Powering India's Secondary Steel Transition

The Business Case for Cluster-Based Renewable Electricity Procurement

Supported by Climate Catalyst

Authors
JMK Research and Analytics: Jyoti Gulia; Prabhakar, Pulkit Moudgil
WWF-India: Vishal Dev, Mansi Chauhan
Climate Catalyst: Kinshu Dang
CII-GBC: Vinoth Bala Kumar

Acknowledgement
The transition to green steel requires accelerated adoption of renewable energy as a key pathway to decarbonise India's steel sector. The report, *Powering India's Secondary Steel Transition: The Business Case for Cluster-Based Renewable Electricity Procurement*, has been prepared by JMK Research and Analytics in collaboration with WWF-India, Climate Catalyst and CII-Green Business Centre (GBC).

We are thankful to Mr. Rajiv Mangal, Chairman, India Green Steel Coalition (IGSC), for his guidance and to the members of the IGSC Renewable Energy Action Group and IGSC member body for their valuable inputs. We sincerely thank all stakeholders who participated in consultations and provided insights that helped shape the analysis and recommendations.

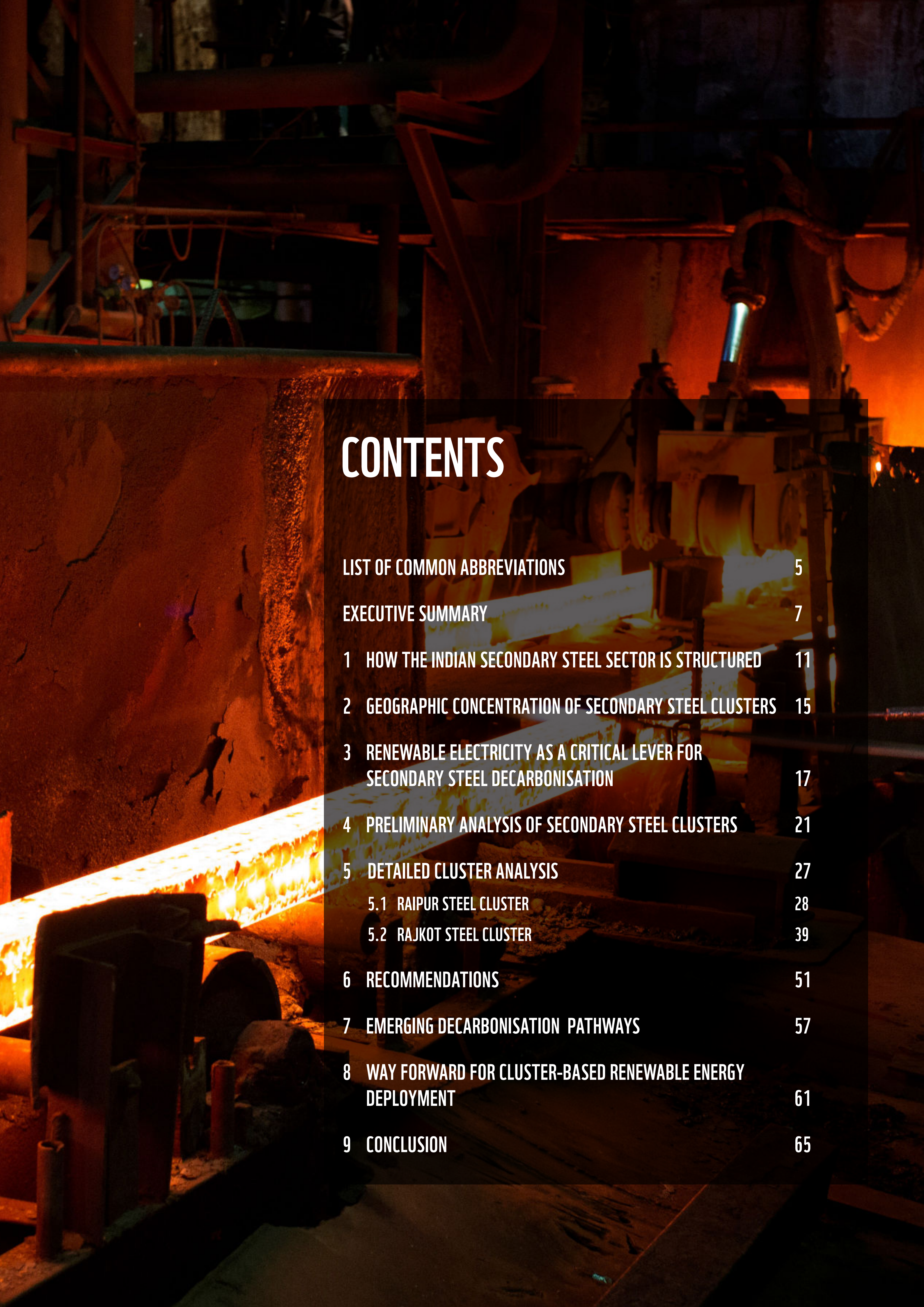
Finally, we would like to thank all the members of the team who were involved in the development process at various stages of the initiative. The report is produced under a project supported by Climate Catalyst's India Green Steel Network (IGSN). The report does not necessarily reflect the views of the funder.

Reviewed by
Mr Bernt Nordman, Head of Climate Programme, WWF-Finland
Mr Naveen Ahlawat, President and Head – Sustainability and Decarbonisation Jindal Steel Ltd.
Mr Karthik Shetty, Consultant, CEEW

Design by
Simijaison Designs

Photo credit

Published in August 2026



CONTENTS

LIST OF COMMON ABBREVIATIONS

Abbreviation	Definition
EAF	Electric arc furnace
EIF	Electric induction furnace
BF-BOF	Blast furnace-basic oxygen furnace
MTPA	Million tonnes per annum
PJ	Petajoules
$MTCO_2$	Million tonnes of CO_2
MSMEs	Micro, small and medium enterprises
DRI	Direct reduced iron
GWh	Gigawatt hour
RE	Renewable energy
GEOA	Green energy open access
WSH	Wind solar hybrid
CUF	Capacity utilisation factor
OA	Open access
CSS	Cross subsidy surcharge
AS	Additional surcharge
LF	Load factor
SPV	Special purpose vehicle
O&M	Operations and maintenance
ISTS	Inter-state transmission system

EXECUTIVE SUMMARY

Renewable electricity as a cost lever for India's secondary steel micro, small and medium enterprises (MSMEs)

Renewable electricity represents a significant decarbonisation opportunity that can simultaneously reduce production costs and greenhouse gas emissions for micro, small and medium enterprises (MSMEs) in India's secondary steel sector. Electricity accounts for up to 40% of the operating cost of India's MSMEs. In several states, renewable electricity is currently available at Rs 4.5–6 per unit, compared with grid tariffs of Rs 7–8 per unit, making renewable energy procurement economically attractive where regulatory and operating conditions are favourable. For a sector that produces approximately 44% of India's crude steel, and emits an estimated 50–60 million tonnes of CO_2e annually, electricity is both a major cost centre and an immediate decarbonisation opportunity.

India is well placed to capture that saving, given it has built one of the world's fastest-growing renewable energy markets, with annual commercial and industrial RE installations rising at a compounded annual growth rate (CAGR) of about 46% over the past five years.

Renewable Energy (RE) offers an immediate pathway to decarbonise melting and rolling operations without requiring changes to existing production routes. At the same time, deep decarbonisation of upstream ironmaking will increasingly rely on emerging technologies such as green hydrogen as they progress towards commercial maturity. Expanding RE today also builds the clean energy infrastructure needed to support future green hydrogen production, making it a critical first step in the sector's long-term decarbonisation pathway.

Yet RE adoption in secondary steel is around 11%, half of the 22% national RE share in electricity generation. The gap is not one of technology or cost, but of institutional and regulatory work crucial for integrating RE into MSME operations at scale. This includes financing structures, open access procedures, state-level implementation, and cluster-level coordination, which make procurement viable in practice. This report examines why this commercially attractive opportunity remains underutilised and identifies the policy interventions needed to unlock it.

What the report examined

The study addresses this challenge through three analytical steps:

FIRST, it develops an RE Attractiveness Index to identify India's major secondary steel clusters with the greatest potential for RE adoption, using state policy, cost savings potential, electricity consumption, market maturity, and land availability as weighted parameters. Raipur, Belgaum, Shimoga, Rajkot, and Bhavnagar emerge as the five most attractive clusters.

SECOND, it undertakes detailed assessments of two contrasting clusters—Raipur in Chhattisgarh and Rajkot in Gujarat. Raipur represents an integrated secondary steel ecosystem operating under a load-factor-based tariff regime with integrated furnace and rolling mill units, and direct reduced iron (DRI)-based sponge iron production. Rajkot represents a smaller ecosystem of scrap-based foundries, forgings, and bearing units, with access to both solar and wind resources.

THIRD, the report models the long-term financial performance of three renewable procurement pathways in Raipur and Rajkot clusters—Full Capex (on-site and off-site), Group Captive, and Third-party Open Access. Financial outcomes are evaluated over a 25-year project life, including annual cashflow savings, landed tariffs, payback periods, and emissions abated.

Key findings

Four findings emerge consistently across the analysis.

1. **Renewable energy (RE) integration reduces production costs while lowering emissions**

Most decarbonisation pathways increase production costs and therefore depend on consumers or downstream buyers paying a green premium. Renewable electricity in secondary steel presents a different proposition by directly lowering electricity costs while simultaneously reducing emissions.

- For a 0.1 million tonnes per annum (MTPA) integrated furnace and rolling mill in Raipur, a 10 megawatt (MW) Group Captive solar installation generates average annual cashflow savings of around Rs 2.4 crore against an equity contribution of Rs 2.7 crore, with landed tariffs approximately 34% below prevailing grid tariffs and a payback period of one to two years. The project also abates approximately 12,500 tCO_2 annually.
- Similarly, for a representative foundry in Rajkot, a 5 MW Group Captive solar project generates average annual savings of around Rs 2.2 crore against Rs 1.4 crore in equity, at landed tariffs of 20% below grid. A wind-solar hybrid at the same scale delivers Rs 2.6 crore in annual cashflow savings on Rs 2.24 crore in equity, at landed tariffs of 14% below grid. Annual emissions reductions range between 6,800 and 9,460 tCO_2 depending on the technology configuration.

Across both clusters, the primary driver for RE adoption is lower electricity costs, with emissions reductions providing an additional co-benefit.

2. Group Captive offers the most viable and scalable procurement model for MSMEs

Among the procurement pathways evaluated, Group Captive consistently offers the strongest balance between financial returns, capital requirements and operational feasibility.

While on-site Full Capex generates the highest lifetime savings, it also demands Rs 17–35 crore in upfront capital, contiguous land, and dedicated operations and maintenance capacity—conditions that are beyond the reach of most MSMEs. Third-party Open Access eliminates upfront investment but remains commercially unattractive because cross subsidy surcharge (CSS) and additional surcharge (AS) keep landed tariffs close to grid rates and therefore, savings are marginal to negative in early years.

Group Captive provides an effective middle path by combining relatively modest equity commitments of Rs 1.4–2.7 crore per MSME with exemptions from CSS and AS under the Indian Electricity Rules, developer-managed project execution, and consistently lower landed electricity tariffs. The economics of the Group Captive model depend significantly on load profile, i.e., how steadily and continuously a unit consumes electricity.

Units operating continuously through the day, like integrated furnaces and larger foundries, typically run at 75–85% load factors and capture the full benefit of Group Captive. In contrast, standalone rolling mills at much lower load factors do not qualify for load-factor-linked rebates on grid power. Their intermittent operations also limit renewable electricity utilisation, resulting in comparatively lower savings.

3. Regulatory implementation is a major challenge to RE adoption at cluster level

The analysis finds that commercially attractive projects are frequently constrained by state-level regulatory implementation rather than technology or project economics.

Although national policy increasingly supports renewable procurement, local tariff structures, open access procedures and distribution company (DISCOM) implementation often dilute the commercial benefits. For example, in Jalna, Maharashtra State Electricity Distribution Company Limited (MSEDCL) offers rebates on grid tariffs to industrial consumers who maintain high load factors. When an MSME shifts part of its consumption to solar, its grid consumption falls, along with its load factor, and its rebate is reduced.

In Rajkot, MSME owners flagged the DISCOMs opposition to increasing the renewable energy capacity beyond a certain quantum as a live constraint even though the Gujarat Integrated Renewable Energy Policy 2025 formally removed capacity restrictions for setting up of RE projects in December 2025. No objection certificate (NOC) requirements, DISCOM-level implementation, and industry perception continue to hold it in place. These examples illustrate that renewable energy adoption depends not only on policy intent but also on consistent implementation by state regulators and DISCOMs.

4. Cluster-based approaches are essential to unlocking scale for MSMEs

The economics of Group Captive hinge on aggregation of RE demand. Five to eight steel units within a 30–50 km radius make the project bankable. Pooling them spreads equity across several firms, lowers the risk any single MSME carries, and improves the credit profile that lenders assess.

Recommendations for an enabling policy environment

The analysis shows that the principal barriers to renewable energy adoption are institutional rather than technological. Policy interventions should therefore focus on enabling commercially viable procurement models through regulatory certainty, improved access to finance and coordinated implementation.

Three priority recommendations emerge:

1. **Introduce time-bound, targeted open access concessions for cluster-based MSME renewable procurement, accompanied by compensatory mechanisms for DISCOMs**

Open access charges are among the most important determinants of renewable energy adoption at the cluster level. Permanent waivers, however, are not sustainable, given DISCOM dependence on cross-subsidy contributions.

A balanced approach would be to provide time-bound concessions for 5–7 years, targeted specifically at industrial decarbonisation in steel MSME clusters and supported by appropriate capacity caps and verification mechanisms. The resulting revenue shortfall could be compensated through transparent state or central budgetary support, broadly aligned with the direction of the draft Electricity Amendment Bill 2025, rather than being absorbed implicitly by DISCOMs.

> *Lead institutions: Ministry of Power, State Electricity Regulatory Commissions (SERCs), State Governments.*

2. **Establish portfolio-level credit guarantees for cluster special purpose vehicles**

Aggregating MSME borrowing into pooled structures backed by partial credit guarantees through Small Industries Development Bank of India (SIDBI) or Indian Renewable Energy Development Agency (IREDA) enables lower collateral requirements, faster approvals, and reduced perceived risk through portfolio diversification. This addresses the financing gap that keeps Group Captive structures inaccessible to individual MSMEs operating on thin working capital.

> *Lead institutions: Ministry of Finance, SIDBI, IREDA.*

3. **Standardise the regulatory framework governing Group Captive implementation across states**

The Green Energy Open Access Rules 2022 has set the policy direction but uneven implementation across states remains the binding constraint. The task at hand is to standardise how the framework is applied, focusing on these. Three areas need standardising:

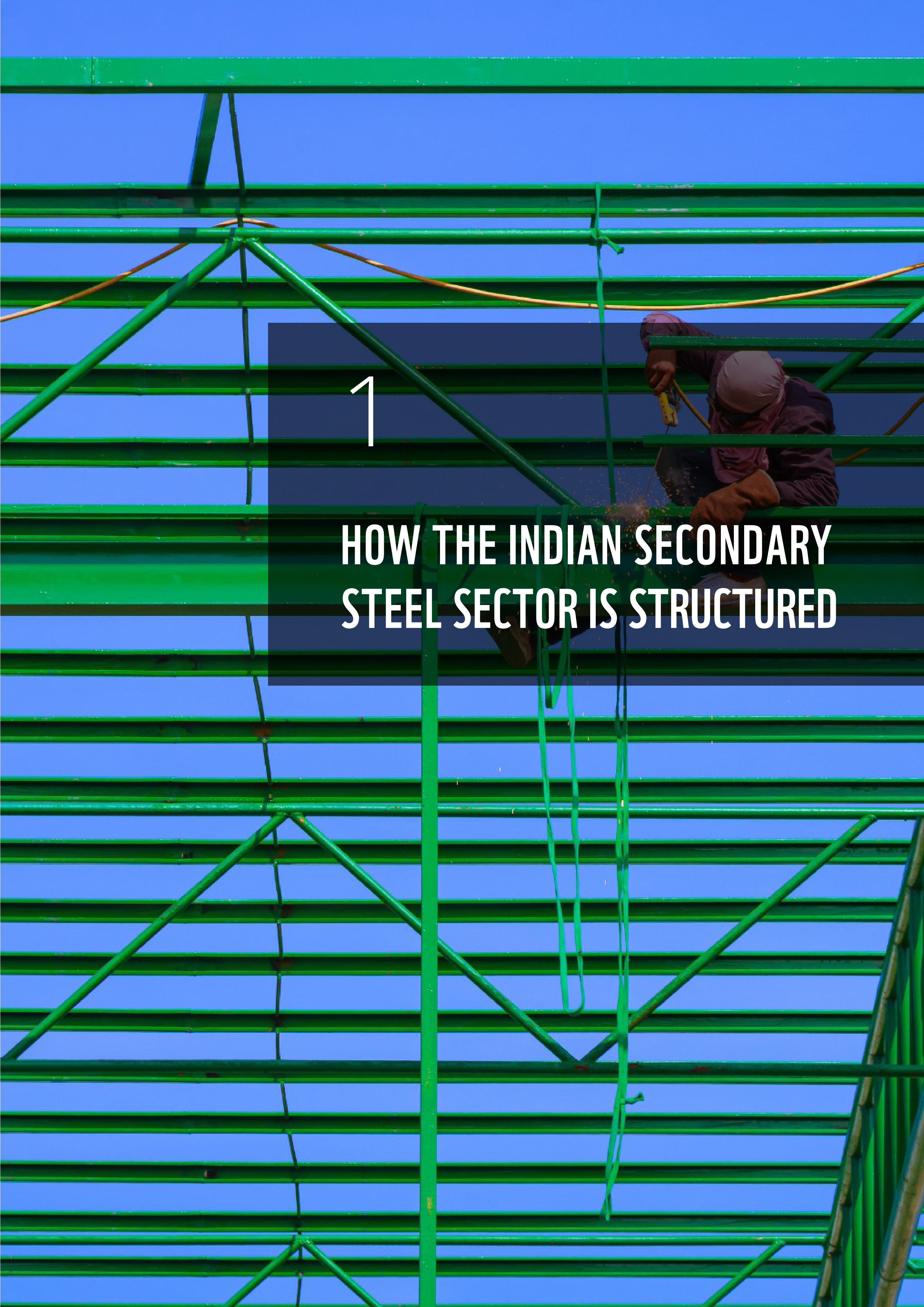
a. State-approved model power purchase agreements (PPAs) would stop each consumer group renegotiating contract terms from scratch.

b. Single-window approvals would compress the interval between a formed group and a commissioned plant.

c. Uniform treatment of banking and load factor in post-RE billing would remove the distortions that currently penalise a unit for moving load to solar, such as losing a load-factor rebate or hitting an unpredictable banking cap.

To keep implementation aligned with the central framework, a model state regulation could be coordinated through the Forum of Regulators and offered to states as a ready template.

> *Lead institutions: Ministry of Power, the Ministry of New and Renewable Energy (MNRE), SERCs, Forum of Regulators.*



1

HOW THE INDIAN SECONDARY STEEL SECTOR IS STRUCTURED

India is the world's second-largest steel producer. The production landscape is divided between integrated primary manufacturers operating ore-to-metal facilities based on the blast furnace-basic oxygen furnace (BF-BOF) route and a vast, decentralised secondary segment that produces steel using scrap, sponge iron, pig iron or combinations thereof in electric arc furnaces (EAF) or electric induction furnaces (EIF).

The secondary steel segment, largely driven by MSMEs, forms a critical pillar of India's steel supply, contributing around 38–40% of India's total crude steel production. These units are highly fragmented, with capacities ranging from 1,000 tonnes per annum to 0.1 million tonnes per annum (MTPA).

India's crude steel production has seen robust expansion, rising from 109 million tonnes (MT) in FY2020 to 152 MT[16] in FY2025 at a CAGR of about 6.7%. Secondary steel production grew in tandem, rising from 44 MT to 61 MT at a CAGR of 6.4% over the same period, maintaining its 40% share of total output.

