



## REPORT

# ECONOMIC CASE FOR GREEN STEEL PRODUCTION IN INDIA

JOSÉ DOMÍNGUEZ BENNETT<sup>1\*</sup>, NEELIMA JAIN<sup>1</sup>,  
EMILIA CHOJKIEWICZ<sup>1,2</sup>, NIKIT ABHYANKAR<sup>1</sup>,  
AMOL PHADKE<sup>1</sup>

<sup>1</sup> India Energy and Climate Center, Goldman School of Public Policy, University of California, Berkeley;

<sup>2</sup> Energy and Resources Group, University of California, Berkeley

\*Corresponding author: ([jose\\_dominguez@berkeley.edu](mailto:jose_dominguez@berkeley.edu))

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**UC Berkeley**  
Goldman School of  
Public Policy

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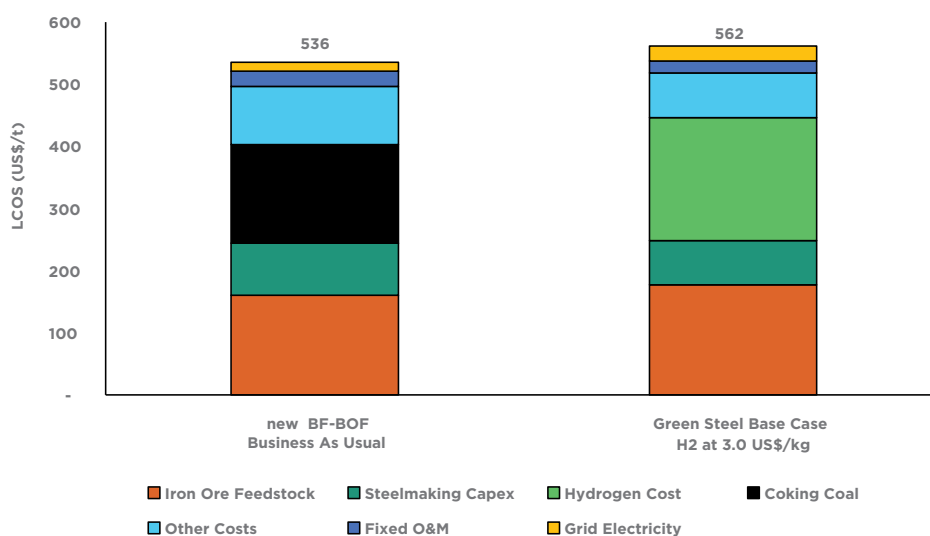
We are grateful to industry stakeholders whose engagement helped strengthen this analysis, particularly through detailed discussions on key assumptions and analytical inputs with Steel Authority of India Limited (SAIL), ArcelorMittal Nippon Steel India (AMNS India), Godawari Power and Ispat Limited, Jindal Steel, and the Confederation of Indian Industry (CII). We thank reviewers for thoughtful comments that further strengthened the report, in particular Deepal Yadav from the Council on Energy, Environment and Water (CEEW), Jagabanta Ningthoujam from RMI, Deependra Kashiva from SIMA, Debarka Chakraborty from Dastur Energy, Bhaskar Bose from Jakson Green Infinity, and Vinoth Balakumar, Kiran Ananth, Nisha Jayaram, and Gargi Pawar from CII. This analysis has been shared with stakeholders and forums in India, including the Ministry of Steel, Ministry of Commerce and Industry, and the India Green Steel Network. Finally, we thank Fernando Augusto of the University of California, Berkeley, for report design and communications support.



# EXECUTIVE SUMMARY

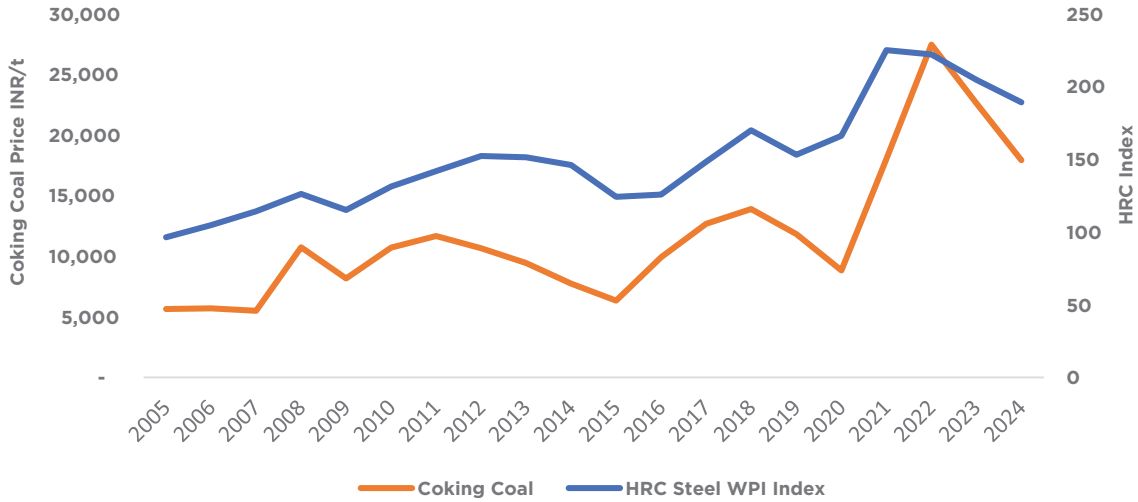
India is the world’s second-largest producer of crude steel, with output of 149 million tonnes in 2024, approximately 8% of global production. India’s National Steel Policy (NSP) targets installed capacity of 300 million tonnes by 2030–31, up from roughly 200 million tonnes in fiscal 2025, with 60–65% of capacity planned to follow the integrated Blast Furnace and Basic Oxygen Furnace (BF-BOF) route. Coking coal is the principal reductant in BF-BOF steelmaking, and the NSP projects requirements of 161 million tonnes per annum by 2030–31. Over 90% of India’s coking coal demand is met through imports. Over a 40-year timeframe this trajectory implies approximately 5.8 billion tonnes of cumulative coking coal imports, USD 1.2 trillion in import expenditure, and 19.5 gigatonnes of committed CO<sub>2</sub> emissions. It also leaves Indian steel exports exposed to carbon border measures in key markets. The European Union, which accounts for two-thirds of India’s iron and steel exports, entered the compliance phase of its Carbon Border Adjustment Mechanism (CBAM) on 1 January 2026. CBAM charges on imports rise as free allowances under the EU Emissions Trading System phase out between 2026 and 2034.

