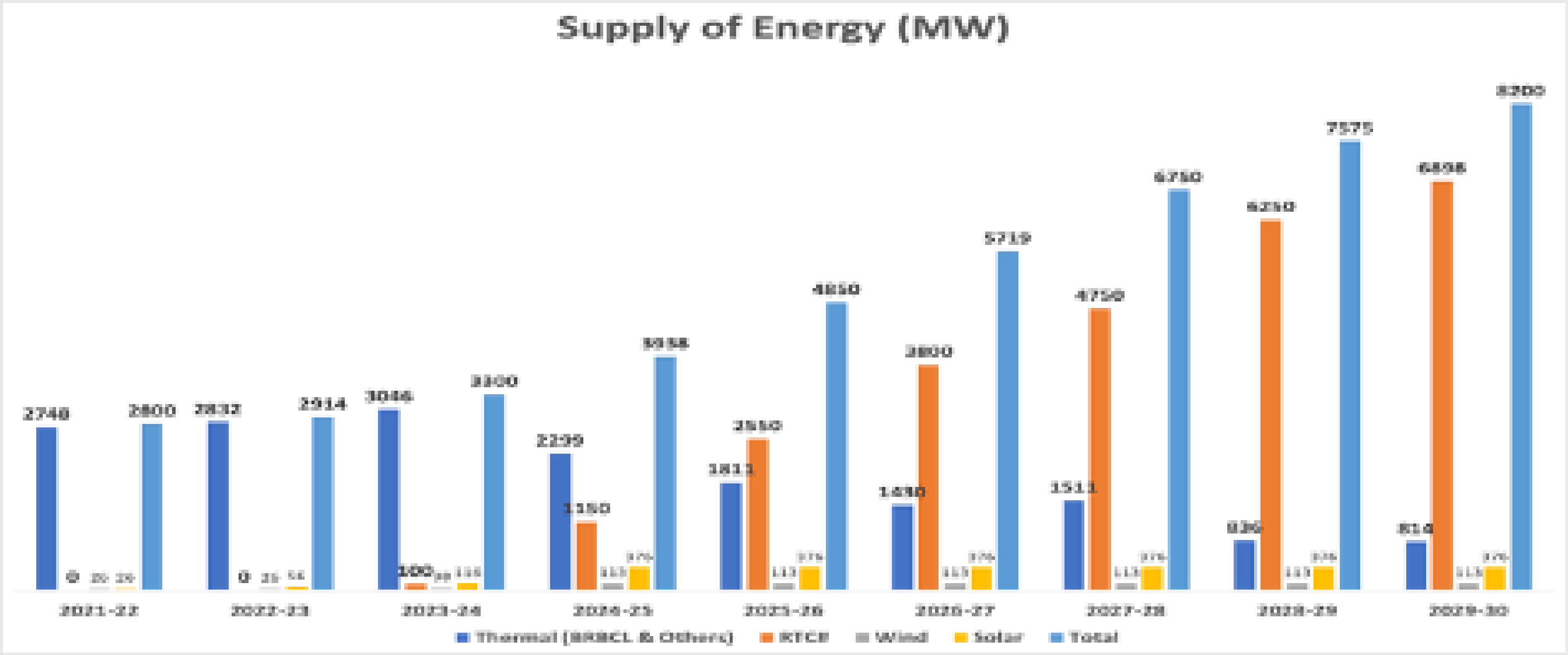


*Planned supply till 2030 in megawatt (MW) peak installed generating capacity*

In FY 2020-21, IR developed a RE plan till FY 2029-30 as part of its Net Zero Carbon Emission (NZCE) Action Plan. As well as the phase out of thermal power, a wholesale shift to RTC is planned.



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By the start of 2025, IR had already secured ('tied up' in the Indian parlance) over 1.5GWp of RE capacity, primarily through sleeved PPAs with new generators, including 4,260 MW of installed solar capacity and 3,427 MW of installed wind capacity. Around half of this has already been commissioned.

| Renewable power capacities commissioned | |
|---|---|
| **Solar (Rooftop + Land)** | **553 MW** |
| **Wind** | **103 MW** |
| **RTC (Round The Clock)**<br><br>**(Hybrid- Solar+wind)** | **100 MW** |
| **Total** | **756 MW** |

*Renewable power capacities commissioned under contract to Indian Railways, February 2025.*



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Nearly of this new capacity supplies station loads or is connected to the grid, **not to the traction network** - even lineside arrays where the yield is being bought by Indian Railways via PPAs.