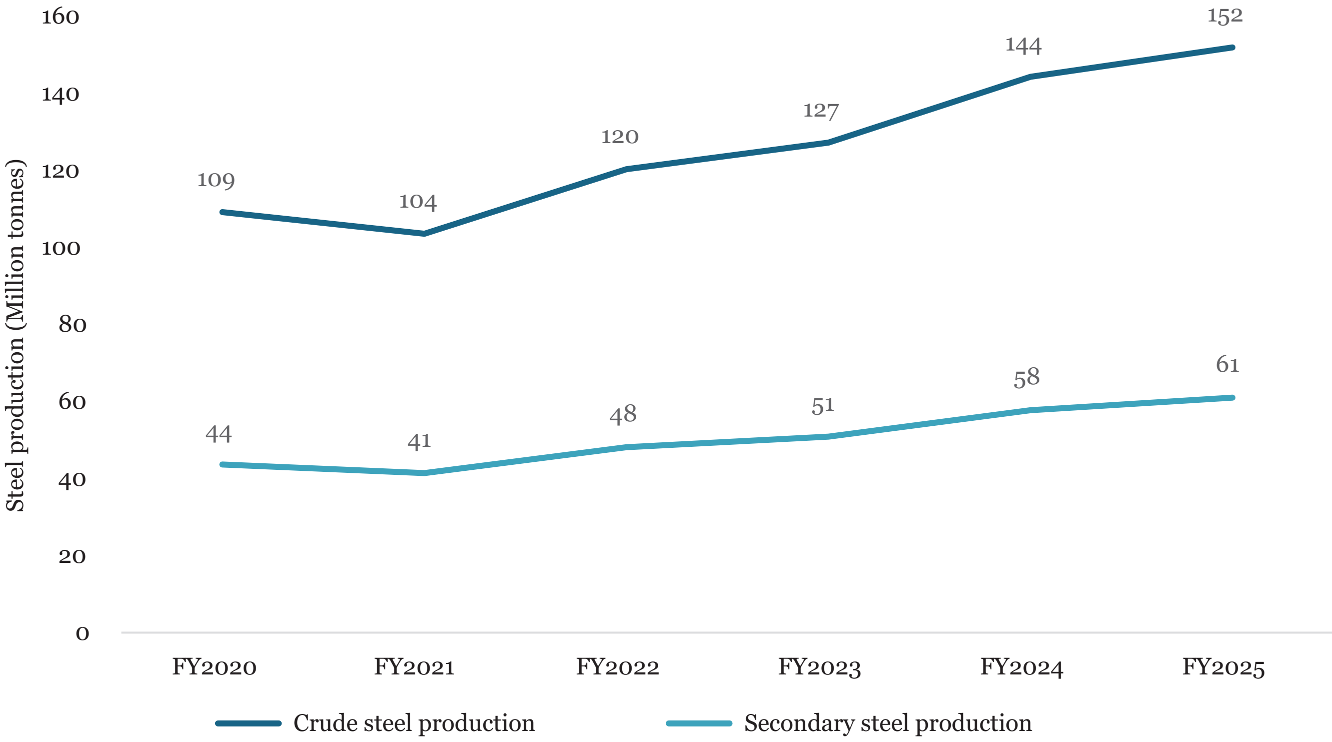
Table 1: Overview of the Indian secondary steel sector

Parameters	Description
Secondary steel production capacity (2023–24)	About 79.79 MTPA
Share of secondary production in Indian crude steel production	About 38–40%
Annual production (FY2025)	61 MTPA
Scrap consumption (FY2025)	35–37 MTPA
Number of units (2024)	1032 EIFs + 40 EAFs
Estimated energy consumption (2023)	485–547 Petajoules (PJ) (134–152 Terawatt hours) (13–15% of consumption in iron and steel sector)
Estimated total emissions (Scope 1 and 2 for 2024)	50–60 million tonnes CO_2 ($MTCO_2$)
Distribution of total scrap across EAF/ EIF (2024)	13–15% in EAF 44–46% in EIF
Distribution of total sponge iron in EAF/EIF (2024)	44–46% in EAF 72–74% in EIF
Products	Steel sheets, coils, TMT bars, pipes, others

Source: Ministry of Steel, BigMint, JMK Research

16 PIB | Current Capacity of Steel Production | July 2025

Figure 1: Annual trend of secondary steel production



Source: TERI, Ministry of Steel, JMK Research

Secondary steel manufacturing process

India's secondary steel[17] manufacturing system operates through two routes, differentiated by the mix of raw materials used (see Figure 2). The first and dominant route blends sponge iron, produced via coal-based or gas-based direct reduction, with scrap. The second route combines blast furnace-produced pig iron with scrap. These raw materials feed into EIFs or EAFs, and in some cases coal-fired melting furnaces such as Cupolas, to produce molten metal.

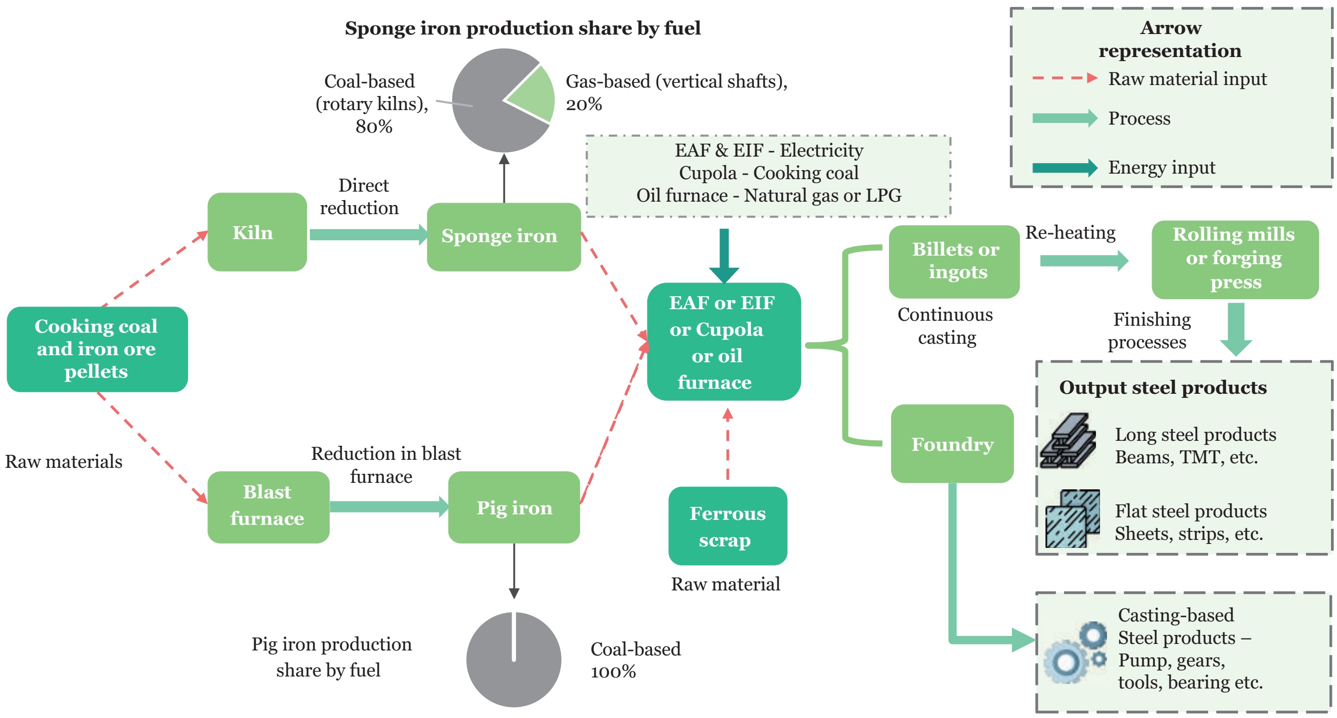
Electricity is the central energy input for both EIFs and EAFs, making power cost, reliability, and quality critical determinants of production efficiency. Most facilities then solidify the molten steel into billets or ingots through continuous casting. Although this constitutes the broad manufacturing flow, significant on-ground variations exist in how units handle molten steel beyond the EAF/EIF stage.

Secondary steel manufacturing encompasses diverse unit types across the value chain, raw material mix, and end-product profile. For the purpose of this study, the secondary steel ecosystem can be broadly classified as follows:

- **Rolling mills** – Includes standalone rolling mills that procure billets or ingots from the market and integrated units where melting and rolling are co-located.
- **Foundry segment** – Encompasses grey cast iron, ductile iron, and specialised processes such as investment casting, typically serving automotive and engineering supply chains.
- **Forging units** – Power-intensive downstream processors that convert billets into shaped components through mechanical deformation and heat treatment.
- **Integrated direct reduced iron (DRI) steelmaking units** – Facilities combining DRI production with melting operations.

17 In India, *primary steel* colloquially refers to steel produced by integrated steel plants via the BF-BOF route, while secondary steel refers to production by units using sponge iron, pig iron, and/or scrap. This differs from international nomenclature, where the distinction is based on feedstock. Notably, the Indian classification is more aligned with the type of furnace used.

Figure 2: Steel manufacturing value chain



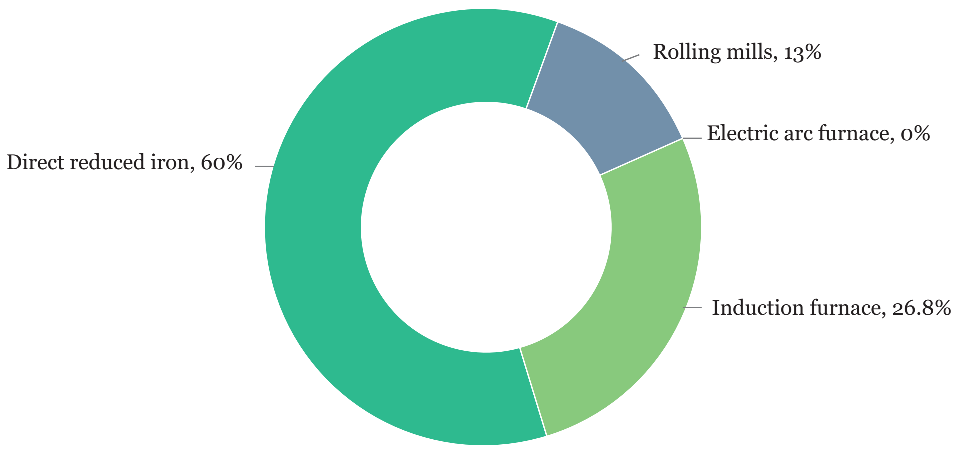
Source: Sameeksha, SIMA, JMK Research

Emission profile

Emissions across the secondary steel value chain concentrate upstream. Coal-based sponge iron production (or DRI) accounts for 60% of the sector's carbon footprint. The EAFs and EIFs contribute around 27%. Downstream units like rolling mills account for the remaining share (see Figure 3).

This distribution points to clear intervention priorities: upstream ironmaking requires process transformation, while the melting and finishing stage offers immediate decarbonisation potential through renewable electricity without requiring process modifications. The report primarily examines secondary steel MSMEs and excludes DRI-based units, as these operations are typically highly consolidated and operate at scales significantly larger than MSMEs.

Figure 3: Share of greenhouse gas emission across DRI-based secondary steel value chain (Scope 1 and Scope 2)



Source: TERI, JMK Research

2

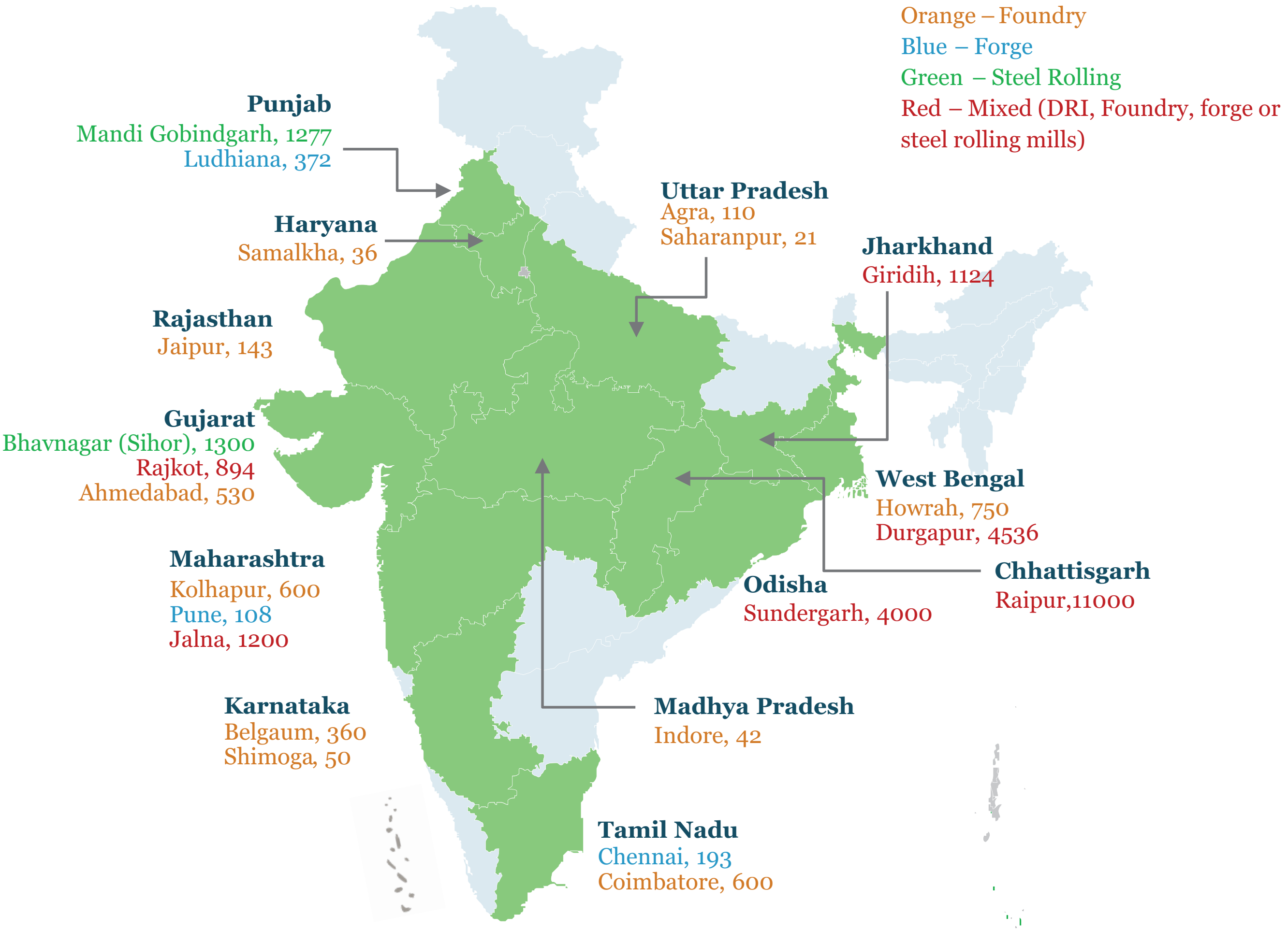
GEOGRAPHIC CONCENTRATION OF SECONDARY STEEL CLUSTERS

India's secondary steel industry clusters are distinct manufacturing belts that have evolved around raw material linkages, labour availability, and established industrial ecosystems. These comprise foundries, forging units, and steel rolling mills, along with associated operations such as ferro-alloy producers and scrap processing units. Figure 4 below illustrates the distribution of these clusters across states.

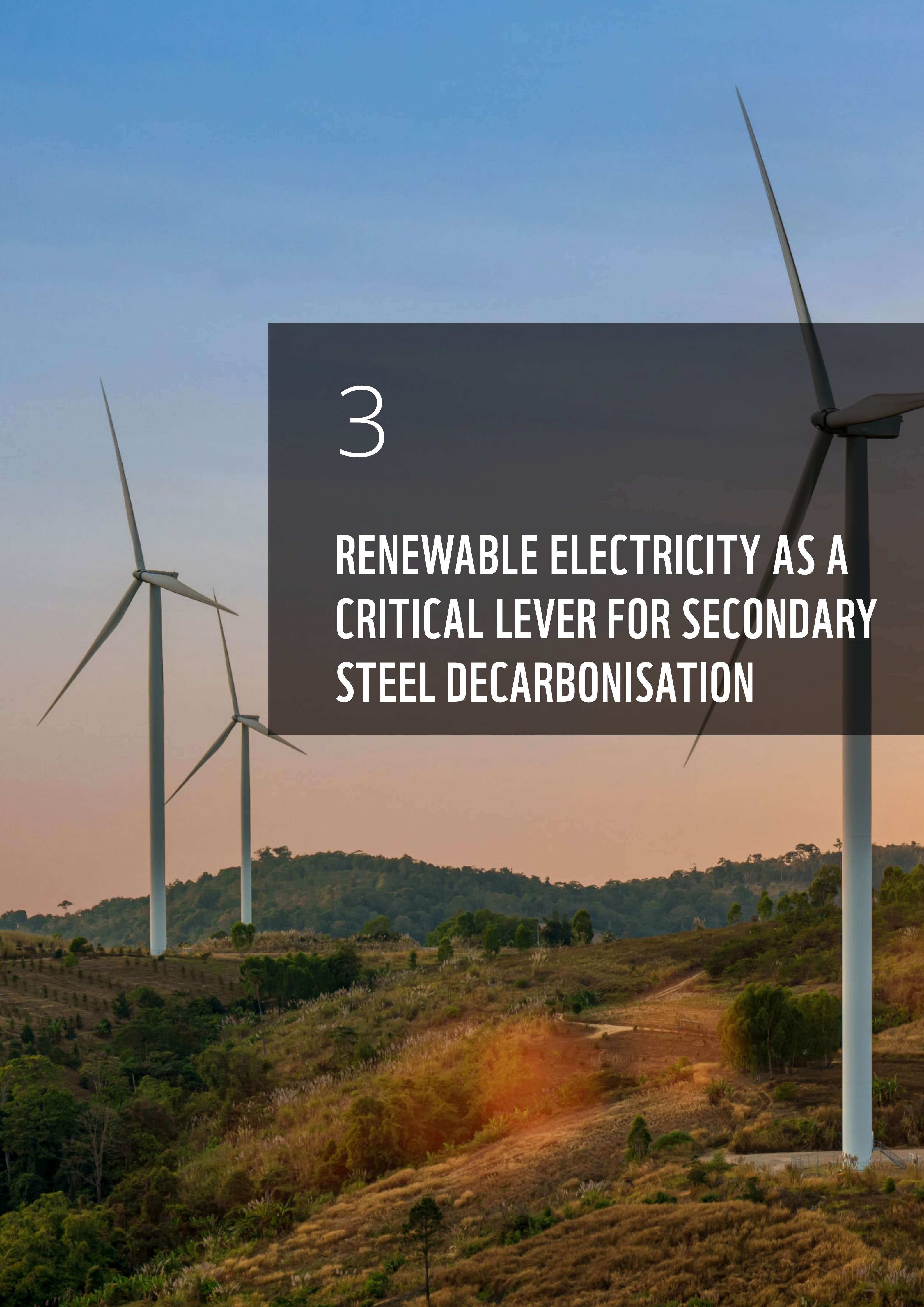
Regional characteristics further influence the technological pathways and raw material choices adopted across clusters:

- **Ore-rich belts in central and eastern India, particularly Chhattisgarh, Jharkhand, and Odisha,** tend to support DRI-based ecosystems, where integrated melting-rolling facilities often include their own sponge iron kilns. While secondary steel units typically range from 1,000 TPA to 0.1 MTPA, these DRI-based integrated operations tend to be at the upper end of this spectrum or exceed it.
- **Port-adjacent and scrap-accessible regions** such as Maharashtra, Gujarat, and parts of southern India exhibit higher scrap usage because of easier access to imported scrap and established coastal logistics.
- **Clusters located near major consumption centres** like Mandi Gobindgarh in Punjab and Howrah in West Bengal lean towards the production of finished products, leveraging proximity to construction, engineering, and automotive markets.

Figure 4: Key Indian secondary steel clusters



Note: Values beside each cluster name indicate annual production output (in thousand tonnes per annum).
Source: Sameeksha, JMK Research



3

RENEWABLE ELECTRICITY AS A CRITICAL LEVER FOR SECONDARY STEEL DECARBONISATION

Electricity-intensive MSME secondary steel units operate under rising cost pressure, with electricity being a critical driver of operating expenditure amid increasing grid tariff volatility. Across the value chain, electricity cost exposure, or the sensitivity of the business to changes in electricity cost, varies for melting and rolling mills. For units operating on thin margins, electricity tariff fluctuations directly affect business viability. Simultaneously, tightening environmental compliance requirements add additional operational and financial obligations, requiring units to manage cost exposure alongside regulatory alignment. The table below summarises the electricity demand characteristics across major secondary steel segments.

As shown in Table 2, EAF units operate with a stable 24-hour baseload profile, reflecting their large-scale continuous operations. EIF units display more heterogeneous load characteristics. Medium-sized EIF units run continuously with periodic load fluctuations, while smaller units operate for only 8–12 hours a day with variable load patterns and greater seasonal sensitivity.

Standalone rolling mills, due to their non-continuous operating pattern, have limited demand-side flexibility and reduced ability to align with variable RE generation.

As India's steel decarbonisation agenda accelerates, reducing indirect emissions (scope 2) has emerged as an immediate and scalable lever, particularly for electricity-intensive MSMEs. Renewable electricity integration offers a practical pathway to help reduce these emissions while improving energy cost stability.