Here we show that green hydrogen can be produced in India at USD 3.0 per kilogram by 2030. At this hydrogen cost, green steel produced through hydrogen-based direct reduced iron paired with electric arc furnaces (H<sub>2</sub>-DRI/EAF) reaches USD 562 per tonne, roughly 5% above the cost of conventional steel from new BF-BOF plants. Targeted reductions in electrolyzer capital costs and improvements in conversion efficiency bring hydrogen to USD 2.5 per kilogram and green steel below USD 500 per tonne by 2035.



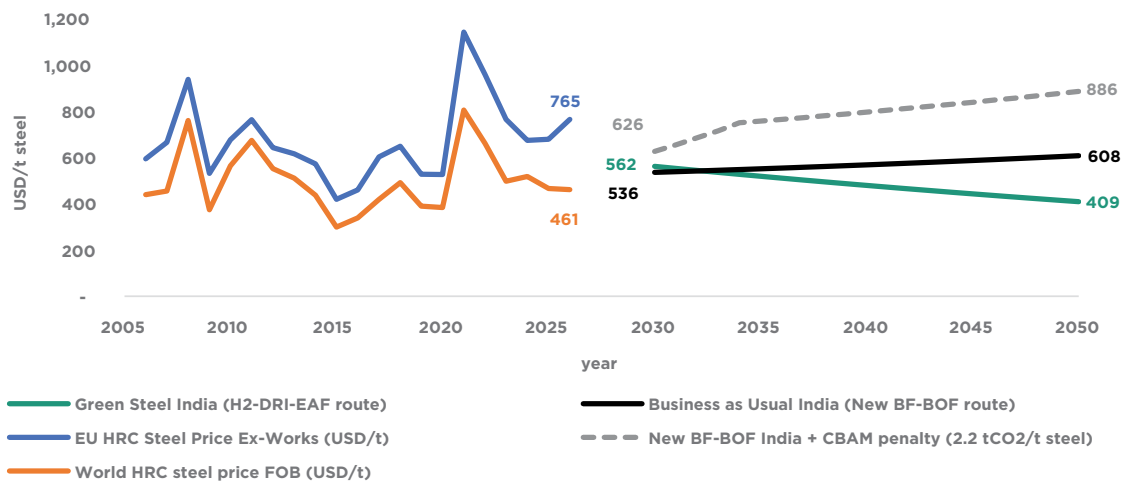
**FIGURE ES-1:** Levelized cost of steel build-up for new BF-BOF versus H<sub>2</sub>-DRI/EAF in India under near-term (2030) base-case assumptions, with H<sub>2</sub> at USD 3.0/kg

Three structural features absent from existing techno-economic comparisons of BF-BOF and H<sub>2</sub>-DRI/EAF in India materially shift this result. First, Indian domestic hot rolled coil prices have moved closely with imported coking coal prices over the past two decades, indicating direct pass-through of global coal-market volatility into Indian steelmaking costs.



**FIGURE ES-2:** Coking coal import prices (INR/tonne) and HRC steel wholesale price index, 2005-2024.

Second, BF-BOF steel relies on coking coal priced in US dollars, while H<sub>2</sub>-DRI/EAF can secure renewable electricity for 25 years through power purchase agreements denominated in Indian rupees. This asymmetry means rupee-denominated BF-BOF costs escalate over time while H<sub>2</sub>-DRI/EAF costs remain flat. The rupee has depreciated against the dollar at 3.2% per year on average over the past two decades, and seaborne coking coal has inflated at 4.2% per year in nominal USD over the same period; combined, these compound to 7.4% annual escalation in rupee-denominated coal costs. Third, our near-term green hydrogen cost estimates are anchored in contract prices from India’s 2025 hydrogen and ammonia auctions. Incorporating these factors, H<sub>2</sub>-DRI/EAF becomes cheaper than new BF-BOF by 2030. CBAM exposure widens the gap further as EU free allowances phase out between 2026 and 2034.