So far, there is just one single project exploring **direct wire traction supply**. In February 2022 Bharat Heavy Electricals Ltd (BHEL) successfully commissioned a 1.7-megawatt solar photovoltaic plant at Bina in Madhya Pradesh, feeding an Indian Railways AC traction substation.

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The potential for direct wire traction supply in India is vast.

We estimate over **5GW of new solar generating capacity** could be connected directly to Indian Railways to power trains on commercially attractive terms.



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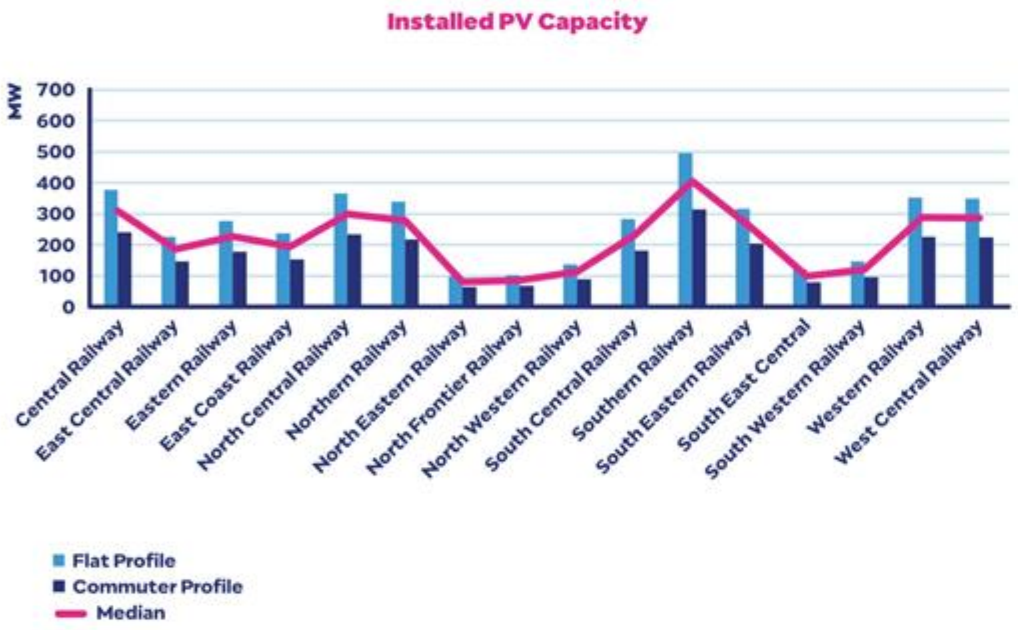
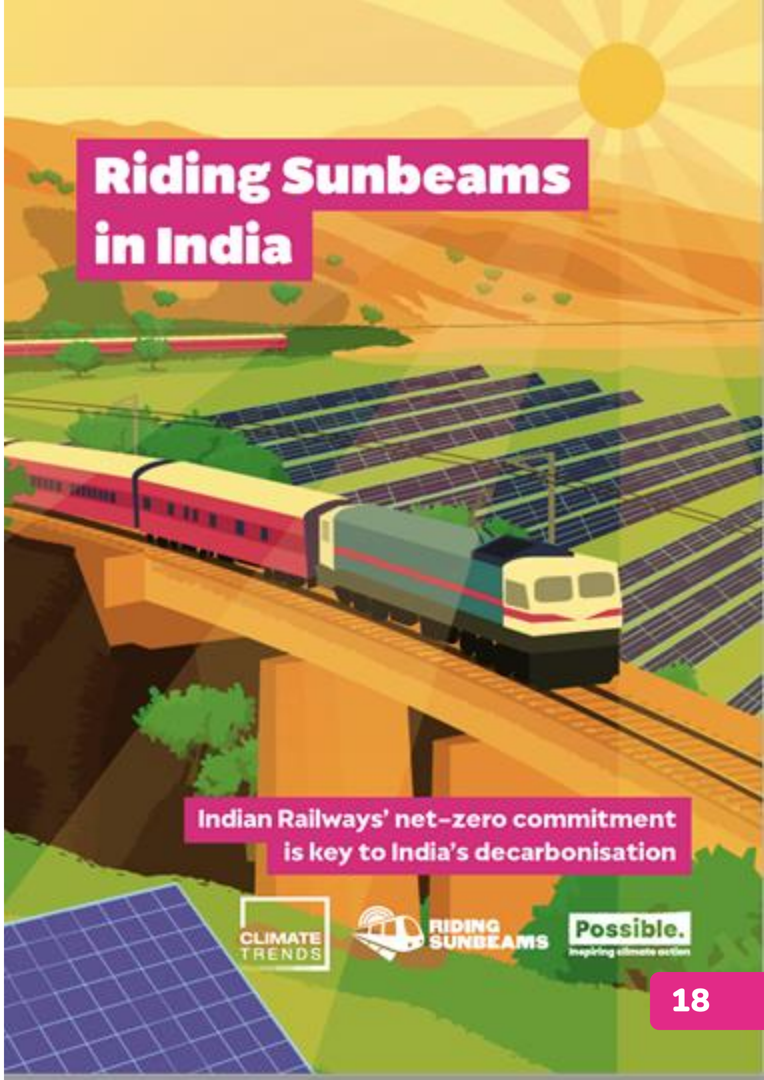