Why renewable electricity makes economic sense

Electricity consumption in the steel sector is projected to double from 94 terawatt-hours (TWh) in 2022 to 184 TWh by 2031, with nearly half of this demand expected to come from secondary steel units. This growing demand presents an opportunity for RE integration. India's Greening Steel Roadmap underscores this shift, setting a target of around 43% renewable

Table 2: Electricity demand characteristics across key secondary steel units

Parameter	EAF units	EIF units
Scale	Large	Medium to small
Estimated units in India	Around 34	1,030
Operating hours	24 hours per day with stable baseload	Medium: 24 hours a day continuous operation with some load fluctuations Small: 8–12 hours a day with variable load profile
Specific electricity consumption	700–1,000 kWh per tonne of crude steel	950–1,100 kWh per tonne of crude steel
Seasonal impact	Operates near-continuously regardless of season	Medium: Moderate seasonality Small: High seasonality during summer and monsoon periods

Source: Ministry of Steel, TERI, Sameeksha, GIZ, BEE, JMK Research
Note: In addition to units above, the secondary steel sector also includes configurations such as standalone rolling mills, operating reheating furnaces, and some foundry units using cupola furnaces. These are not included due to their highly fragmented and heterogeneous operating profiles.

electricity penetration by 2031, with the potential to reduce emissions intensity by approximately 8%.[18] RE in secondary steel is supported by several structural advantages:

- **Cost competitiveness:** RE procurement can deliver lower tariffs than grid power, improving long-term cost visibility for MSMEs. Electricity constitutes up to 40% of operating costs for EIF/EAF-based units (see Figure 5). Across most states, DISCOM tariffs range from Rs 7–8/kWh, while RE can be procured for Rs 4.5–6/kWh.

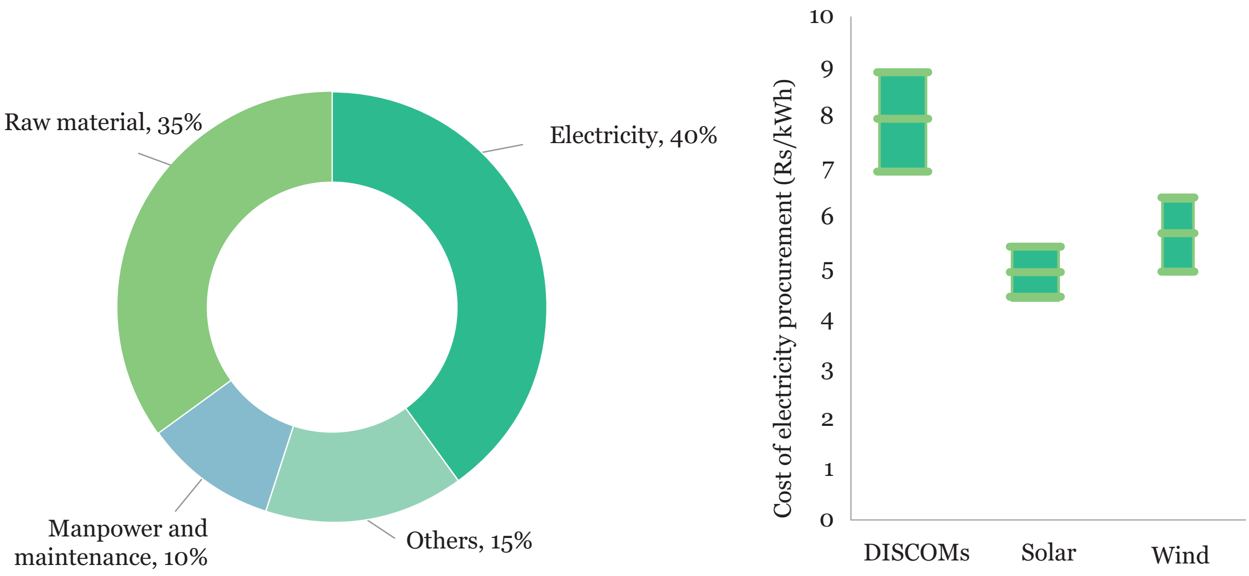
- **Operational compatibility:** Renewable electricity integration requires minimal process changes, making it one of the least disruptive high-impact decarbonisation options for electricity-intensive units. Unlike upstream ironmaking, which will require breakthrough technologies such as hydrogen-based reduction, melting and rolling operations can run on RE without altering the furnace or production route.

- **Immediate emissions reduction:** Transitioning to renewable electricity offers a near-term opportunity to reduce scope 2 emissions without waiting for large-scale technology transitions.

Despite renewable electricity offering lower and more predictable costs, RE adoption among secondary steel units is estimated at only around 11%.[4] This is notably lower than renewable electricity's share in India's overall electricity generation mix, which stands at roughly 22%.[19]

Against this backdrop, this study examines the barriers of scaling RE adoption in the sector, evaluates the economic feasibility of different RE procurement models for MSME units, and identifies the practical and policy enablers required to accelerate clean electricity uptake across major secondary steel clusters.

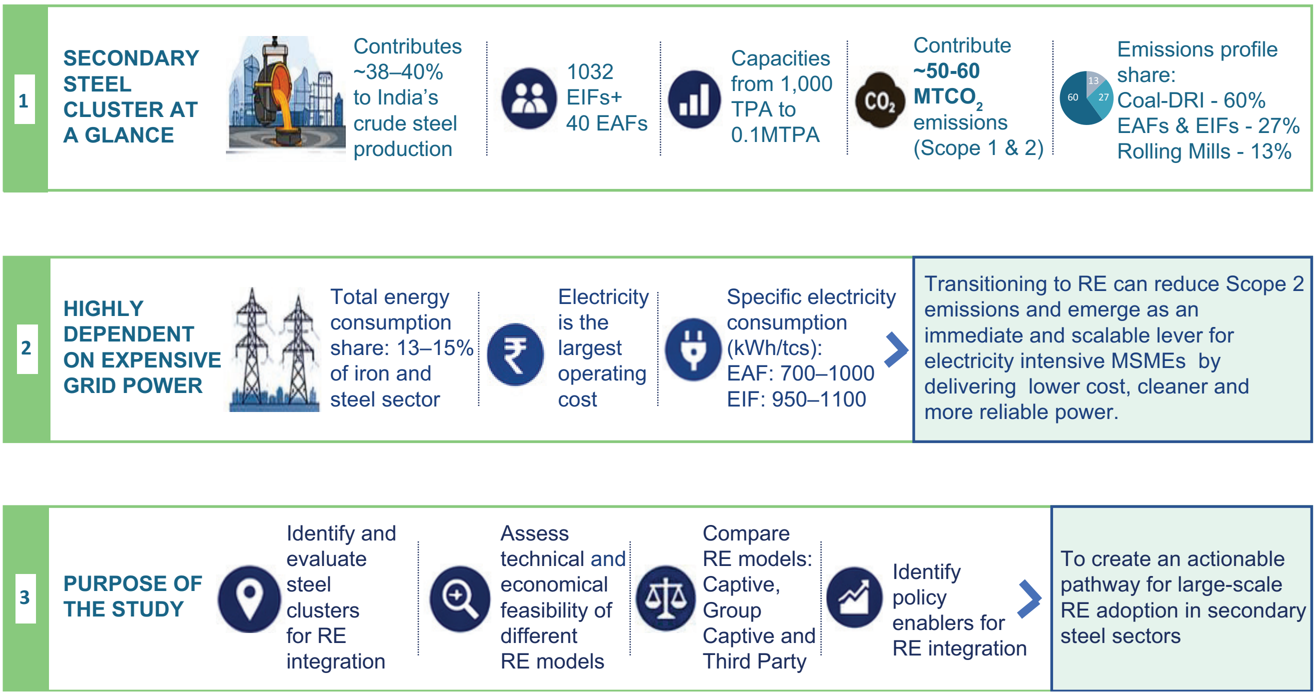
Figure 5: Electricity cost exposure and renewable energy–grid tariff comparison



Source: BEE, JMK Research

3 Ministry of Steel | Greening the Steel Sector in India | September 2024
4 Ministry of Steel | Greening the Steel Sector in India | September 2024

Figure 6: Key characteristics of secondary steel clusters and the case for renewable energy adoption



Source: JMK Research

4

PRELIMINARY ANALYSIS OF SECONDARY STEEL CLUSTERS

India's secondary steel landscape consists of various manufacturing clusters, each differing in electricity consumption, production scale, and regulatory environment. These differences create significant variation in the economic feasibility and attractiveness of RE adoption across clusters.

To compare these clusters and identify those with the greatest potential for RE adoption, a scoring-based analytical approach was adopted. This enables a structured, quantitative evaluation that moves beyond anecdotal evidence and provides a clear basis for prioritising clusters for deeper analysis and engagement.

Methodology

Given the heterogeneity across clusters, direct comparison of raw values is not meaningful. Parameters such as electricity consumption, land availability, or policy favourability are measured on different scales. To ensure fair comparability, each parameter was standardised using z-score normalisation, which converts raw data into a common statistical scale while preserving the magnitude and direction of variation across clusters.

In addition to quantitative indicators, several parameters, including State Open Access Policy adoption and its on-ground implementation, are qualitative. These were evaluated using a categorical scoring scale (High/Medium/Low) based on regulatory analysis and industry interactions. The qualitative values were drawn from state open access policy documents, tariff orders, and related regulatory references, while quantitative inputs were compiled through secondary research and primary interactions with more than 15 stakeholders, including manufacturers, association representatives, and RE developers.

The table below summarises the parameters considered, their weightages (and sub-weightages), and the influencing factors. The description column provides the rationale for why each parameter was selected and how it affects RE adoption potential.

Table 3: Weighted parameter framework for secondary steel cluster assessment

Parameter	Total weightage	Sub-weights	Influencing parameter	Description
State GEOA policy favourability	35%	10%	State Open Access policy adoption	Assesses overall openness and clarity of the state's green energy open access (GEOA) framework. States with transparent approval procedures, predictable regulations, and supportive OA norms enable smoother RE adoption by steel clusters
		15%	Banking ecosystem (charges[20], settlement[21], and withdrawals)[22]	High banking charges, shorter settlement cycles, or restrictive withdrawal rules significantly reduce the economic benefits of RE for steel units
		10%	On-ground implementation	Includes operational aspects such as ease of securing evacuation pathways[23] and substation connectivity[24]

20 A regulatory mechanism that allows surplus renewable energy injected into the grid to be withdrawn by the consumer at a later time, subject to time limits, charges, and losses specified by the state regulator.

21 The defined period over which injected and withdrawn energy is netted or financially settled.

22 The conditions governing when and how banked energy can be withdrawn (e.g., time of day restrictions, seasonal limits, or peak hour exclusions), which directly affect the usable value of banked renewable power.

23 The availability of transmission or distribution infrastructure required to transport electricity from a renewable generation source to the grid or end consumer.

24 The ability to connect a generation asset or consumer to an appropriate grid substation with sufficient capacity, voltage compatibility, and timely approval for power injection or withdrawal.

Parameter	Total weightage	Sub-weights	Influencing parameter	Description
Electricity cost savings potential	25%	-	Difference between state grid tariff and RE landed costs	Higher tariff differentials improve cost competitiveness of RE
Electricity consumption	20%	10%	Current electricity consumption	Captures the existing power demand of the cluster. Higher electricity consumption indicates stronger economic incentives for shifting to RE
		10%	Future electricity consumption	Assesses the expected growth in electricity demand based on planned expansions, new units, and increasing production volumes.
Unexplored market	10%	-	Potential of RE penetration in the cluster	Indicates the remaining untapped RE potential in the cluster based on developer presence
Land	10%	5%	Land availability	Assesses availability of contiguous land parcels suitable for RE projects
		5%	Right of way issues[25]	Evaluates the ease of securing transmission corridors, grid connectivity, and power evacuation

Source: JMK Research

Final cluster scores were computed as the weighted sum of the normalised (z-score) values across all selected parameters. This produced a single composite score for each cluster, enabling a comparative ranking across India's major secondary steel hubs.

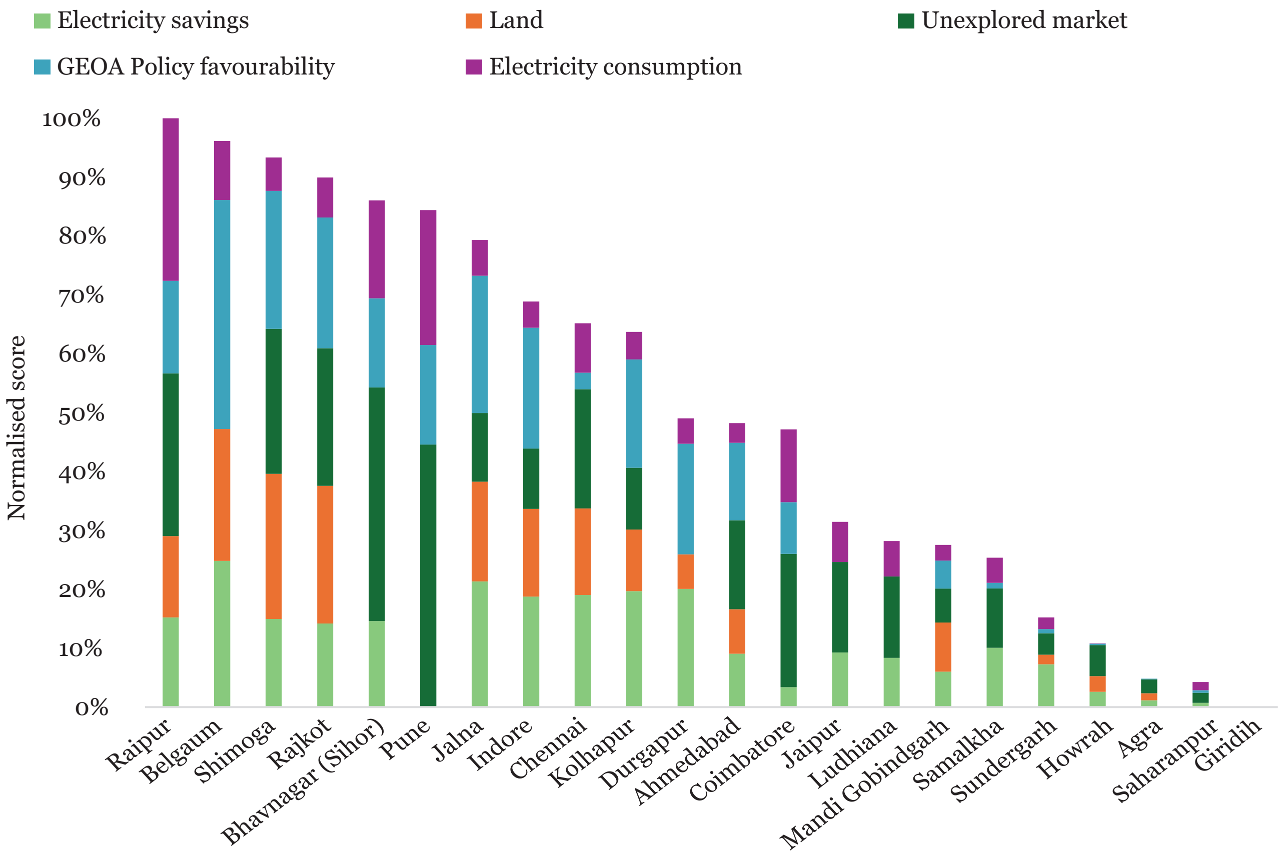
With the scoring framework established, it was applied to India's major secondary steel clusters to derive a composite measure of their RE adoption potential (see cluster deep-dives on **Raipur Steel Cluster** and **Rajkot Steel Cluster** in subsequent sections). The resulting Renewable Energy Electrification Attractiveness Score provides a comparative ranking of clusters.

Renewable energy electrification attractiveness index

The Renewable Energy Electrification Attractiveness Score ranks secondary steel clusters based on their relative potential for RE adoption.

10 Regulatory and land-access clearances necessary for constructing and maintaining transmission infrastructure

Figure 7: Cluster-wise Renewable Energy Attractiveness Index



Source: JMK Research

Note: Cluster rankings are based on a relative assessment using the z-score normalisation method. The index reflects comparative performance across the evaluated clusters and should not be interpreted as an absolute measure of renewable energy attractiveness.

Raipur (Chhattisgarh) ranks the highest score, reflecting its large and diversified industrial base, substantial electricity consumption across induction furnace and rolling mill operations, and strong economic viability for RE integration.

The Karnataka clusters of Belgaum and Shimoga follow, scoring 96% and 93%, respectively, supported by favourable policy conditions and steady industrial loads. However, their relatively homogeneous industrial profiles limit their potential to demonstrate replicability across diverse unit types.

Rajkot ranks next at 90%, underpinned by a diverse MSME ecosystem spanning forging, foundry, casting, and precision engineering. This broad industrial mix creates a varied and stable electricity demand. It offers a greater potential to demonstrate RE adoption across multiple segments. Rajkot has been selected for deeper assessment for this reason and its stronger ecosystem readiness, which can support implementation pathways and facilitate stakeholder alignment for RE integration. Bhavnagar (Sihor) completes the top five with a score of 86%, anchored by its re-rolling and ship-recycling-linked consumption profile.

Collectively, these top five clusters stand out due to their combination of scale, consistent electricity usage, and supportive state-level conditions, placing them in the highest tier of attractiveness for RE deployment.

Table 4: Summary of top five clusters for RE integration

State	Cluster name	Estimated electricity consumption (as of 2024)	Cluster profile	Favourable factors
Chhattisgarh	Raipur	6,862 GWh	Mixed (DRI, foundry, forging, rolling mills, others)	• High electricity demand and strong industrial scale • Mixed cluster profile enabling diversified RE adoption • High un-explored market potential • Supportive banking provisions with manageable implementation risks
Karnataka	Belgaum and Shimoga	Belgaum: 608 GWh Shimoga: 94 GWh	Foundry	• Favourable state-level regulatory and banking provisions • Stable foundry-dominated electricity demand • Low implementation risks and favourable withdrawal rules • Strong policy alignment for RE integration
Gujarat	Rajkot	1,250 GWh	Mixed (foundry, forging, others)	• High developer presence and market maturity • Favourable policy adoption with low on-ground barriers • Stable medium-scale electricity consumption
Gujarat	Bhavnagar (Sihor)	248 GWh	Rolling mills	• Rolling mill-dominated cluster with consistent load patterns • High policy favourability and low implementation challenges • Good land availability supporting solar deployment • Medium electricity demand with strong RE savings potential

Source: JMK Research

The following figure summarises the key takeaways from the cluster-level renewable energy attractiveness assessment.

Figure 8: Key takeaways from the cluster-level renewable energy attractiveness analysis

Key takeaways

RE potential varies significantly across clusters, driven by **differences in electricity demand, industrial scale, land availability, and state-level policy frameworks.**

A weighted Renewable Energy Electrification Attractiveness Index was developed using parameters such as **policy support, cost competitiveness, power consumption, market potential, and land access** to objectively prioritise clusters.

The top five clusters identified were **Raipur, Rajkot, Belgaum, Shimoga, and Bhavnagar,** distinguished by their scale, stable electricity demand, and favourable state conditions, placing them in the highest tier for RE adoption.

Source: JMK Research

5

DETAILED CLUSTER ANALYSIS

Following the development of the Renewable Energy Electrification Attractiveness Index, a deeper assessment was undertaken to understand the practical feasibility of RE adoption within high-potential clusters. As part of this phase, the JMK Research team conducted field visits to the secondary steel clusters in Raipur (Urla and Siltara) and Rajkot (Metoda and Shapar). These visits enabled first-hand interactions with steel MSMEs and cluster associations to understand on-ground challenges, operational realities, and industry perspectives on RE adoption.

Purpose of the cluster-level assessment

This analysis had two objectives:

- Validate the scoring model against ground realities, by examining the production mix, energy consumption patterns, policy implementation challenges, and RE adoption perceptions among steel units.
- Develop a consumer-centric financial model to quantify cost savings and carbon abatement potential of RE adoption in Raipur and Rajkot under different procurement structures.

5.1 Raipur Steel Cluster

Cluster overview

Raipur is one of India's largest and most diverse secondary steel clusters, with over 300[26] MSME-scale induction furnace and rolling mill units. The cluster benefits from strong raw material linkages, with sponge iron and ferrous scrap readily available, making it largely self-sufficient in metallic inputs. The industrial belt is anchored by Urla and Siltara areas. Urla, the older steel-processing zone, now faces development restrictions due to expanding residential areas and environmental sensitivities, while Siltara has become the primary centre for new capacity additions and modernisation.

Over the years, the Raipur cluster has been shifting towards more induction-furnace-plus-rolling-mill configurations. Based on stakeholder consultations, roughly two-thirds of units operate as integrated facilities, while the remaining third continue as standalone rolling mills. The region also has a high concentration of coal-based sponge iron units operating horizontal rotary kilns, reinforcing Raipur's position as a major DRI-producing hub. Stakeholder interactions indicate that many standalone rolling

Table 5: Raipur cluster overview (as of 2025)

Parameter	Description
Number of MSMEs	200–300
Cluster profile	Mixed (induction furnace with rolling mills, standalone rolling mills and DRI units)
Finished steel via EIF	5.9 MTPA (million tonnes per annum)
Annual sponge iron output (DRI)	5.34 MTPA
Steel rolling mill production	0.5 MTPA
Total energy consumption	152 PJ (about 42 TWh/year)
Share of scrap usage	25–30%
Electricity consumption	6.86 TWh/year
Employment	15,000+ people

Source: Stakeholder consultations, Sameeksha, JMK Research

11 Sameeksha | Situation Analysis of Raipur Secondary Steel Cluster | 2024

mills face limited long-term business viability due to sustained margin pressure and the ongoing shift towards integrated operations.

This composition results in one of the highest levels of energy consumption among secondary steel clusters, with electricity contributing around 16% and the remaining 84% driven primarily by coal-based thermal energy.

From an RE standpoint, solar remains the primary opportunity in Raipur. Stakeholder discussions and resource assessments indicate that wind potential in the region is negligible. Therefore, wind-based procurement or hybrid wind-solar configurations are not practically feasible for cluster consumers.

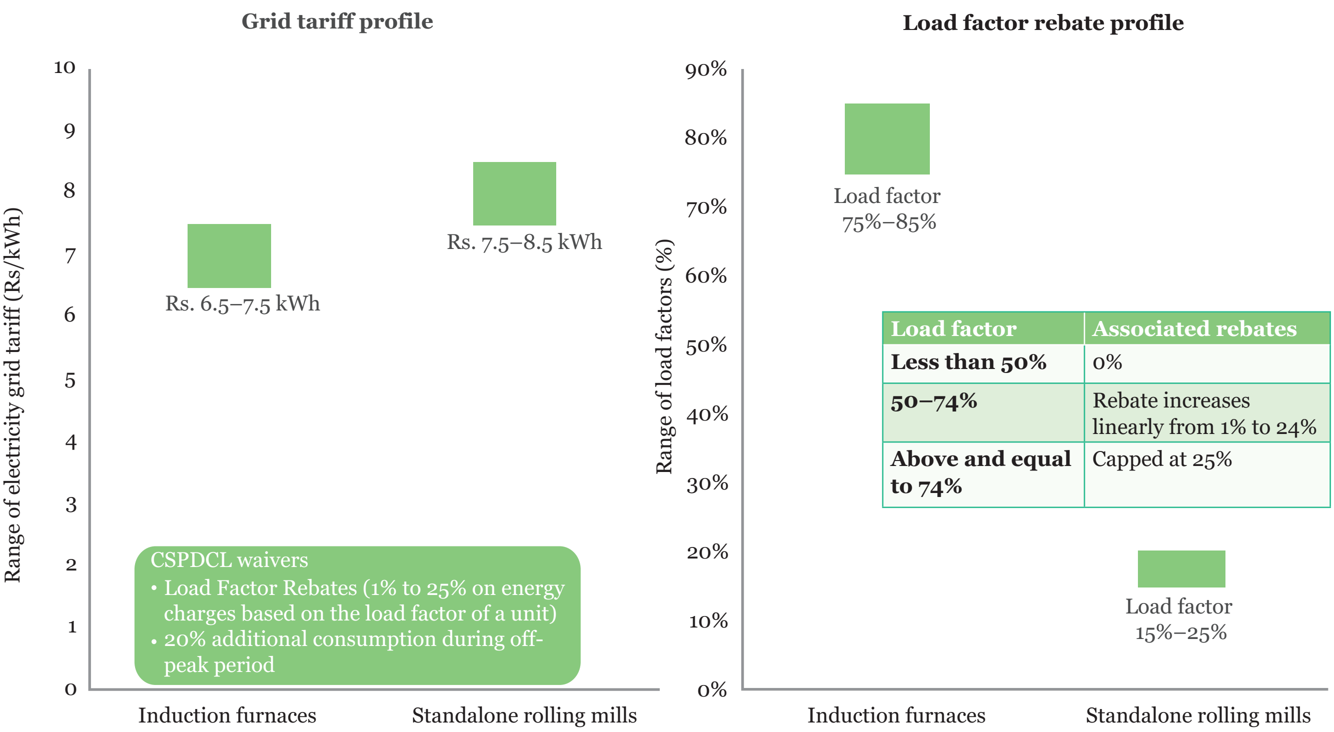
Beyond these established hubs, Tilda, located northeast of Raipur, is emerging as the next potential growth centre because of available land and its proximity to the Raipur-Bilaspur power transmission corridor, which offers favourable connectivity for future industrial expansion.

Grid tariff profile

The Raipur steel cluster is supplied by Chhattisgarh State Power Distribution Company Limited (CSPDCL). As an energy-surplus state with strong infrastructure, Chhattisgarh offers high supply reliability, with minimal outages even during peak industrial operations.

A key determinant of the effective tariff paid by secondary steel units is CSPDCL's Load Factor (LF)[27]-based rebate structure. Units operating above a 50% LF receive rebates on the energy charges that increase linearly up to a maximum of 25% at LF ≥74%. Units operating below 50% LF receive no rebate. CSPDCL also provides an additional incentive for off-peak consumption, allowing withdrawal of up to 20% extra power between 12:00 AM and 5:00 AM, which benefits operations capable of shifting load to night hours.

Figure 9: Grid tariff profile and load factor profile for secondary steel units in Raipur (as of 2025)



Load factor	Associated rebates
Less than 50%	0%
50–74%	Rebate increases linearly from 1% to 24%
Above and equal to 74%	Capped at 25%

Source: CSERC Tariff Order, JMK Research

12 A measure of how consistently electrical capacity is used over time, calculated as average demand divided by peak demand

These LF-linked incentives create distinct tariff outcomes for different unit types. Induction furnace-based units, which typically operate at 75–85% LF, qualify for the maximum 25% rebate and therefore realise a lower effective tariff of Rs 6.5–7.5/kWh. Many furnace operations also take advantage of the off-peak power allowance to further optimise electricity costs.

In contrast, standalone rolling mills operate intermittently and generally maintain LFs of only 15–25%. Since they do not qualify for any LF rebate, their effective tariffs remain significantly higher, ranging from Rs 7.5–8.5/kWh as shown in Figure 9.

While this creates an apparent tariff disadvantage for rolling mills, the relative attractiveness of RE cannot be inferred from tariff levels alone. The overall economics of RE procurement also depend on factors such as load factor, eligibility for tariff rebates, and the applicable open access charges, which vary across consumer categories. Together, the interplay of LF, rebate eligibility, and voltage-level connectivity shapes the tariff landscape in the Raipur cluster and is a central factor influencing RE adoption decisions across unit types.

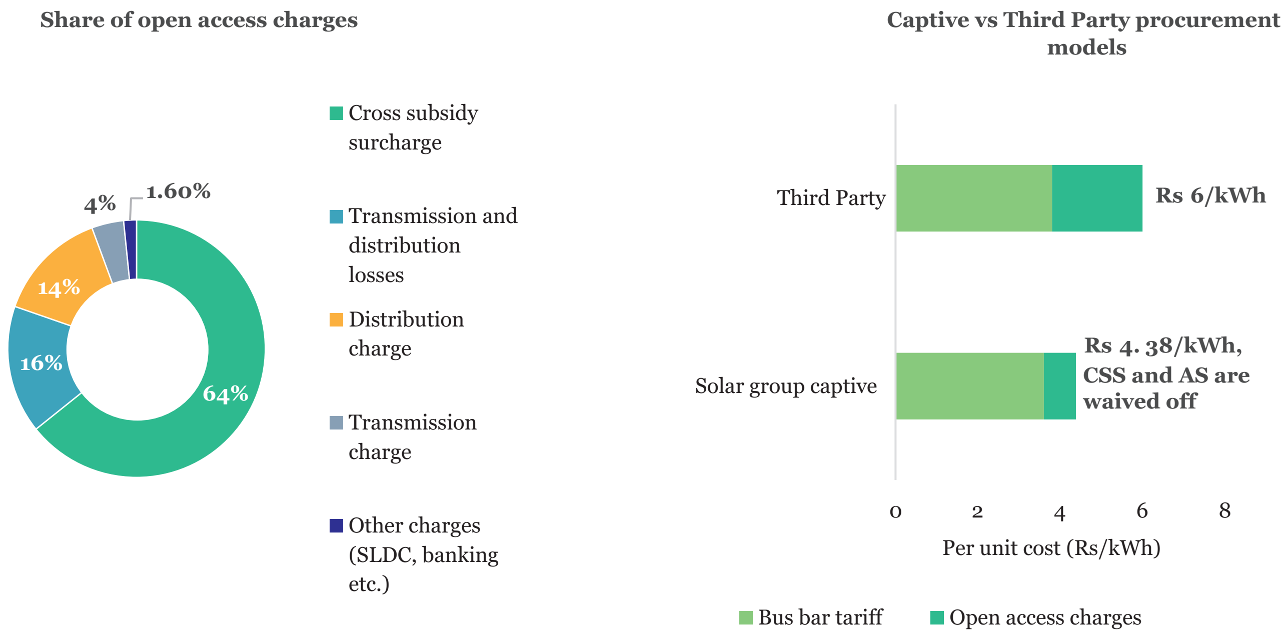
Open access charges profile

Open access charges play a decisive role in shaping the landed cost of RE for steel units in the Raipur cluster. This is especially the case for off-site renewable procurement, where power is transmitted through the state grid network instead of being consumed at the generation site. Because off-site RE must flow through transmission and, in some cases, distribution infrastructure, multiple regulatory charges and losses accumulate along the way, significantly influencing the delivered tariff.

The charges include transmission and wheeling charges, transmission losses, wheeling losses, and surcharges such as the Cross Subsidy Surcharge (CSS) and Additional Surcharge (AS). Among these, CSS constitutes the largest share of total open access (OA) costs, materially affecting the economics of RE procurement for MSME consumers.

As illustrated in the figure above, open access charges form a significant component of the landed solar cost for MSME steel units in Raipur. The composition charts also show that CSS dominates the OA cost

Figure 10: Open access charge composition and landed cost comparison for MSME steel units in Raipur



Source: CSERC Tariff Order, JMK Research stack (64%), making it the single most influential determinant of renewable power competitiveness in the cluster.

While the full suite of OA charges applies by default, certain components such as CSS, AS, or transmission OA charges may be waived depending on the procurement structure or through state-specific concessions. These waivers play a significant role in determining the final landed cost of RE power and are discussed in subsequent sections.

On-ground challenges

Despite Raipur’s strong RE potential, on-ground interactions with rolling mills and integrated units revealed a set of practical constraints that shape the pace and feasibility of RE adoption. Understanding these issues is essential because they directly influence the bankability of RE projects. The table below summarises the key on-ground challenges that emerged during the stakeholder consultations across Urla and Siltara.

Renewable energy procurement analysis

Building on the cluster-level insights and the financial modelling framework, this section assesses the economic viability of RE adoption for integrated furnace-plus-rolling-mill units. The analysis evaluates three procurement pathways: Full Capex, Group Captive, and Third-party Open Access.

Inter-State Transmission System (ISTS)-based procurement is not considered in this analysis, given the phasing out of transmission charge waivers, limited suitability for MSME steel consumers operating at lower voltage levels, and delays associated with ISTS connectivity and approvals.

Table 6 provides below provides a comparative overview of the key characteristics of the three procurement models assessed in this study. A critical differentiator across these models is the treatment of open access charges. On-site Full Capex systems avoid

Table 6: Key challenges to renewable energy integration in Raipur

Challenges	Description
Land	▪ Limited availability of contiguous land parcels for RE projects and fragmented landholding patterns. ▪ Sharp increases in land prices once plots are identified for solar use, making acquisition difficult.
Evacuation and substation connectivity issues	▪ Limited availability of affordable land near major substations, causing delays in securing evacuation connectivity. ▪ Existing substations around Siltara and Tilda are already load-constrained, creating bottlenecks for new connections.
Financing access	▪ Tight working-capital cycles restrict MSMEs’ ability to allocate funds for high-capex RE projects. ▪ Limited access to long-tenure, low-cost financing remains a barrier for smaller units.
Awareness and coordination	▪ Many MSMEs lack awareness of the Group Captive procurement model, equity participation rules, and procedural requirements. ▪ Smaller units struggle with coordination for aggregation-based RE procurement.
Operational constraints	▪ Heavy dust accumulation in Urla and Siltara reduces panel efficiency and increases cleaning requirements. ▪ Limited rooftop and ground space restrict the feasibility of on-site solar projects.

Source: Stakeholder Consultations, JMK Research all major open access because the generation is not routed through the grid, while Group Captive projects qualify as captive generation under the Electricity Rules, enabling CSS and AS waivers when equity and consumption criteria are met. These structural exemptions materially lower the landed cost compared to Third-party Open Access, where the full suite of OA charges continues to apply.

The financial model incorporates key assumptions presented in the table below. The model considers a representative secondary steel consumer operating an induction furnace and rolling mill configuration with an annual production of approximately 0.1 MTPA. This scale is aligned with typical on-ground operating profiles and reflects a medium-scale long-product manufacturer. The assumed production level provides a realistic baseline for assessing renewable procurement strategies for a secondary steel unit with a steady, high-load power demand.

Figure 11: Comparative matrix of renewable energy procurement options

RE procurement mode	Ownership details	Upfront investment	O&M responsibility	Financial requirement	Land requirement	Risk	Tariff profile
Full Capex (on-site)	100% owned by the consumer	Full project capex borne by consumer	Consumer	Consumer raises and services debt	Within consumer premises	Fully with the consumer	Lowest long-term cost
Full Capex (Off-site)	100% owned by the consumer	Full project capex borne by consumer	Consumer	Consumer raises and services debt	Consumer procures land	Fully with the consumer	Lower than OA; higher than on-site
Group Captive	Shared ownership (≥26% consumer equity; 51% consumption)	Consumers invest only their equity share	Developer handles O&M	Equity contribution; debt at consumer level (if needed)	Developer procures land	Shared	Lower than third-party; higher than Full Capex
Third-party Open Access	100% owned by developer	No capex from consumer	Developer fully manages O&M	None	Developer procures land	Developer	Highest landed cost

Source: JMK Research

Note: Operations and maintenance (O&M) responsibility refers to the party responsible for the day-to-day operation, performance monitoring, maintenance, and repair of the RE asset throughout its lifecycle, including ensuring plant availability and managing technical risks.

Table 7: Key assumption parameters for integrated units at Raipur

Parameters	Full Capex	Group Captive	Third Party
Project size	10 MW_{AC}; 12.5MW_{DC}	10 MW_{AC}/consumer; 12.5 MW_{DC}/ consumer	10 MW_{AC}; 12.5 MW_{DC}
Debt-equity ration (project level)	70:30 (consumer financed)	70:30 (SPV level)	70:30 (developer financed)
Capex (including transmission and land)	Induction and rolling mills - $Solar_{DC}$ - Rs 2.85 Crore/MWp ($solar_{AC}$ - Rs 3.5 crore/MW)		
Debt terms (as of October 2025)	8% repayable in 10 years		Nil
Steel unit load factor	Induction furnace + rolling mills – 80%		
Grid emission factor	0.71 tCO_2/MWh		

Source: JMK Research

Note: Alternating Current (AC) refers to the usable electrical output capacity delivered to the grid or consumer connection point, while Direct Current (DC) refers to the installed solar module capacity before conversion through inverters. During conversion from DC to AC, some energy losses occur due to inverter efficiency limits and system design, which is why solar projects are typically sized higher in MW_{DC} than MW_{AC} to compensate for these conversion losses and maximise effective output. Grid emission factor represents the average CO_2 emissions intensity of electricity supplied from the grid, calculated using the Combined Margin methodology published by the Central Electricity Authority (CEA).

For each procurement pathway, the model calculates three core outputs over a 25-year RE project lifespan:

- **Cash flow:** Computed annually over the 25-year project life to quantify the net financial gain to the consumer.
- **Average annual cost savings per consumer:** A single representative value that captures the typical yearly savings from renewable procurement, enabling comparison across models.
- **Average annual carbon abatement:** Calculated using the grid emission factor (0.71 tCO_2/MWh), reflecting the average yearly CO_2 reduction achievable through renewable electricity.

In addition to the modelled financial and emissions outcomes, emerging carbon pricing mechanisms in India, such as the proposed Carbon Credit Trading Scheme (CCTS), are expected to be operationalised over the next few years and could enable monetisation of emission reductions, creating an additional revenue stream for early adopters of low-carbon electricity.

The following subsections present the results for each procurement pathway, followed by a comparative summary of savings potential, landed cost differences, and carbon abatement across procurement models.

Full Capex (on-site and off-site)

The 25-year cashflow profile for integrated units shows a distinct gap between on-site and off-site configurations, with on-site installations consistently delivering the highest and most sustained savings because all generated electricity is consumed directly at the plant.

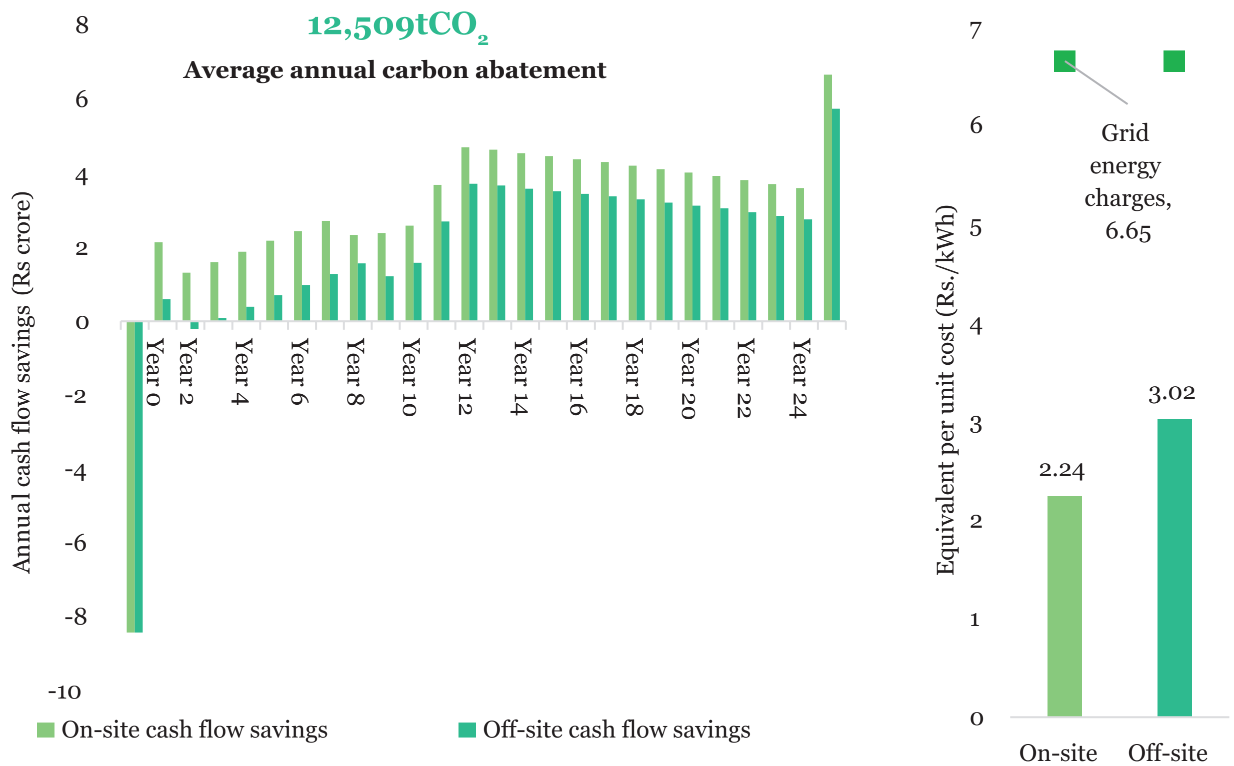
Across both configurations, early-period cash flows are shaped largely by debt servicing. Annual savings increase steadily through the loan tenure and rise sharply once debt obligations end, allowing the full difference between renewable power costs and grid electricity tariffs to accrue to the consumer.

A 10 MW_{AC} on-site solar installation requires an upfront investment of roughly Rs 35 crore, delivering average annual cashflow savings of about Rs 3.5 crore post-debt tenure, compared to approximately Rs 2.3 crore for off-site configurations. The project is estimated to abate approximately 12,509 tCO_2 annually. The uplift observed in the final year reflects the salvage value incorporated into both asset configurations, boosting end-of-life returns. A practical factor unique to Raipur is the region's heavy dust deposition, which increases panel cleaning frequency and can reduce on-site solar output if not managed proactively.