## 5,272 MW
## Total Indian Railways solar traction potential
## =
## 7 million tCO2e per annum saved!



## For railways

On-site solar power is clean, cheaper than any other option, and getting cheaper all the time

Indian grid supplied power is highly carbon intensive, and becoming more expensive

Thousands of miles of track to connect in to independent of grid

# Why it works

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## For solar

High costs and long waits to get a grid connection

Strong value proposition including avoided costs to supply a big end-user directly

Need on-site customers who can commit to buy power for 20+ years

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Direct wire supply aka captive generation which is integrated into traction power systems is intrinsically the lowest cost source of electricity available - although certain market distortions in India currently favour remote generation.

# AC interface design
## Power electronics - existing options

The mainline railway operates on single-phase electricity, and renewable generation typically outputs on a MW scale as three-phase AC through the use of inverters. Therefore a conversion device suitable for the rail environment and at an appropriate price point is required to interface between the two systems. Existing options available on market today:

**Static Frequency Converter**
Large, heavy duty, over-engineered and £1-2m per MW

**Domestic inverter**
Up to 10kW and £1.5k per unit, not built for rail environment

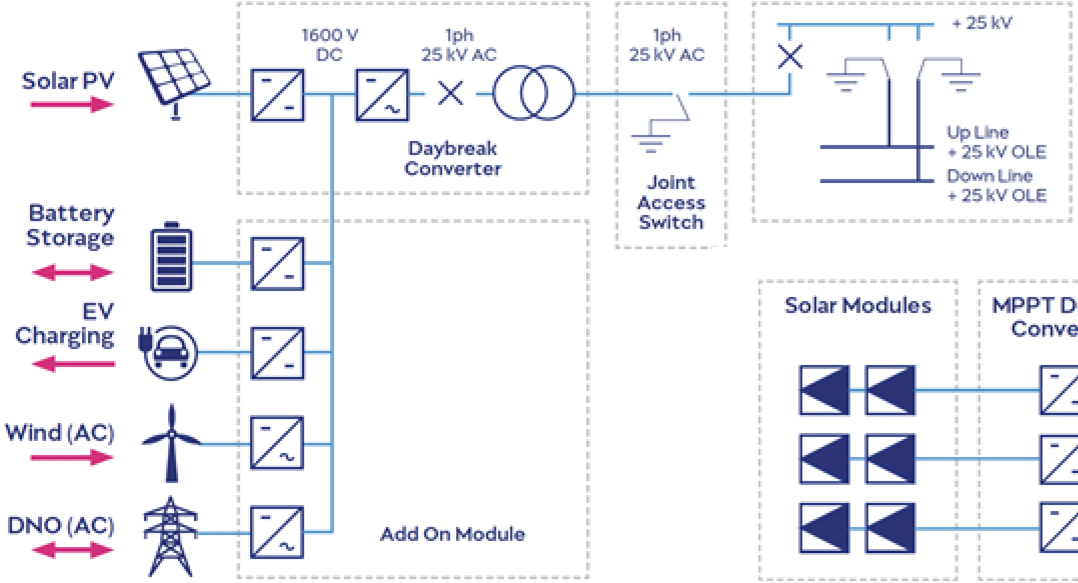
**Neither is suitable for our purposes.**

Picture: ABB

# AC interface design

## Our solution: Daybreak

Fig 2. Example deployment arrangement.