Group Captive

The Group Captive results show a strong and stable savings profile over the 25-year period. A consumer invests a relatively small share of project equity of Rs 2.73 crore for a 10 MW allocation. This equity can be financed through consumer-level debt, while the project-level investment is financed separately through Special Purpose Vehicle (SPV)-level debt managed by the developer. As a result, the consumer's balance sheet exposure remains minimal, yet the savings profile reflects the economic efficiency of a fully debt-leveraged utility-scale project.

Figure 12: Annual cashflow savings profile for induction furnace + rolling mill units under Full Capex (on-site vs off-site) solar procurement



Source: JMK Research

Note: Escalation applied in the model - energy charge escalation of 2% per annum for the first 10 years, then 0.3% per annum thereafter. Dip in the ninth to tenth year corresponds to the expiry of the tax loss carry-forward period. The spike in 2025 includes salvage value of the RE asset.

The cashflow profile for the Group Captive model is shaped by two factors:

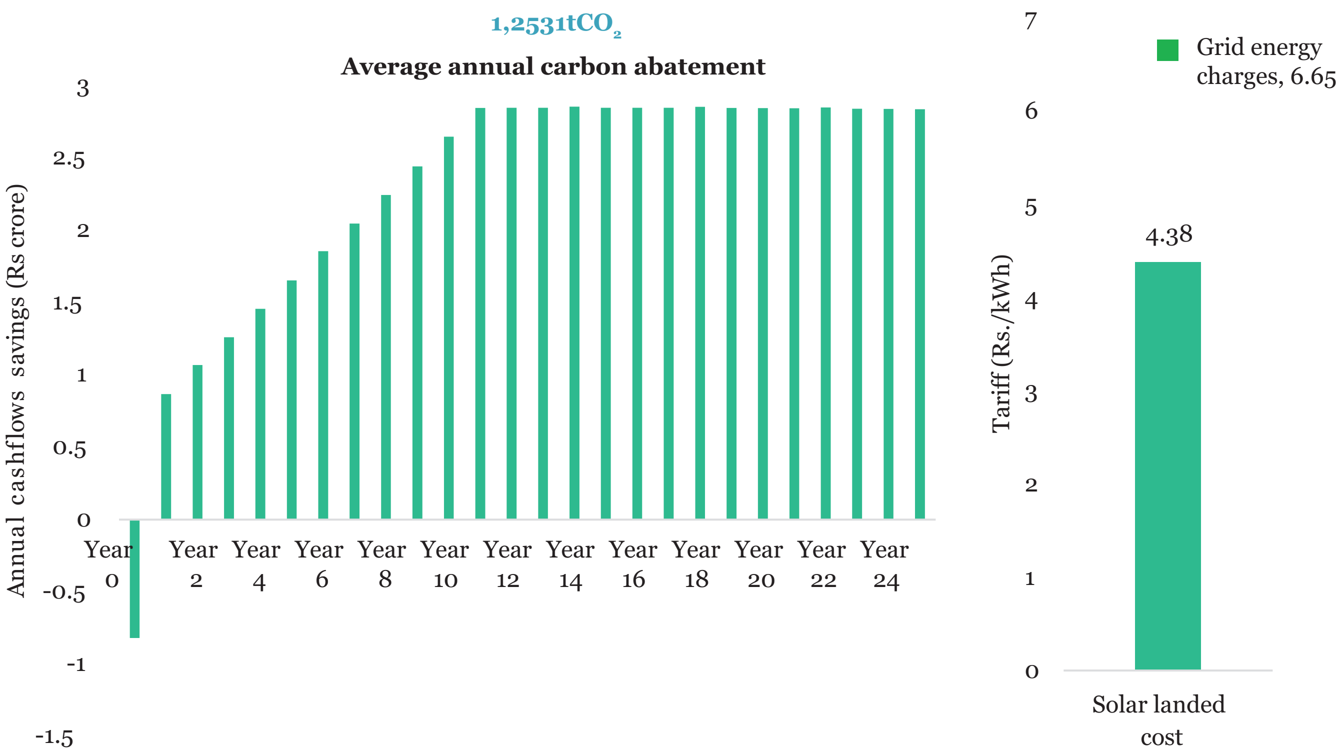
- Limited upfront equity contribution
- Strong tariff spread between the landed solar cost and energy charges, meaning the effective tariff remains significantly lower than the prevailing grid energy charge, allowing consumers to realise consistent per-unit savings over the project life.

During the years in which the SPV services its project-level debt, consumer savings rise steadily. Over the project life, average annual cashflow savings are approximately Rs 2.4 crore, driven by the relatively lower and stable landed cost of solar power compared to grid tariffs, along with the high and consistent utilisation levels typical of furnace-plus-rolling-mill units.

Beyond the tariff advantage, the Group Captive model also reduces operational responsibility for the consumer, as the developer manages project construction, performance, and O&M. This shifts key implementation risks away from the consumer while still providing ownership-linked tariff stability and predictable long-term returns.

As shown in the figure below, the Group Captive configuration delivers an average annual carbon abatement of approximately 12,531 tCO_2, while maintaining a competitive landed solar tariff of about Rs 4.38/kWh compared to prevailing grid energy charges of roughly Rs 6.65/kWh.

Figure 13: Annual cash flow savings for induction-furnace-plus-rolling-mill units under the group captive model



Source: JMK Research

Note: Grid energy charge escalation at 2% annually for the first 10 years and 0.3% thereafter; open access charges escalation at 0.3% annually.

Third party

The Third-Party model produces the weakest savings curve of all options. Savings are not realised in the initial years and improve only gradually over time, turning marginally positive in the later years.

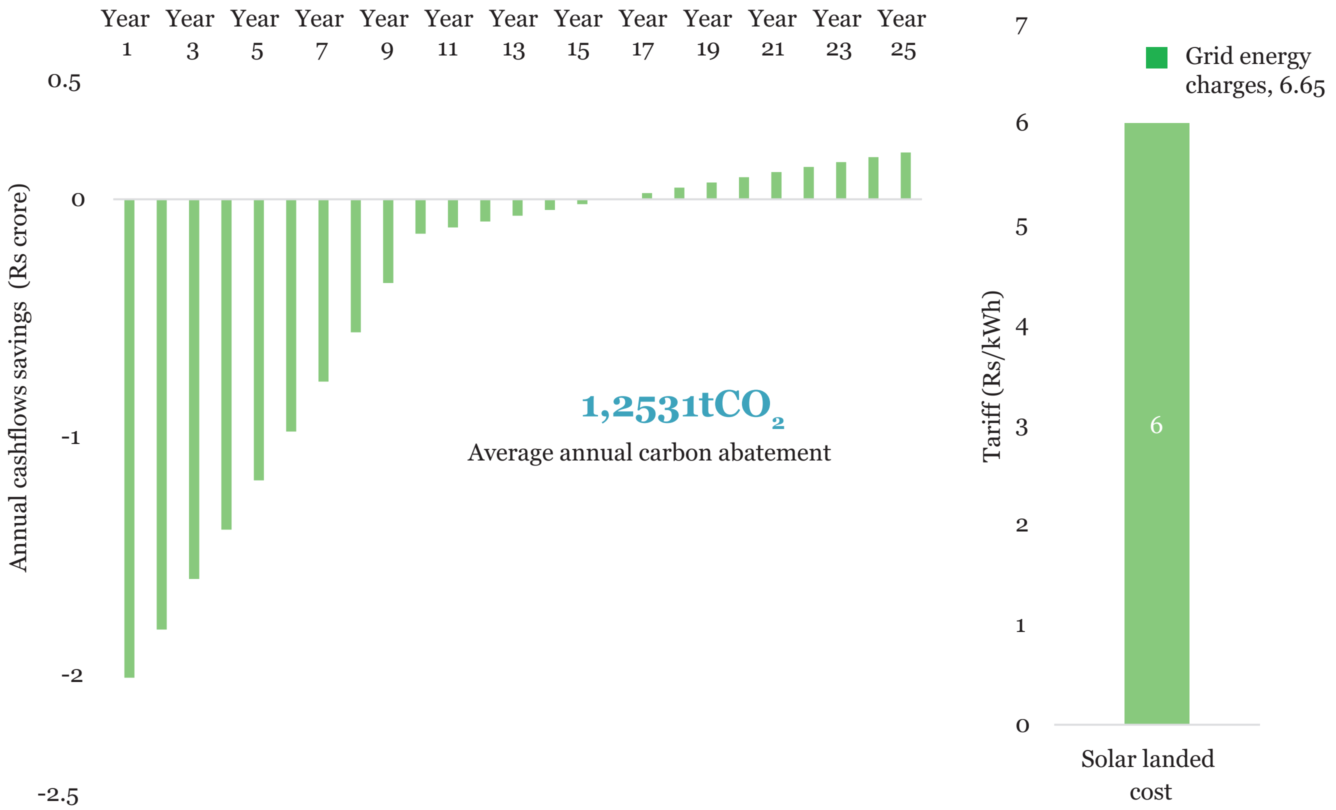
The model's performance is highly sensitive to regulatory changes. Any increase in open access charges (CSS or AS) or tightening of the transmission-charge waiver can erode the projected savings. Operational factors such as Power Purchase Agreement (PPA)[28] tenor, billing and settlement timelines, and exposure to curtailment or scheduling-related losses also shape realised savings and can directly reduce the already-thin margin.

Overall, while the Third-Party route offers simplicity and zero capital exposure, it remains the least value-accretive pathway over a 25-year horizon compared to other alternatives.

Comparative evaluation of RE procurement models

The 25-year cashflow analysis establishes a clear performance hierarchy among the procurement routes: On-site Full Capex delivers the highest lifetime benefit, followed closely by Group Captive, with off-site Full Capex and third party trailing due to higher exposure to grid-routed adjustments.

Figure 14: Annual cashflow savings for the Third-party Open Access model for induction furnace + rolling mill units



Source: JMK Research

Note: The model assumes an annual escalation of 2% in grid energy charges for the first 10 years, reducing to 0.3% thereafter, while open access charges escalate at 0.3% per year.
Savings are not realised during the initial years due to the 25% load factor rebate applied to grid energy charges. They turn positive only once grid tariff escalation becomes sufficient to offset the impact of these rebates.

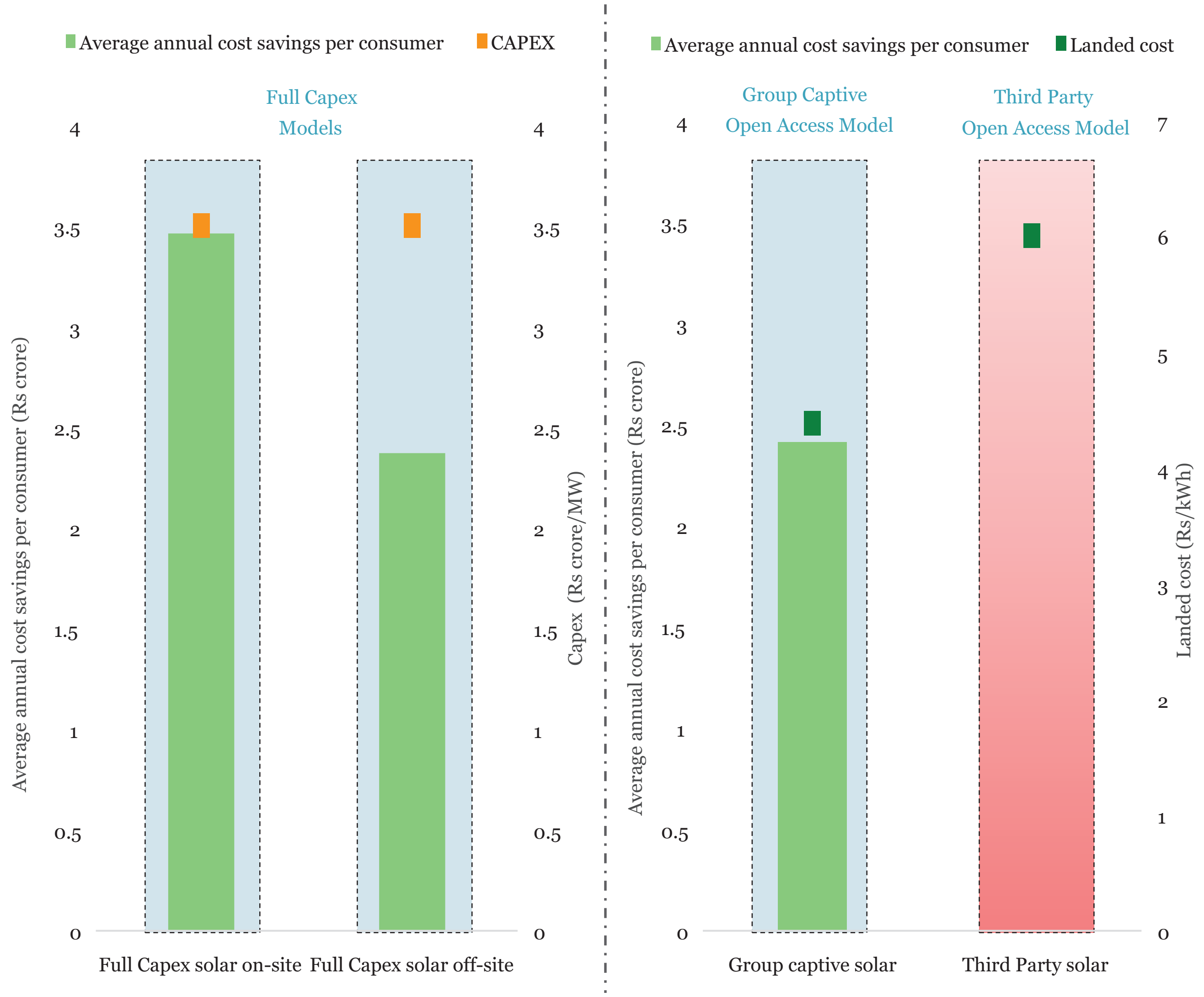
13 PPA (Power Purchase Agreement) refers to the long-term contractual arrangement between the electricity buyer and the renewable energy developer that defines tariff terms. The conditions of the PPA influence price certainty, financing structure, and the stability of realised savings over the project life.

A major determinant of these differences is the volume of energy ultimately delivered to the consumer. Any procurement model that injects power into the grid faces transmission and distribution losses and other OA-linked adjustments that compress the effective tariff advantage. On-site Full Capex avoids almost all these losses, enabling the highest long-term savings. That said, the on-site model must account for Raipur's heavy dust environment, which necessitates more frequent cleaning and may heavily impact performance if not managed proactively.

Taken together, the results suggest a clear set of procurement choices. On-site Full Capex is the strongest economic option wherever land and capital capacity are available, while Group Captive offers a highly competitive alternative with far lower upfront commitment and smoother savings over time. Off-site Full Capex and Third Party remain viable but deliver lower cashflow savings due to grid-injection losses and higher sensitivity to regulatory adjustments. That said, Group Captive models should be preferred in practice, as it enables steel producers to focus on core steelmaking while outsourcing power supply to specialised RE developers.

Landed electricity cost (Rs/kWh) is shown only for open-access procurement models (Group Captive and Third Party), where consumers pay a delivered tariff.

Figure 15: Comparative annual cost savings, landed cost, and capex requirements across renewable energy procurement models for induction furnace–plus–rolling-mill units in Raipur



Source: JMK Research

Note: Green shaded bars indicate financially viable procurement models based on the modelled savings and tariff outcomes, while red shaded bars represent comparatively less viable configurations.

For Full Capex models, the relevant financial metric is upfront CAPEX (Rs Cr/MW) rather than landed cost, as electricity is generated and consumed behind the meter.

As compared to the induction-plus-rolling-mills, the standalone rolling mills in Raipur face comparatively higher business uncertainty and weaker long-term operational visibility, which makes committing to 25-year RE assets more challenging. Lower and less stable load utilisation reduces the effective capture of solar savings, and fixed open-access and regulatory costs further compress margins, particularly for off-site structures.

The figure below summarises the key financial and carbon abatement indicators across procurement models for induction furnace–plus–rolling-mill units in Raipur.

Figure 16: Key findings for RE procurement models for Raipur

12,500 tCO_2 abated annually

RE procurement model suitability for a 0.1 MTPA integrated steel producer

Group Captive

Most practical route

Investment required
Rs 2.7 crore

Tariff savings vs grid
34%

Annual cash flow savings of about
Rs 2.4 crore,
over 25 years

Simple payback
1–2 years

34% below grid
Tariff discount

Full Capex

On-site and off-site

Investment required
Rs. 35 crore

Tariff savings vs grid
Up to 55–66%

Annual cash flow savings of about
Rs 3.4–2.3 crore
over 25-years

Simple payback
On-site: 4–5 years
Off-site: 7–8 years

Heavy dust risk
Frequent cleaning

Third Party

Least viable route

Investment required
Nil

Tariff savings vs grid
Negligible

Annual cash-flow savings
Zero

Simple payback
-

Regulatory risk
CSS and waiver exposure

Source: JMK Research

Note: The numbers above are indicative values. The actual figures can vary significantly due to substantial on-ground heterogeneity across unit types, including differences in scale, production configurations, and operating practices.

5.2 Rajkot steel cluster

Cluster overview

Rajkot is one of India's most diversified secondary steel and metalworking ecosystems, comprising a mix of foundries (sand casting and investment casting), forging units, grey iron (cast iron) manufacturers, and a well-established bearing industry.

Based on stakeholder interactions, the industrial composition is dominated by grey cast iron units (roughly 55–60% of establishments), followed by forging units (~15–20%), investment casting (~10–15%), and other specialised engineering segments, including bearing manufacturing, forming the remainder.

Easy access to scrap through nearby trading hubs such as Bhavnagar, combined with a predominantly scrap-based production route, contributes to relatively lower process emissions than in coal-intensive clusters. Raw material procurement remains largely market-based, with DRI and pig iron sourced externally rather than produced within the cluster.

A large share of Rajkot's production, particularly investment castings, is export-oriented, linking the cluster closely to international demand cycles and exposing it to geopolitical trade-related fluctuations. As global markets increasingly prioritise low-carbon manufacturing, through mechanisms such as the Carbon Border Adjustment Mechanism, producers face mounting pressure to reduce embedded emissions and remain competitive.

Table 8: Rajkot cluster overview (as of 2025)

Parameter	Description
Number of MSMEs	About 2,000+ grey iron and ductile iron units; 170–225 investment casting units; 150–200 forging units and more than 150 bearing units
Cluster profile	Mixed (investment casting, sand casting, forging, grey cast iron, bearing industry)
Production output	About 1.5 MTPA (foundry 0.69 MTPA, investment casting 0.072 MTPA, forging 0.63 MTPA)
Total energy consumption	83 PJ (about 23 TWh)
Share of scrap usage	About 40–70%
Electricity consumption	About 1.25 TWh/year
Employment	More than 30,000 in foundries; around 15,000 in forging and bearing segments combined

Source: Sameeksha, JMK Research

Note: The production output, electricity consumption and energy consumption are estimated.

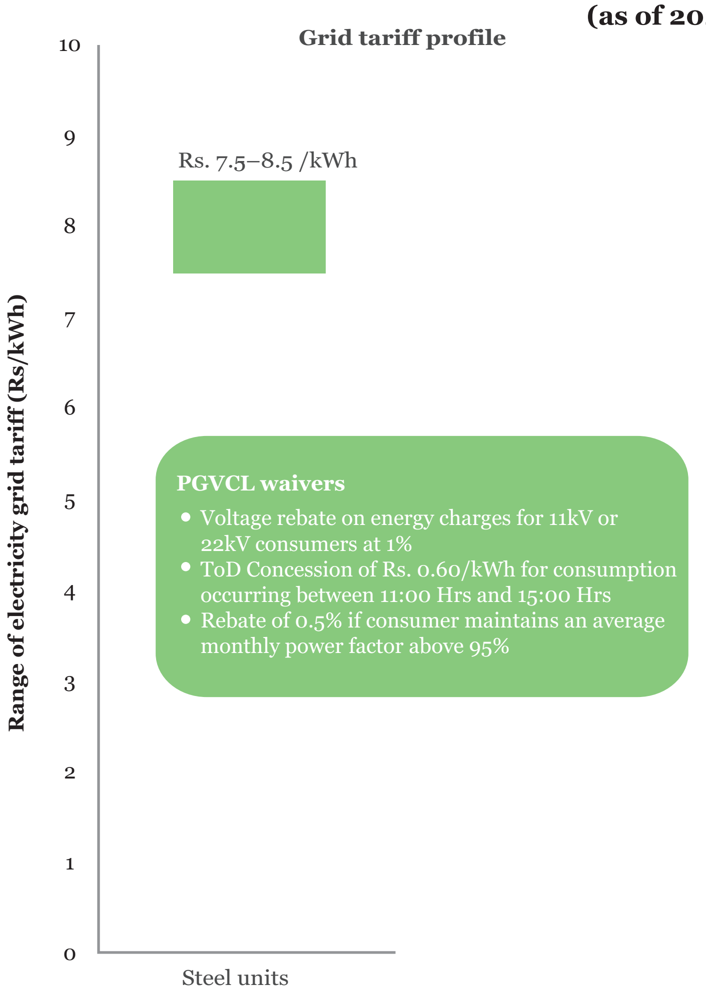
From an RE perspective, Rajkot has already seen adoption across several casting and forging units, supported by the presence of experienced EPC players[29] and growing familiarity with open-access procurement models. While renewable integration is already visible within parts of the cluster, significant headroom remains for further deployment as companies continue to align project sizing with operational load profiles and evolving policy conditions. Moreover, Rajkot benefits from access to viable wind resources in nearby districts, enabling wind and wind–solar hybrid (WSH) procurement pathways alongside solar-based solutions. Together, these factors position the cluster as a mature yet still expanding RE market within the secondary steel ecosystem.

Grid tariff profile

The Rajkot steel and engineering cluster is supplied by Paschim Gujarat Vij Company Limited (PGVCL), with most units connected at the 11 kV tariff category. Electricity supply across the region is stable, enabling continuous-process operations typical of foundries. As illustrated in the figure below, the effective grid tariff is shaped by a combination of contract demand-linked energy charges, time-of-day (ToD) adjustments, and periodic fuel cost revisions.

Under the tariff framework, industrial consumers are billed through fixed demand charges, base energy charges, and the fuel and power purchase

Figure 17: Grid tariff profile and time-of-day structure for secondary steel units in Rajkot (as of 2025)



Energy charge structure by billing demand

Billing contract demand	Energy charges applicable
Up to 500 kVA of billing demand	Rs 4/kWh
Above 500 kVA and up to 2500 kVA of billing demand	Rs 4.2/kWh
Above 2500 kVA of billing demand	Rs 4.3/kWh

Time-of-day pricing structure for industrial consumers

Time Period	Category	Additional charge/concession
07:00 to 11:00 and 18:00 to 22:00	Peak hours	Rs 0.45/kWh (Demand up to 500 kVA) or Rs 85/kWh (Demand > 500 kVA)
11:00 to 15:00	Solar hours	- Rs 0.6/kWh **(Rebate)**
15:00 to 18:00 and 22:00 to 07:00	Normal hours	Base energy rate

Source: PGVCL Tariff Order, JMK Research

Note: Time of day charges and discounts charges are applicable only to consumers with smart meters.

14 EPC (Engineering, Procurement and Construction) players are specialised project developers responsible for the end-to-end execution of renewable energy installations, including system design, equipment procurement, construction, commissioning, and performance integration.

adjustment surcharge (FPPAS). FPPAS reflects fluctuations in the utility's power procurement costs and introduces variability in realised tariffs even when base energy rates remain unchanged. Energy charges also vary by contract demand slabs, meaning that units with higher sanctioned demand experience different cost structures.

In addition to the base tariff structure, PGVCL applies ToD adjustments that influence operational scheduling. Peak-hour consumption attracts additional charges, while specific daytime and off-peak windows provide concessional energy rates, encouraging load shifting where feasible. The tariff order also includes electrical efficiency-linked incentives, such as power factor (PF) rebates for consumers maintaining PF levels above prescribed thresholds, alongside voltage-level benefits for higher-tension connections. Unlike clusters such as Raipur, where load factor rebates materially reduce effective tariffs, Rajkot's tariff is primarily driven by ToD behaviour and electrical efficiency measures.

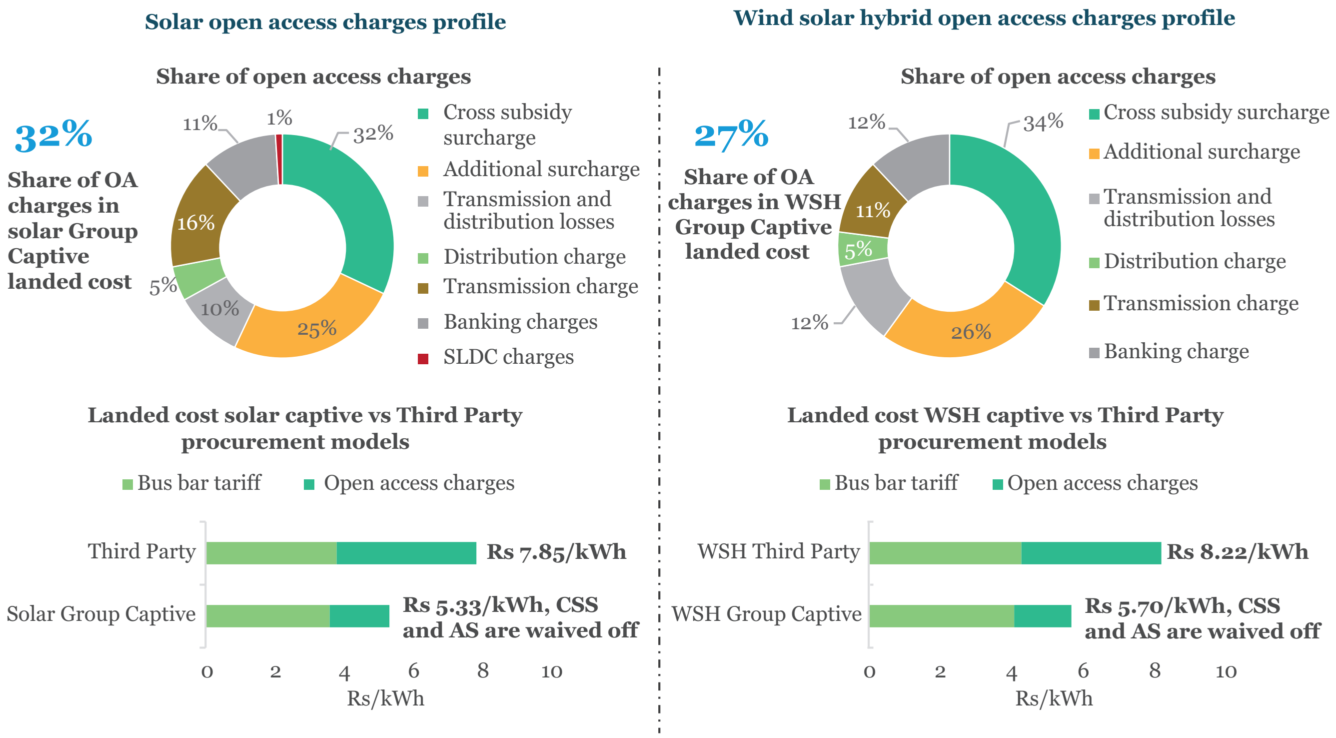
Overall, the interaction between 11 kV connectivity, contract demand structures, ToD tariff adjustments, and FPPAS variability defines the grid tariff landscape in the Rajkot cluster. These factors collectively shape electricity cost outcomes and play a central role in influencing RE adoption decisions across steel units.

Open access charges profile

Rajkot's steel MSMEs are connected at the 11 kV level, where open access charges play a decisive role in determining the realised cost of renewable electricity. As illustrated below, open access charges account for roughly 32% of the landed cost in solar Group Captive configurations and about 27% in WSH procurement.

The composition of charges reflects that CSS and AS form the largest share of the open access costs across both solar and WSH pathways. A distinctive feature of Gujarat's framework is the application of a fixed banking charge of approximately Rs 1.50/kWh on banked RE. This flat-rate mechanism introduces a cost layer that influences optimal system sizing decisions for MSMEs.

Figure 18: Open access charge composition and landed cost comparison for solar and WSH energy procurement



Source: PGVCL Tariff Order, JMK Research

Earlier policy frameworks (like Gujarat Solar Power Policy 2015) permitted relatively flexible within-cycle banking without explicit per-unit charges or defined quantitative limits, which has since evolved under the GERC Green Energy Open Access Regulations (2024) into a capped, charge-based structure. Gujarat currently permits banking up to 30% of the injected energy, which becomes particularly relevant given the relatively high-capacity utilisation factors (CUF) of solar and wind across the region. The combination of strong CUFs and capped banking encourages power consumers to balance renewable capacity with daytime consumption profiles rather than relying excessively on banked energy.

Cost comparisons further highlight the role of procurement structure in managing open access exposure. Third-party procurement results in landed tariffs of approximately Rs 7.85/kWh for solar and Rs 8.16/kWh for WSH, whereas Group Captive or captive arrangements, where CSS and AS are waived, reduce landed costs to about Rs 5.33/kWh and Rs 5.64/kWh, respectively.

Unlike clusters like Raipur, where tariff optimisation is driven by load factor rebates, RE adoption in Rajkot is primarily driven by demonstrated cost savings. However, realising these savings is contingent on navigating Gujarat's regulatory framework, where procurement structuring and banking constraints present operational challenges.

On-ground challenges

Stakeholder interactions across Rajkot indicate that RE adoption is influenced less by financing constraints than by regulatory design, operational alignment, and procurement structuring challenges. The table below summarises the key on-ground challenges observed during stakeholder consultations across the Rajkot cluster.

Table 9: Key challenges to RE integration in Rajkot

Challenges	Description
Land issues	▪ Identifying contiguous land parcels near evacuation infrastructure remains challenging despite overall industrial growth ▪ Competition from industrial expansion and speculative pricing increases the complexity of securing land for renewable projects
Banking restrictions and capacity downsizing	▪ Gujarat's 30% banking quantum limit constrains the scale of renewable installations. ▪ Gujarat GEOA framework requires energy scheduling and settlement on 15-minute time blocks, which complicates banking utilisation and increases the risk of energy lapsing if not precisely matched with consumption. ▪ Several units intentionally size solar plants conservatively to avoid excess generation that may not be fully settled against consumption.
Awareness	▪ While solar adoption is familiar within the cluster, there is limited understanding of Group Captive procurement structures.
Scheduling and compliance requirements	▪ Steel MSMEs lack the in-house technical capacity to manage forecasting, scheduling, and settlement processes required under the banking framework and therefore rely on external scheduling or energy management agencies.
Operational constraints	▪ Limited rooftop and ground space reduce the feasibility of deploying on-site solar projects

Source: Stakeholder Consultations, JMK Research

Renewable energy procurement analysis

Building on the RE procurement analysis framework introduced in this study, this section applies the same financial modelling approach to the Rajkot cluster to evaluate procurement outcomes under Gujarat's regulatory context. The assessment considers a foundry unit, reflecting typical operational characteristics observed during stakeholder consultations, and extends the analysis to include both solar and WSH procurement pathways given the cluster's resource profile. The table below summarises the key assumptions applied in the analysis.

Based on stakeholder consultations, representative investment casting units operate at around 2,400 tonnes per annum, while grey iron casting facilities typically produce 10,000–12,000 tonnes annually.

Unlike the Raipur assessment, which focused on integrated furnace units and solar procurement, the Rajkot analysis evaluates foundry units and incorporates both solar and WSH pathways due to the cluster's favourable wind resource profile.

Full Capex (on-site and off-site)

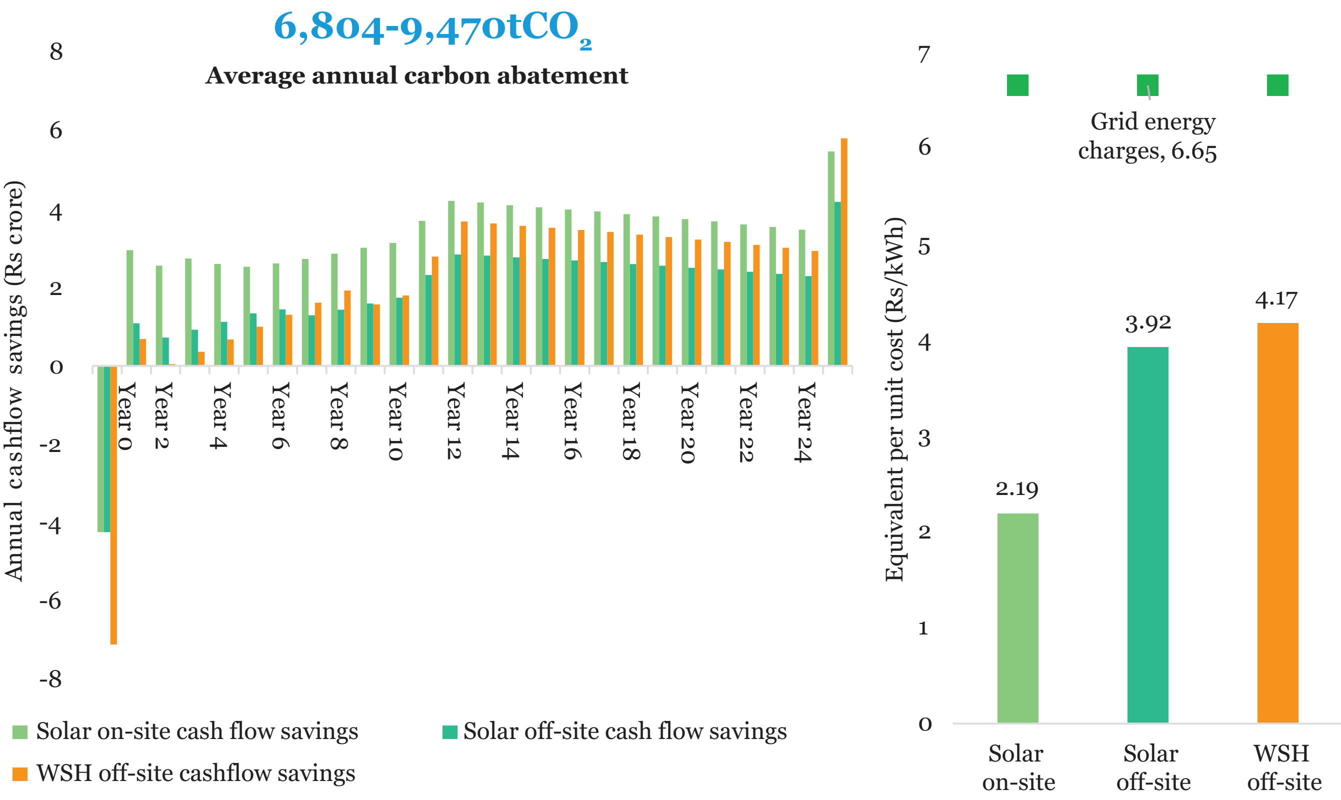
In Rajkot, several steel MSMEs have already adopted Full Capex solar procurement, supported by clearer cost visibility and the ability to maximise direct renewable utilisation. Consistent with the on-site versus off-site dynamics established for Raipur, on-site solar again delivers the highest savings. The Rajkot assessment additionally evaluates a WSH off-site procurement, reflecting the cluster's wind resource, a configuration not available in Raipur.

Table 10: Key assumption parameters for Rajkot foundries

Parameters	Solar Full Capex (on-site and off-site)	Solar Group Captive	Solar Third Party	WSH Full Capex (Off-site)	WSH Group Captive	WSH Third Party
Project size	5 MW_{AC}; 6.25MW_{DC}	5 MW_{AC}/ consumer; 6.25MW_{DC}	5 MW_{AC}/ consumer; 6.25MW_{DC}	5 MW_{AC}; 6.25MW_{DC}	5 MW_{AC}/ consumer; 6.25MW_{DC}	5 MW_{AC}/consumer; 6.25MW_{DC}
Debt-equity ratio (project level)	70:30 (Consumer financed)	70:30 (SPV level)	70:30 (developer financed)	70:30 (consumer financed)	70:30 (SPV level)	70:30 (developer financed)
Capex (incl transmission and land)	$Solar_{DC}$- Rs 2.85 crore/MWp ($Solar_{AC}$- Rs 3.5 crore/MW) and WSH – Rs 6 crore/MW					
Debt terms at consumer level (as of January 2026)	8% repayable in 10 Years		Nil	8% repayable in 10 Years		Nil
Grid emission factor	0.71 tCO_2/MWh					

Source: JMK Research

Figure 19: Annual cashflow savings profile under Full Capex (on-site vs off-site) solar procurement



Source: JMK Research

Note: The model assumes an annual energy charge escalation and FPPAS of 2% for the first 10 years, then 0.3% per annum thereafter.

The cashflow profile reflects a front-loaded investment phase followed by steadily rising savings as tariff escalation compounds over time. On-site systems demonstrate stronger early-period performance, while off-site configurations show a more gradual increase in savings.

A comparison of the procurement pathways highlights clear differences in cashflow performance. On-site solar delivers the highest savings, supported by direct consumption. Off-site solar exhibits lower but stable savings, reflecting the influence of open-access charges on realised tariffs. WSH off-site projects show the largest initial cashflow decline due to higher capital, while the hybrid generation profile enables a steadily increasing savings trajectory over the project life.

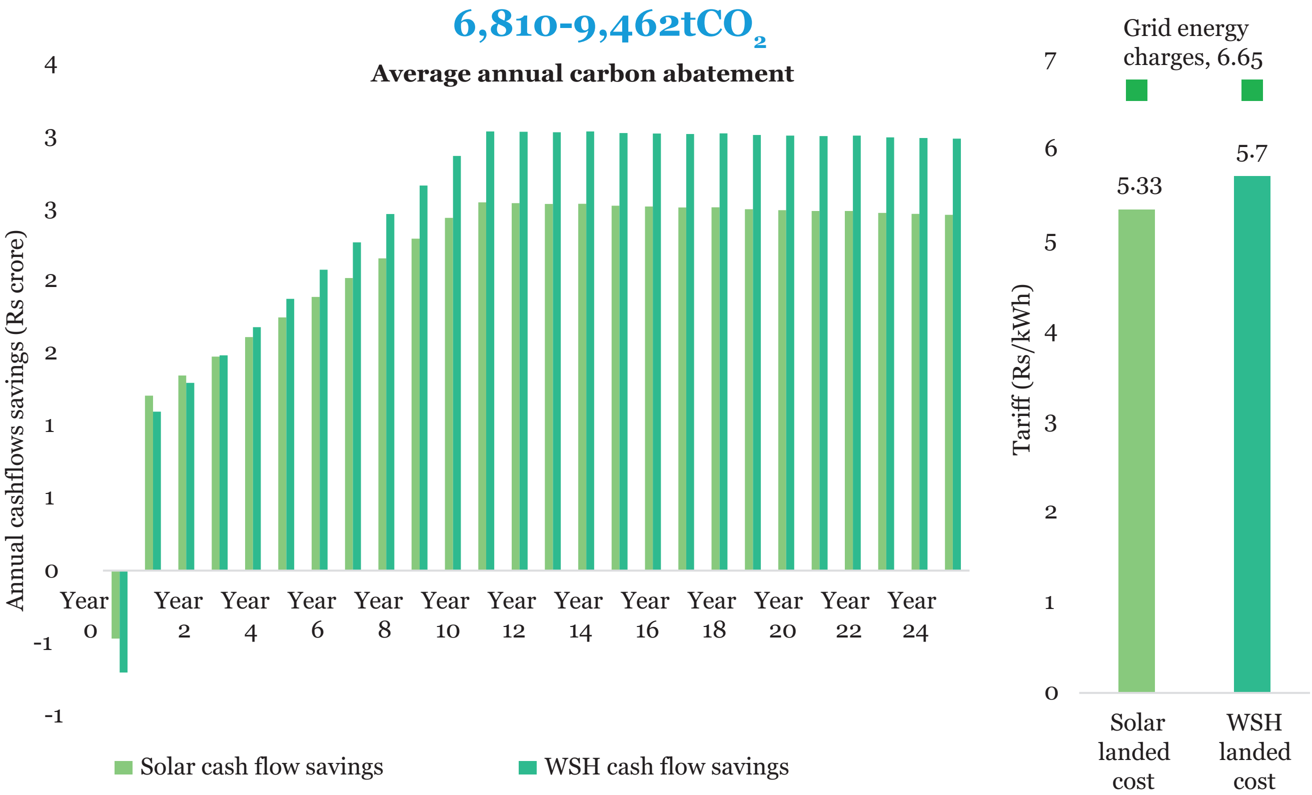
As observed across several mature industrial clusters, limited ground-space availability significantly restricts the realistic scale of on-site installations. Many units operate within densely packed industrial plots where expansion opportunities are minimal, making off-site solar a more practical pathway despite marginally lower savings. These spatial constraints also explain the exclusion of on-site WSH from the analysis, as hybrid configurations generally require larger contiguous land parcels that are not feasible within existing industrial premises.

Group Captive

Building on the procurement structure outlined earlier, the Group Captive model in Rajkot demonstrates a balanced savings profile while still accessing ownership-linked tariff benefits.