Bi-directional power flow capability enables wide range of other use cases from **wind and battery integration** to **rapid EV charging** in station car parks. Full technical specifications available on request.

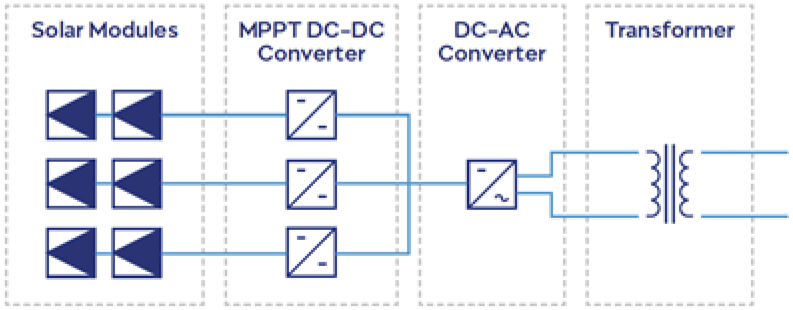



Fig 1. Daybreak converter development for connecting solar PV to 25 kV AC traction networks

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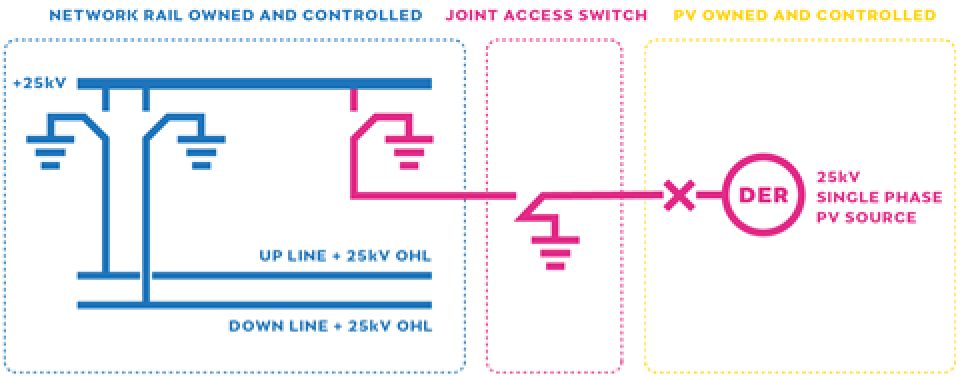
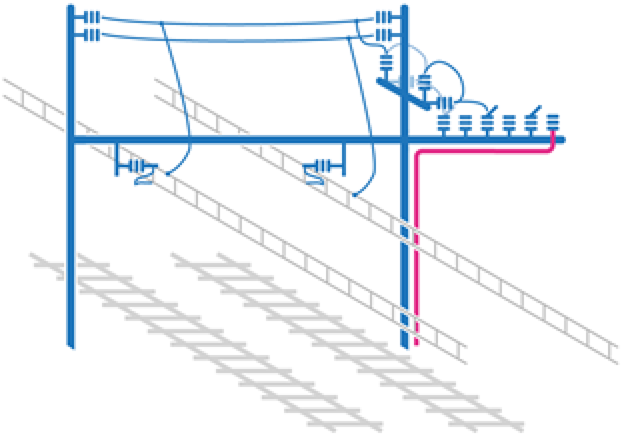



▲ 1 x 25 kV traction system



There is limited space at the traction substations. Solution is to build a gantry over the OHL and use air switches to connect the DER to the 25kV traction system.

◀ **Illustrative image of the gantry required to connect the renewable generation source to the over head line.**

# AC interface design

## Outline go-anywhere connection methodology

There is no need to connect Daybreak to existing power electronics infrastructure such as Bulk Supply Points, static frequency converters, traction substations or autotransformers.

Daybreak converter feeds can be connected directly to the overhead lines via a dedicated gantry and circuit breaker at 25kV with the necessary protection and controls.



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Making private wire solar traction supply happen at scale in India means partnering with an Indian power electronics volume manufacturer, supplying first the domestic market - and then the world.