As illustrated in the figure below, both solar and WSH Group Captive configurations generate stable annual cashflow savings over the project horizon. WSH projects show higher savings compared to solar, while solar Group Captive projects exhibit a smoother savings trajectory aligned with daytime industrial

Figure 20: Annual cash flow savings under the solar and WSH group captive model



Source: JMK Research

Note: Escalation applied in the model: Energy charge escalation and FPPAS of 2% per annum for the first 10 years, then 0.3% per annum thereafter.

load patterns. This is primarily due to the higher CUF and more diversified generation profile, which enable greater energy offtake.

The tariff comparison further highlights the competitiveness of the Group Captive structure within Gujarat's regulatory environment. Landed tariffs of roughly Rs 5.33/kWh for solar and Rs 5.7/kWh for WSH remain below prevailing grid energy charges, enabling consistent long-term savings despite the presence of fixed banking charges and other open access components discussed earlier.

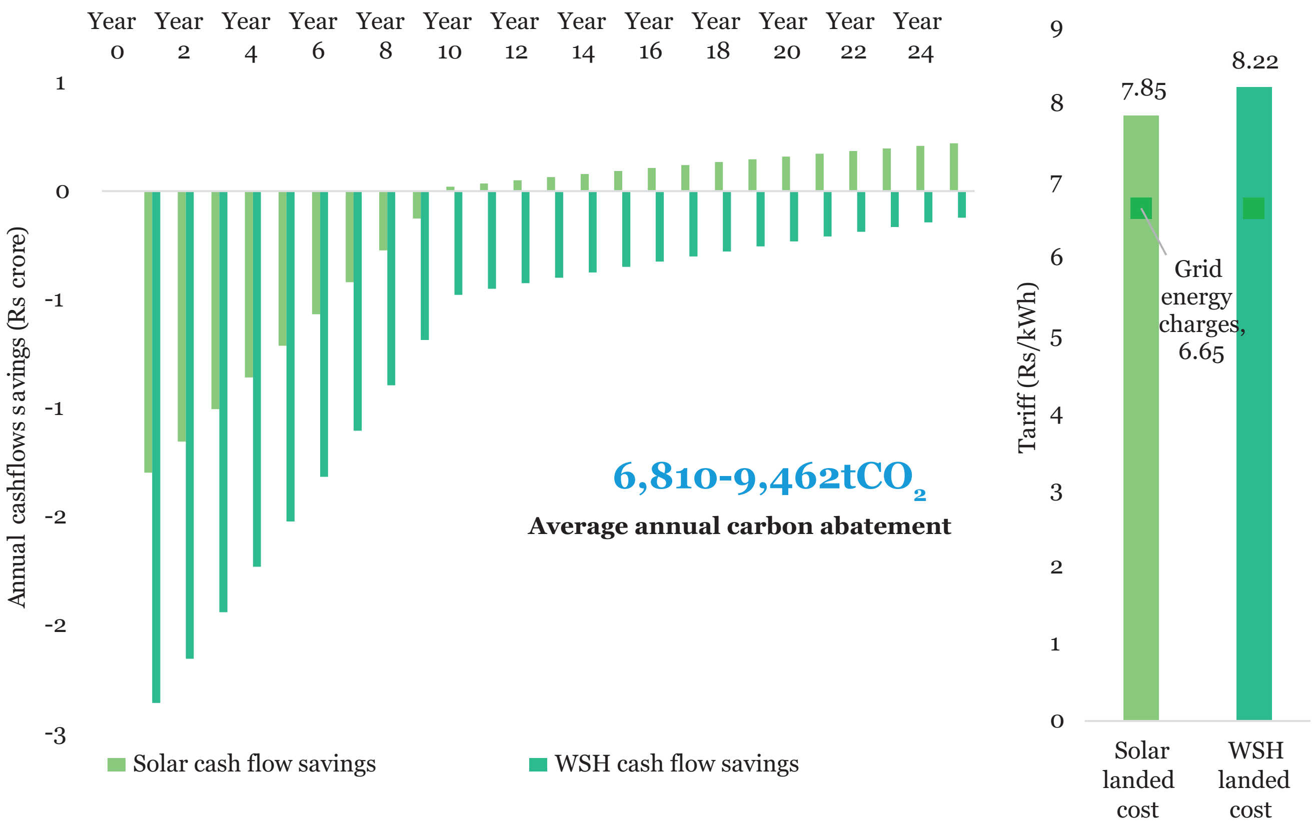
Group Captive adoption within the Rajkot cluster remains limited, with many MSMEs having little to no awareness of this procurement model. It is an attractive pathway for Rajkot units operating under tight production schedules because forecasting, scheduling, and compliance responsibilities are delegated to the SPV or developer. This reduces the internal administrative burden of scaling renewable adoption without significantly increasing managerial overhead.

Third party

As in Raipur, the third-party is the weakest pathway. Rajkot's case is marginally less attractive due to the applicability of open-access surcharges and banking charges, which keep landed tariffs higher than grid rates. As shown in the figure below, both solar and WSH configurations exhibit limited savings potential during the initial years, with meaningful savings accruing only in the later stages of the project life.

Stakeholder consultations indicate that awareness of this model within the cluster is currently limited, with negligible interest among MSMEs and minimal near-term viability for new project development under this structure.

Figure 21: Annual cash flow savings for the solar and WSH Third-Party Open Access model



Source: JMK Research

Note: Escalation applied in the model: Energy charge escalation and FPPAS of 2% per annum for the first 10 years, and 0.3% thereafter.

Comparative evaluation of renewable energy procurement models

The comparative evaluation across procurement pathways shows that Full Capex ownership models (across both solar and WSH) deliver the highest savings. On-site solar Full Capex achieves the highest annual savings, while off-site solar Full Capex records lower savings for the reasons established in the Raipur evaluation. Off-site WSH Full Capex, although more capital intensive, provides a stronger and more stable generation profile. However, its landed cost remains slightly higher than solar Full Capex configurations, making it a complementary option.

This improved generation stability offered by the wind component comes with trade-offs on the execution side. Wind projects typically require land aggregation across multiple dispersed parcels, increasing development complexity and timelines. In addition, wind generation is constrained by high capex and infrastructure requirements, along with inherent seasonality in generation.

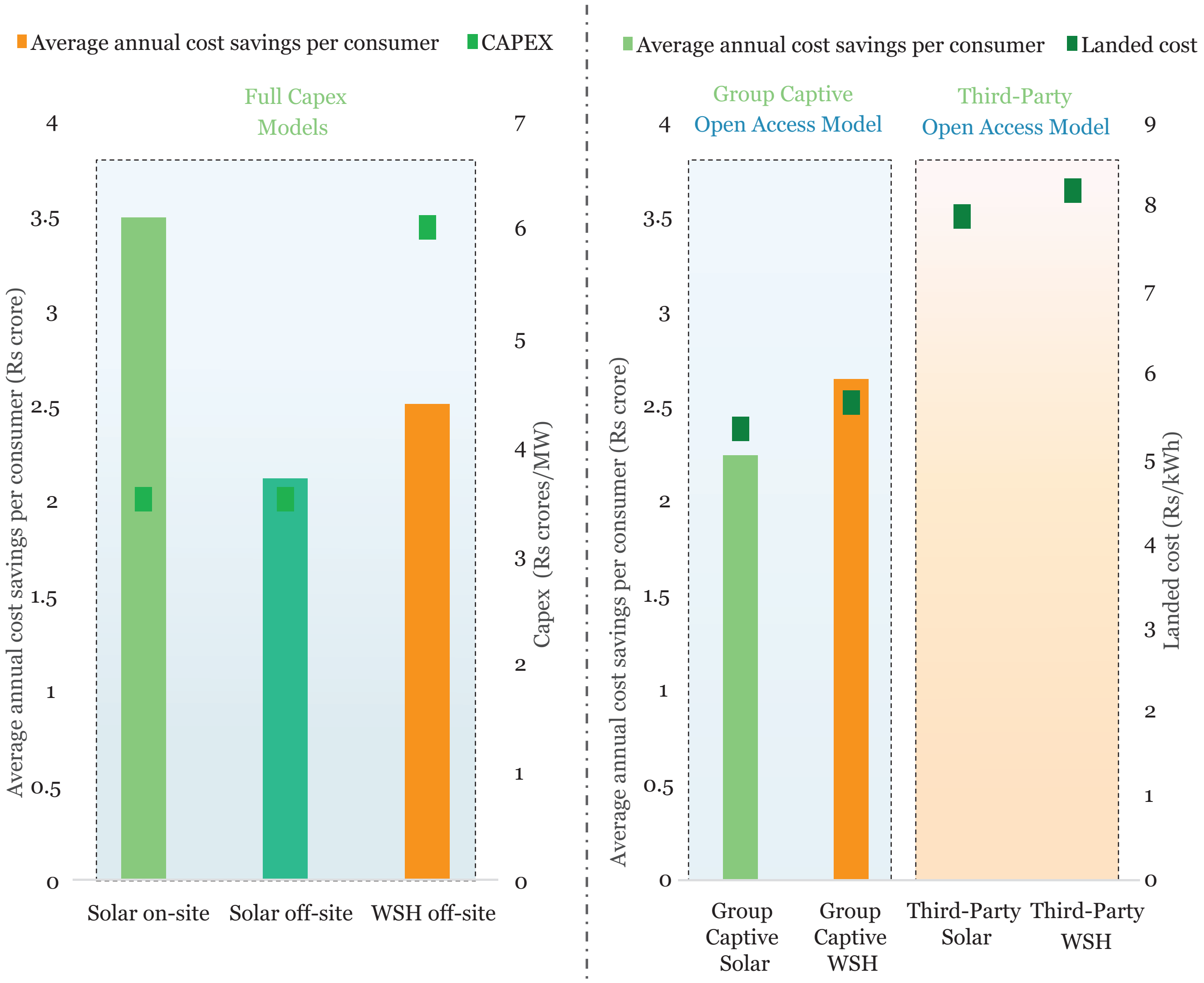
Group Captive procurement emerges as a competitive alternative to Full Capex models across both technologies. The model delivers landed tariffs close to ownership-linked pathways, while requiring lower upfront investment and reducing execution risk through the SPV framework. Although Full Capex configurations deliver roughly 10–15% higher annual savings on average, Group Captive offers a stronger balance of financial performance with capital efficiency and operating practicality. In Gujarat, regulatory requirements such as short-interval scheduling and settlement processes further strengthen the case for pooled procurement, as aggregated scheduling at the pooling substation can reduce DSM[15] exposure and provide a scalable pathway for integrating battery energy storage.

While battery energy storage systems (BESS) are gaining policy and market attention, their adoption among steel MSMEs remains absent, given high upfront costs and evolving commercial viability. At present, BESS remains a highly nascent and limited segment in this cluster.

Third-party procurement remains the least attractive pathway for Rajkot MSMEs across solar and WSH. Persistent surcharge exposure and landed tariffs that remain close to prevailing grid rates compress the achievable savings spread, limiting long-term financial upside.

The Rajkot analysis reinforces the findings from Raipur, demonstrating that the Group Captive model offers the best balance of financial returns, capital intensity and operational feasibility. The figure below summarises the key financial and environmental outcomes across the procurement models evaluated for units in Rajkot.

Figure 22: Comparative annual cost savings, landed cost, and capex requirements across solar procurement models for Rajkot



Source: JMK Research

15 DSM (Deviation Settlement Mechanism) charges refer to financial penalties or incentives applied when actual power drawl deviates from the scheduled energy profile. Under open-access and captive procurement structures, consumers or aggregators are required to follow day-ahead or intra-day schedules.

Figure 23: Key findings RE procurement models for Rajkot

6,800–9,460 tCO_2 abated annually

Solar & Wind - Solar Hybrid procurement options for a 10,000 tonnes per annum foundry unit

Group Captive

Most practical route

	SOLAR	WSH
Investment required	Rs 1.4 crore	Rs 2.24 crore
Tariff savings vs grid	20%	14%
Annual cash-flow savings	Rs 2.2 crore over 25 years	Rs 2.6 crore over 25 years
Simple payback	1–2 yrs	1–2 yrs

20% below grid
Tariff discount

Full Capex

On-site and off-site

	SOLAR	WSH
Investment required	Rs 17.5 crore	Rs 30 crore
Tariff savings vs grid	41–67%	37%
Annual cash-flow savings	Rs 2–3.5 crore over 25 years	Rs 2.5 crore over 25 years
Simple payback	1–5 yrs	7–8 yrs

Rs 17.5–30 crore upfront
High capex outlay

Third Party

Least viable route

	SOLAR	WSH
Investment required	Nil	Nil
Tariff savings vs grid	Negligible	Negligible
Annual cash-flow savings	Zero	Zero
Simple payback	–	–

No savings
Tariff above grid rate

Source: JMK Research

Note: The numbers above are indicative values. The actual figures can vary significantly due to substantial on-ground heterogeneity across unit types, including differences in scale, production configurations, and operating practices.

Jalna Steel Cluster Renewable Adoption Challenges

Jalna emerged as one of the most promising steel clusters during the initial cluster assessment phase due to its scale of operations and concentration of electricity-intensive steel manufacturing units. However, insights gathered through stakeholder consultations during the on-site visit highlighted a noticeable gap between the cluster's suitability for renewable energy adoption and the on ground realities. This section examines the factors that contribute to that divergence.

Jalna steel cluster, located within the Maharashtra Industrial Development Corporation (MIDC) area, is a prominent induction furnace-based secondary steel hub anchored by medium and large-scale manufacturing units. The cluster comprises roughly 10 integrated furnace-plus-rolling operations alongside a smaller and declining base of standalone rolling mills, collectively contributing close to 300,000 tonnes of steel production per month across major consumers.

High scrap utilisation levels, established supply chains, and dedicated feeder infrastructure connected to higher-voltage substations support consistent utilisation, positioning Jalna as an operationally mature cluster with the technical capability to evaluate renewable electricity integration.

However, the regulatory and tariff framework in Maharashtra introduces constraints that influence renewable adoption economics. Steel units in Jalna currently benefit from load factor–linked rebates under the Maharashtra State Electricity Distribution Company Limited (MSEDCL) tariff structure, with incentives ranging from 0.75% to 1% on energy charges for high utilisation levels and capped at 15%. Because renewable procurement reduces measured grid consumption, a portion of these incentives may be diluted when demand shifts toward open-access or behind-the-meter supply. Compared to clusters such as Raipur, the rebate thresholds and operational conditions are more stringent, making the economic comparison between conventional grid power and renewable procurement more sensitive to regulatory interpretation and settlement mechanisms.

Furthermore, current MERC regulations constrain the co-location of wind and solar assets across different sites, limiting the feasibility of hybrid configurations that could otherwise provide more stable round-the-clock supply suited to continuous steel operations (MERC Order in Case No. 97 of 2024).

Nonetheless, stakeholder interactions indicate that existing incentive structures, settlement practices, and past responses to renewable procurement proposals have collectively shaped a local regulatory environment that continues to favour sustained grid utilisation over shifts toward renewable power. Jalna therefore highlights how regulatory structures, alongside technical and economic factors, can play a decisive role in shaping renewable energy uptake within secondary steel clusters.

6

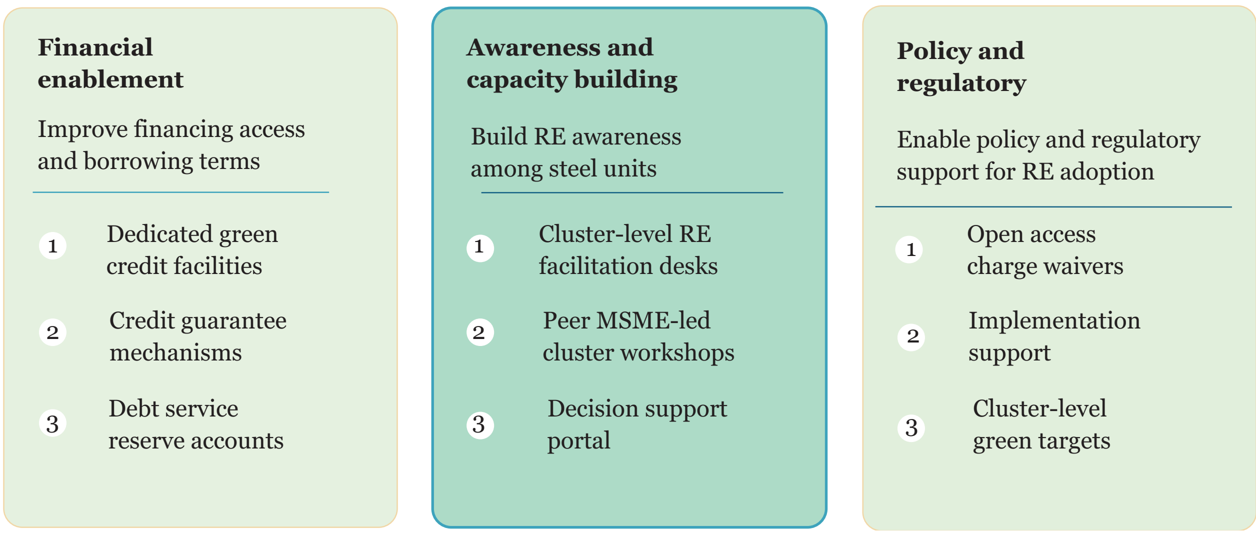
RECOMMENDATIONS

Addressing the barriers to RE adoption in the secondary steel sector will require a multi-faceted approach spanning financing, awareness building and policy support. While the clusters have unique industrial characteristics and regulatory contexts, their business operations and many of the underlying challenges are the same, making the recommended interventions broadly applicable across clusters.

Improving access to affordable finance is central to scaling RE procurement among MSMEs. Green credit lines, credit risk guarantees, Debt Service Reserve Account (DSRA)[16] and cluster-based Special Purpose Vehicle (SPV) can improve financing terms, reduce lending risks, and enable MSMEs to aggregate demand and secure more favourable financing terms.

Several MSME steel owners often view sustainability as secondary to topline growth and capacity expansion. Hence, awareness and capacity building efforts will be critical to actualise on paper RE benefits. Cluster-level facilitation desks, workshops led by peer MSMEs who have adopted solar and formulating standard evaluation and decision support tools will enable the secondary steel entities to actively participate in the RE transition opportunities identified through this study.

Figure 24: Recommendations classification to scale renewable energy adoption by secondary steel entities



Source: JMK Research

16 DSRA (Debt Service Reserve Account) refers to a dedicated reserve maintained by the borrower to cover scheduled debt repayments for a predefined period, providing lenders with additional repayment security and reducing financing risk.

Table 11: Recommendations to scale RE adoption by secondary steel entities

Title	Description	Stakeholders
Near term (1–2 years)		
Dedicated green credit facilities	▪ Establish a **sector-specific renewable procurement credit line** through SIDBI/IREDA tailored for EAF/IF units. ▪ Structure loans with **concessional interest rates** and **reduced collateral requirements**, based on reduced tariff volatility and stable PPA-backed repayment. ▪ **Extend SIDBI's 4E and MSE-GIFT schemes**[17] (currently focused on energy efficiency) to explicitly cover RE procurement, for EAF-IF.	▪ Policy direction/ Scheme expansion: Ministry of Steel (MoS), Ministry of Finance (MoF) ▪ Financing and credit line implementation: SIDBI, IREDA ▪ Programme alignment and oversight: MoF
Credit enhancement and risk mitigation	▪ Depending on whether MSMEs borrow individually or through a cluster SPV, two different guarantee structures can be used for de-risk lending: ▪ **Partial credit guarantee (PCG)** for RE loans taken by individual MSME units**,** where a **government or financial agency covers 40–60%** of the loan exposure. This directly lowers lender risk, enables reduced collateral requirements and moderately lower interest rates. ▪ **Cluster-level (portfolio) guarantees** for **loans routed through a cluster SPV**, where a **single guarantee covers a diversified loan pool**. Because multiple MSMEs are aggregated into one borrower entity, the perceived credit risk is lower, allowing **30–40% collateral** at the portfolio level and faster loan approvals. ▪ While the **guarantee mechanism is similar**, **portfolio guarantees benefit from risk diversification** across many MSMEs, resulting in **significantly higher lender confidence than individual PCG**. Additionally, a **cluster SPV supports standardisation of documents** and presents lenders with a single, coordinated borrower interface.	▪ Guarantee framework design: Ministry of Finance (MoF), RBI ▪ Credit guarantee implementation: SIDBI, IREDA ▪ Regulatory oversight: RBI
Working capital support	Provide **working capital linked** to support mechanisms such as **Debt Service Reserve Accounts** allowing MSMEs or cluster SPVs to maintain 1–3 months of repayment buffer.	▪ Lending and working capital provision: Banks, NBFCs ▪ Refinance/MSME Financing Support: SIDBI

17 SIDBI's 4E (end-to-end energy efficiency) programme provides concessional finance and technical assistance to MSMEs for adopting energy-efficient technologies. The MSE-GIFT (Green Investment and Financing for Transformation) scheme supports access to affordable finance for micro and small enterprises, primarily targeting energy efficiency and cleaner production investments.

Title	Description	Stakeholders
Medium term (3–4 years)		
Facilitation desks	▪ Establish **facilitation desks** at cluster level to provide end-to-end support from evaluating offers by developers to completing open access applications and interpreting complex state-specific regulations. ▪ Provide **cluster-level technical advisory sessions** on load profile assessment to support informed decision-making rather than sales-led persuasion.	▪ Cluster-level implementation: State Government ▪ Operational coordination and approvals: DISCOMs ▪ Industry outreach and capacity building: Industry associations: (CII/SIMA)
Targeted peer demonstration	▪ Conduct **cluster-specific workshops** led by peer **MSME owners who have adopted RE**. ▪ Focus discussions **on tangible outcomes** like **reduction in landed power cost**, **reliability improvements**, and how group captive equity structures can be practically managed.	▪ Programme Facilitation Industry association ▪ Policy support and coordination: State Government
Standardised evaluation and decision support tools	▪ Develop easy-to-use **comparison templates** that allow MSMEs to **evaluate quoted tariffs**, banking rules, O&M charges, termination clauses, and escalation terms across developers. ▪ Develop a **decision-support portal** that allows MSMEs to enter their contract demand, load profile, and energy consumption, and **estimate the optimal renewable capacity**, **expected cost savings, and CO_2 abatement potential.** ▪ Create standard **PPA term-sheets and model checklists (especially for Group Captive** equity participation and open access billing).	▪ Policy guidance and national frameworks: MNRE, Ministry of Power (MoP) ▪ Tool development and dissemination: Industry associations
Tariff and banking settlement	▪ Provide **time-bound, targeted concessions** on **wheeling and transmission charges for cluster-based RE procurement** by secondary steel MSMEs**,** with compensatory mechanisms**, to offset DISCOM revenue impact** ▪ Allow steel MSMEs to **redeem banked energy across any time block within the settlement cycle** without additional withdrawal penalties in initial phase, with a gradual phase-out of such flexibility over time. ▪ Account for reduced contract demand post RE installation in **load factor calculations** to ease the financial impact of load factor incentive losses.	▪ Regulatory formulation: SERCs ▪ Implementation and billing administration: DISCOMs ▪ Policy alignment: MoP, MNRE

Title	Description	Stakeholders
Curtailment compensation framework	▪ Introduce a **deemed generation framework** for renewable projects supplying secondary steel MSMEs under open access or group captive arrangements, where **curtailment due to grid congestion or commercial backing down** is **compensated**, with the option to **carry forward curtailed units** into subsequent banking or settlement cycles. ▪ Mandate **time-stamped curtailment reporting** by SLDCs with **clear cause attribution**, supported by a **monthly reconciliation mechanism** to ensure accurate settlement of compensable curtailment volumes and preserve project bankability for cluster-level RE investments.	▪ Regulatory formulation: CERC, SERCs ▪ Reporting and settlement: SLDCs, DISCOMs ▪ Policy alignment: MoP
Long term (5–7 years)		
Behavioral awareness and perception shift	Owners of MSMEs in the steel sector often view **sustainability as secondary to topline growth and capacity expansion**. Awareness campaigns should **position RE adoption as a business efficiency measure** emphasising tariff stability, **long-term cost savings, and competitiveness** in steel value chains.	▪ Strategic messaging and sector outreach: Ministry of Steel (MoS) ▪ Programme support: MNRE ▪ Industry engagement: Industry associations: Industry Associations
Project implementation support	▪ Establish a **single-window approval cell for open access**, interconnection and land/evacuation for MSME steel clusters. ▪ Publish **state-approved model PPAs** for group captive and third-party OA to reduce time and legal advisory costs.	▪ Single-window facilitation and state execution ▪ Grid integration and approval: DISCOMs ▪ Policy and OA framework alignment: MoP
Demand creation	▪ Incorporate mandatory **green power procurement targets for steel units in industrial policy** (e.g., 30% of power from RE by 2030) to give a targeted and clear green transition signal. ▪ Additionally, introduce a **graded incentive–disincentive mechanism** where units not able to achieve RE share face incremental surcharges or enhanced reporting requirements. ▪ Production-linked incentives tied to RE penetration thresholds for instance, incentivising secondary steel units that source 30% or 50% of their electricity from renewable sources ▪ Provide demand measures such as ALCM[18] requirements relaxation for steel open-access renewable projects, and reduced GST/customs duties for components.	▪ Industrial policy and targets: Ministry of Steel (MoS), State Government ▪ Power market and OA policy: MoP ▪ Renewable policy alignment: MNRE

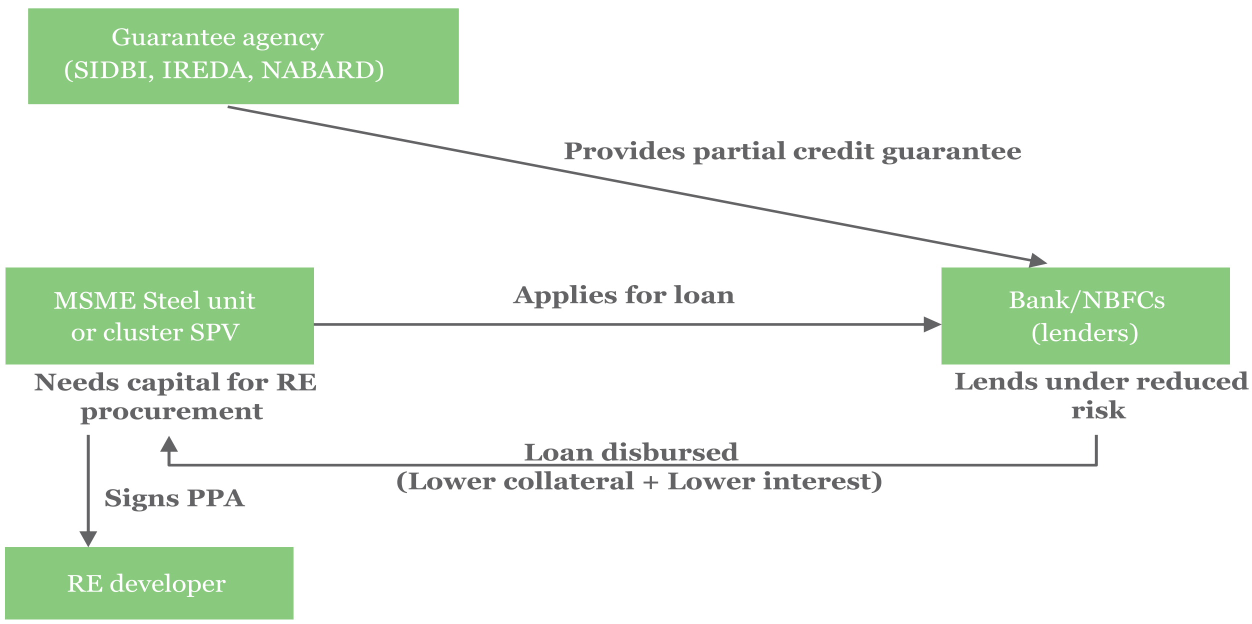
Source: JMK Research

The financing structure illustrated in Figure 25 below highlights how guarantee-backed lending can reduce perceived credit risk for RE investments by secondary steel MSMEs. Under an individual credit guarantee, the guarantee agency partially backs each MSME loan, typically covering around 40–60% of the exposure and enabling lenders to reduce collateral requirements. In contrast, an SPV-level guarantee aggregates multiple MSMEs into a pooled borrowing structure, diversifying risk across the portfolio and allowing faster approvals, lower interest rates, and improved access to capital.

The on-ground experience during this study indicates that policy support and long-term regulatory clarity will be the most important enablers of RE adoption in the secondary steel sector. Time-bound, targeted waivers on open access charges can improve RE project profitability while signalling government commitment to green electrification. Faster project approvals, state-approved model PPAs and clearly defined state level green power targets for the clusters will also be essential for entities their transition journey.

Going ahead, a clear and phased approach to implementing these recommendations will be essential for ensuring their long-term impact. The execution of each measure matters, as it strengthens the viability of RE projects for secondary steel players. Moreover, some actions will need to be prioritised over others. For instance, establishing portfolio-level credit guarantees and offering open-access waivers should come first, given their immediate and decisive benefits. Beyond the recommendations outlined above, several emerging pathways could further enhance renewable energy procurement options for steel MSMEs over the long term.

Figure 25: Credit guarantee structure for individual MSMEs or cluster SPVs



Source: JMK Research

18 ALCM (Approved List of Models and Manufacturers) refers to the Ministry of New and Renewable Energy's notified list of eligible solar photovoltaic module manufacturers permitted for use in government-supported and certain grid-connected solar projects in India.

7

EMERGING DECARBONISATION PATHWAYS

There are some emerging decarbonisation pathways and enabling technologies on the horizon which have had little to no adoption in the secondary steel market until now but hold significant potential. Their relevance is driven by prevailing industry constraints, including land availability limitations, grid bottlenecks, existing furnace configurations, and increasing decarbonisation mandates. While the medium- to large-scale players will be their early adopters, the adoption by the small manufacturers can gradually rise as it becomes more prevalent in the overall industry.

Inter-state transmission system green OA

Sourcing green power through Inter-state transmission system (ISTS) will be an attractive option for steel clusters in states with unsupportive policies or low irradiation potential. However, access to the central transmission utility (CTU) network will be essential to ensure RE project viability. CTU connected steel units are not reliant on local DISCOM infrastructure and thereby incur no wheeling/distribution or any other OA charges such as grid support and standby among others. In contrast, STU-connected units may still depend on the local DISCOM framework depending on the specific network configuration and project structuring and therefore may continue to be subject to applicable state-level charges.

Steel entities aiming to set up new manufacturing units in the future should aim to locate them close to CTU or STU substations, to minimise the additional feeder laying costs. At the same time, there is a parallel need for coordinated grid expansion and strengthening at both central and state levels to enable industrial growth in logistically optimal locations, rather than constraining siting decisions purely based on transmission access.

Green hydrogen

The production of green hydrogen powered by RE requires significant additional capacity and is expected to become a vital and effective component in green steel manufacturing. However, its integration in the Indian secondary steel units is constrained by the MSME type and associated furnace technologies currently in use and the high cost of green hydrogen relative to conventional fuels.

Green hydrogen is relevant for ore-based steelmaking routes, particularly in sponge iron production. A majority of the secondary steel units are scrap-based, where hydrogen has limited applicability, thereby limiting the use case for green hydrogen integration. Within the ore-based segment, most existing secondary steel units in India rely on horizontal rotary kilns, whereas green hydrogen is more suited to vertical shaft furnaces. With the ever-increasing emphasis on green hydrogen integration, upcoming steel units are likely to deploy vertical shaft furnaces in sponge iron manufacturing.

Recent studies indicate that hydrogen-based rotary kilns could emerge as a transitional decarbonisation pathway for India's MSME-dominated sponge iron segment. Unlike vertical shaft furnaces, hydrogen rotary kilns can leverage existing kiln infrastructure with relatively lower capital retrofits, offer flexibility in iron ore feedstock, and operate across a wider load range improving compatibility with renewable power supply.[19]

However, these concepts remain at pilot and demonstration stages, and commercial viability will depend on hydrogen cost trajectories, infrastructure readiness, and operational validation under Indian conditions.

19 TERI | Hydrogen Rotary Kilns for Ironmaking in India | 2025

Energy storage systems (ESS) and round-the-clock (RTC) power

Energy storage viability will heavily depend on state and site-specific dynamics. Most of the steel cluster electricity consumers are high priority for DISCOMs and receive prioritised grid power through dedicated feeders to ensure 24/7 availability. As the current business case for energy storage integration in industries is primarily for the backup power supply, its viability of ESS in secondary steel remains limited, especially in energy surplus states like Chhattisgarh.

ESS adoption remains absent across the broader Commercial and Industrial (C&I) segment in India, not just in secondary steel. Despite growing interest, actual deployment has been negligible due to high capital costs and the absence of established financing structures. Stakeholder consultations with industry associations and unit owners in Raipur and Rajkot corroborated this. While awareness of storage solutions is increasing, no units have moved beyond discussions, reflecting the absence of demonstrated use cases in comparable industrial settings.

That said, the underlying drivers for ESS adoption are strengthening. As grid tariffs continue to rise and the emphasis on firm, dispatchable RE power grows, the economic case for storage integration will improve. For states with high or rising industrial power costs such as Maharashtra, ESS will grow increasingly attractive over time.

On the supply side, the emerging merchant BESS model offers a route through which firm renewable supply could eventually reach these clusters. Unlike consumer-side backup storage, a merchant battery is a standalone, developer-owned grid asset that earns revenue through price arbitrage, charging on surplus daytime solar and discharging into the evening peak. The model is gaining traction, with India's first such project commissioned in Rajasthan in December 2025.[20] For steel MSMEs, it opens a future pathway to procure firmed, round-the-clock renewable power through developer-managed structures, though its viability hinges on regulatory clarity around grid-charging restrictions.

20 Juniper Green Energy. Juniper Green Energy Commissions India's First Merchant Battery Energy Storage System (BESS)

8

WAY FORWARD FOR CLUSTER-BASED RENEWABLE ENERGY DEPLOYMENT

At present, RE adoption across the Raipur and Rajkot clusters remains largely driven by Full Capex ownership models, where individual units invest capital upfront and assume responsibility for plant development, operations, and performance risks. Stakeholder consultations during this study indicate that this ownership-led approach reflects the broader pattern observed across India's steel industry, where firms prioritise direct asset control despite operational complexity. While this model has enabled early renewable uptake, it also limits scalability, particularly for MSME units with constrained balance sheets or limited technical bandwidth.

The assessment undertaken in this study demonstrates that the group captive procurement structure outperforms traditional ownership-led approaches across key parameters including operational simplicity and implementation flexibility. In Raipur, group captive structures deliver a landed cost of Rs 4.38/kWh (34% below prevailing grid tariffs) with annual carbon abatement of approximately 12,500 tCO_2. In Rajkot, group captive solar achieves a landed cost of Rs 5.33/kWh (20% below grid), abating 6,800–9,500 tCO_2 annually. Despite the advantages that the group captive structure offers, awareness and adoption of this model within the secondary steel ecosystem remains minimal, reflecting gaps in market familiarity, regulatory complexity, and limited demonstration projects.

A cluster-based deployment strategy, combined with the policy and institutional recommendations outlined earlier in this report, provides a pathway to unlock this opportunity at scale. Aggregating demand through industrial associations can improve project bankability, enable optimal plant sizing, and distribute equity participation across multiple consumers, thereby lowering individual risk exposure. Such a coordinated approach can help transition the industry away from fragmented, asset-heavy procurement toward more structured and financially efficient models.

Translating this strategic direction into on-ground execution will require pilot implementation within representative industrial clusters. Such pilots can validate the operational viability of group captive structures, clarify regulatory pathways, and build confidence among lenders, developers, and industrial consumers. Establishing proof of concept is particularly important for a sector where investment decisions are often driven by peer experience and demonstrated outcomes. Successful pilots can therefore serve as credible templates for replication across other secondary steel hubs nationwide.

Cluster characteristics suggest that implementation pathways will differ between Raipur and Rajkot. Raipur's larger, power-intensive units with relatively stable load profiles are well suited to solar-led group captive structures. Rajkot, by contrast, comprises smaller but financially resilient forging and foundry units operating at lower voltage levels. These structural differences reinforce the need for tailored deployment strategies while maintaining a common objective of renewable integration in the secondary steel industry.

Operationalising the pilot

Translating the Group Captive model from financial assessment to execution will follow four stages: institutional mobilisation, consumer aggregation, project development, and contractual closure.

Figure 26: Implementation framework for group captive renewable energy projects

1 Institutional mobilisation

- Industrial associations lead mobilisation
- Interface with DISCOMs, SLDCs, nodal agencies
- Secure waivers and approvals

↓

2 Consumer aggregation

- 5–8 units within a 30–50 km radius
- Prioritize stable daytime operators
- Favour existing commercial linkages

↓

3 Project development

- Detailed Project Report (DPR)
- Engage developers and lenders
- Select on capability, financing, tariffs

↓

4 Contractual closure

- Shareholders and share purchase agreements
- Power Purchase Agreements (PPA)
- Open access and energy accounting

Source: JMK Research

Strong institutional coordination is critical as it reduces fragmentation and enables collective action. Industrial associations such as the Chhattisgarh Sponge Iron Manufacturers Association in Raipur or foundry associations in Rajkot could help mobilise participation, run awareness and outreach efforts, and facilitate peer engagement. In parallel, they can coordinate with developers, regulators, and consumers.

They could also serve as the primary interface with DISCOMs, State Load Dispatch Centres (SLDCs), and state nodal agencies to align with open access procedures, banking provisions, and connectivity timelines. A focused effort is required to coordinate with DISCOMs and secure applicable waivers and approvals, maximising viability at the outset. Following the initial pilot, a standardised approval and facilitation mechanism should be established to enable faster replication at scale.

Units with stable daytime operations align best with solar generation and should be prioritised. Aggregating 5–8 such units within a 30–50 km radius yields bankable scale without straining coordination. Units with prior commercial linkages, such as shared suppliers, logistics, or procurement arrangements, are preferable because existing trust reduces friction in equity participation and offtake commitments.

Figure 27: Indicative pilot project specifications for Raipur and Rajkot

Business model	RE technology	Implementation
Group Captive	**Solar**	**18–24 months**

Raipur

Induction furnace + rolling mills

Consumers
5–7

Plant size
50–70 MW_{AC}
10–12 MW_{AC} Per consumer

Investment per consumer
Rs 2.73 crore

Tariff savings vs grid
~34%

Annual cash flow savings
About Rs 2.4 crores
Over 25 years

Annual CO_2 abatement per consumer
About 12,500 tCO_2

Rajkot

Foundries/Investment casting

Consumers
6–8

Plant size
30–48 MW_{AC}
5–6 MW_{AC} Per consumer

Investment per consumer
Rs 1.3 crore

Tariff savings vs grid
~20%

Annual cash flow savings
About Rs 2.2 crore
Over 25 years

Annual CO_2 abatement per consumer
About 6,800 tCO_2

Source: JMK Research

Project development begins once a core consumer group is established. A Detailed Project Report (DPR) should define load profiles, technology configuration, plant sizing, land availability, evacuation strategy, and financial projections. This forms the basis for engaging developers and lenders. Developer selection should prioritise credible developers with proven technical capability, financing strength, and competitive tariffs.

Following developer selection, contractual formalisation should be completed, including agreements such as the Shareholders Agreement (SHA), Share Purchase Agreement (SPA), PPA and, Open Access/Energy Accounting arrangements. This structured approach enables efficient pilot execution while creating a foundation for scalable replication across similar industrial clusters.

9

CONCLUSION

India's commercial and industrial sector is witnessing steady growth in RE adoption through both open access and on-site solar, with annual installations rising at a CAGR of about 46% over the past five years. Globally, steelmakers are accelerating decarbonisation efforts, and RE procurement is emerging as the most accessible first step in reducing the carbon intensity of electric arc- and induction furnace-based operations. For India's secondary steel sector, this transition is particularly compelling. The RE economics are already demonstrably favourable on paper, particularly for those units with stable load profiles and high operating hours.

There is also a clear shift in the behaviour of steel enterprises. Many are now proactively exploring RE procurement models, evaluating business cases, and engaging developers with a sense of urgency. This growing readiness suggests that the sector is on the cusp of broader adoption, awaiting supportive policy and market signals to accelerate investment.

In the near term, early adoption pathways are likely to diverge across cluster types. Larger integrated induction-furnace units and rolling mills in Raipur are positioned to lead. In contrast, Rajkot's foundry and casting MSMEs will advance through solar-based procurement models that accommodate variability in load profiles.

The technical and financial case for RE integration in secondary steel is established; the constraint is no longer viability but execution. Bridging awareness gaps, navigating regulatory procedures, and structuring bankable projects remain the practical barriers for MSMEs without dedicated energy management capabilities. An equally critical constraint lies in operational capability, as steel MSMEs typically lack the in-house expertise to manage forecasting, scheduling, and settlement processes required under the open access framework. As power consumers rather than generators, they are not equipped to handle the variability of renewable energy or the associated regulatory complexity.

The cluster-based approach and pilot frameworks outlined in this report offer a pathway to address these constraints. But their effectiveness will depend on timely and coordinated implementation. As initial projects deliver results, market confidence among lenders, developers, and peer enterprises is expected to deepen, creating a self-reinforcing cycle of adoption across the secondary steel value chain.

The combined analysis of Raipur and Rajkot reinforces the importance of conducting similar cluster-specific techno-commercial studies in other major steel regions. Industrial setups, grid constraints, policy implementations, open access charges, and DISCOM engagement vary significantly across sectors. By conducting similar assessments in additional clusters, we can tailor RE adoption strategies to local conditions and create a clearer nationwide roadmap for MSME-led decarbonisation in the secondary steel sector.

WWF