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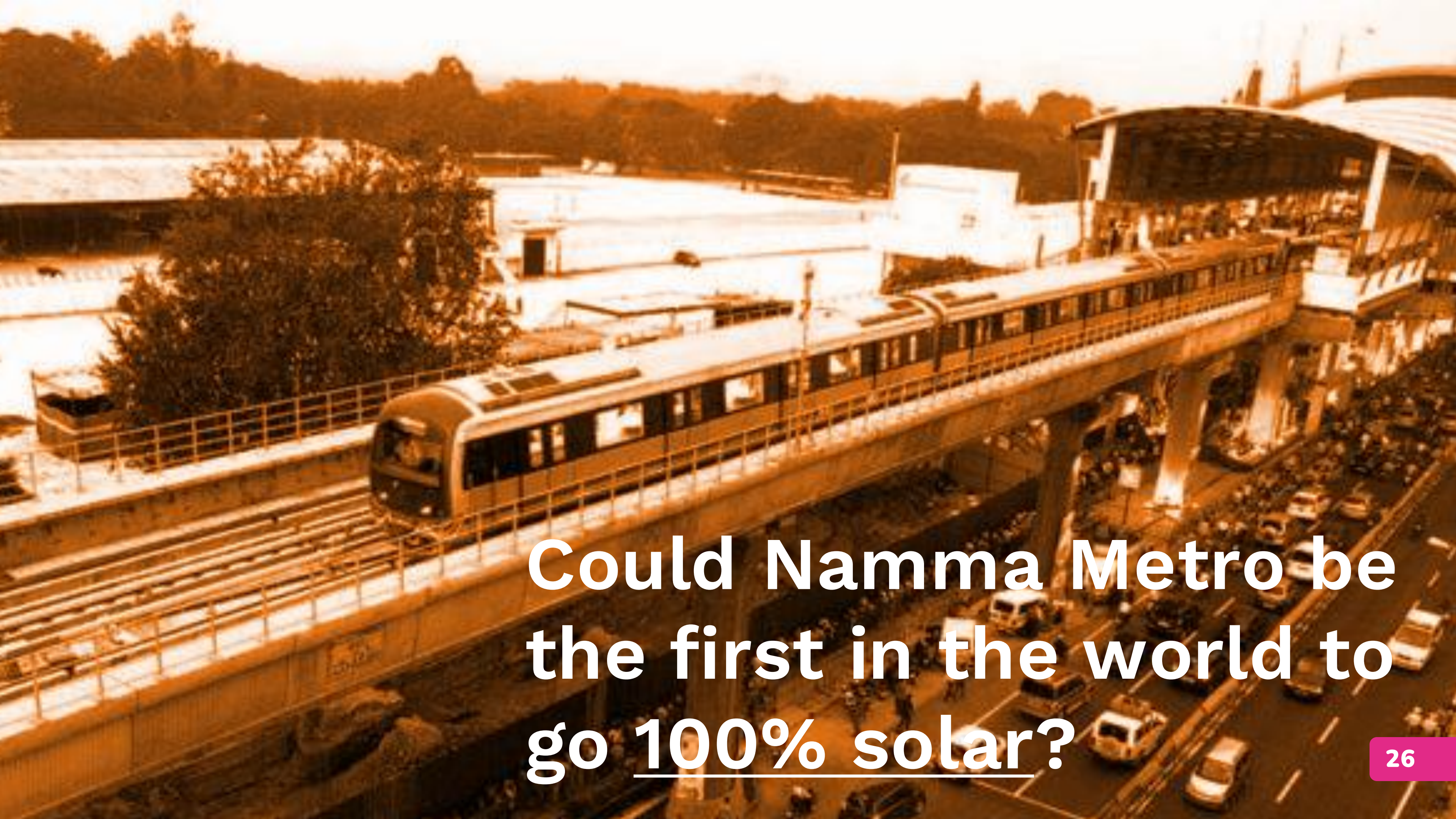
As well as the world’s largest fully electrified rail network, India has a number of major urban metros that use the same electrical architecture as the DC third rail network in the south of England which our demonstrator project is connected to.



# Could Namma Metro be the first in the world to go 100% solar?

# Namma Metro Project Suncatcher

Namma is India's second largest metro by route kms and is undergoing rapid growth. Namma is **already a solar rail pioneer,** with five major stations solarised and PV planned for all new stations as the network expands.

However **no solar power has yet been sourced from third party sites or suppliers**, and no battery storage has been used on the system.

Riding Sunbeams is working with the Indian Institute of Science in Bangalore to develop a feasibility study for Namma to do this.


Delhi Metro is currently installing a first-of-a-kind vertical PV array using bifacial modules on an elevated viaduct at Okhla Vihar station in New Delhi.

ITES

Part of the UK-India Net Zero Innovation Virtual Centre

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# Thank you for listening!

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