**FIGURE ES-3:** Steel historical market prices and production cost projections by route, nominal USD/tonne, 2005–2050. Forward series show levelized production costs for new plants commissioned in 2030; BF-BOF + CBAM trajectory reflects the legislated free-allowance phase-out schedule.

H<sub>2</sub>-DRI/EAF becomes the lower-cost route in India by 2030 under historical depreciation and coal inflation rates. Realizing this at speed and scale will require conducive policy instruments such as public procurement and long-term offtake contracts, building on the approach India has used to drive down the costs of solar and storage.



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# INTRODUCTION

Steelmaking underpins economic development and infrastructure build-out, yet the sector's contribution to greenhouse gas (GHG) emissions has come under increasing scrutiny in recent years in the context of climate change mitigation efforts. Globally, the steel industry accounts for approximately 2.8 gigatons of CO<sub>2</sub> emissions per year or 7-10% of total emissions<sup>22, 32</sup>. This is largely a result of the heavy reliance of steel production on coal, which is widely used in the form of coke as a reducing agent to extract iron from iron ore and provide the carbon content needed in steel. Around 1.4 billion tons or 70% of global steel is produced via the conventional BF-BOF route<sup>42</sup>, which first combines iron ore, coke, and limestone in a Blast Furnace (BF) to produce a liquid stream of pig iron that is further mixed with oxygen, and potentially recycled steel, in a Blast Oxygen Furnace (BOF) to reduce the carbon content, remove impurities and produce crude steel. Another 560 million tons or 30% of global steel is produced via the Electric Arc Furnace (EAF) route<sup>42</sup>, which employs electrical currents to produce crude steel either directly from recycled steel or from Direct Reduced Iron (DRI) that uses natural gas or gasified coal. Due to the limited availability of scrap steel for secondary steel production, nearly 80% of steel is produced via primary methods, of which BF-BOF has significantly higher direct and indirect carbon dioxide emissions - at an average of 2.2 tons CO<sub>2</sub>/ton of crude steel (t CO<sub>2</sub>/tcs) - as compared to DRI-EAF, which averages 1.4 t CO<sub>2</sub>/tcs<sup>41,24</sup>.

Given that fossil fuel-fired electricity inputs in the steelmaking process can be readily substituted with renewable energy, the challenge of full steel decarbonization lies with the decarbonization of the initial ironmaking stage. Three main options for decarbonizing ironmaking are recognized today: (i) hydrogen (H<sub>2</sub>)-based DRI, utilizing green hydrogen produced with renewable electricity, (ii) installing carbon capture, utilization, and storage (CCUS) systems on existing fossil-fuel DRI processes, and (iii) direct iron electrolysis<sup>6,10,32</sup>. Assessing these three options for their emissions abatement, technological maturity, and commercial development, the H<sub>2</sub>-DRI route is widely regarded as the leading option for deep decarbonization of ironmaking in the present day, leveraging the industry's familiarity with the DRI process<sup>2</sup>. This is evidenced by the several H<sub>2</sub>-DRI-EAF pilot projects underway around the world and particularly in Europe, where the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM) will, when it becomes fully operational in 2026, increasingly levy carbon tariffs on imported steel that does not meet the bloc's carbon emission standards to prevent carbon leakage<sup>7</sup>. This pending policy is driving nearly 60 low-emission steel projects across Europe today - including HYBRIT, H<sub>2</sub> Green Steel, ArcelorMittal, Primetals, and Hydnum Steel - which together have the potential to reduce CO<sub>2</sub> emissions by 81.5 million tons per year by 2030, supporting the European steel industry's target to cut carbon emissions by 55% by 2030 compared to 1990 levels<sup>9</sup>.

Despite the ongoing development of low- and near-zero emission green steel projects in Europe and the promise of H<sub>2</sub>-DRI-EAF technology, high-emission projects still make up around two-thirds of all announced steel projects worldwide<sup>23</sup>. This is particularly true in emerging economies, where, unlike advanced economies, which can leverage a sizable supply of scrap steel for secondary steel production, steel demand is projected to grow rapidly in the coming decades. This requires new primary steel production to support economic growth. For example, India is the second-largest steel producer in the world behind China, accounting for about 5% of global steel production, yet demand is forecast to double by 2030 and quadruple by 2050<sup>21</sup>. India's iron ore deposits are of mid-to-high quality<sup>52</sup>: the majority of production comes from hematite ores, with over 85% of hematite ore reserves being of medium to high-grade, i.e., >62% iron<sup>37,18</sup>. This is also reflected in lower costs: as of September 2025, Iron Ore fines with relatively higher Fe content (63%, Odisha) are traded at relatively lower costs 18%<sup>48</sup> compared to international benchmarks with even lower Fe content (Qingdao 62% Fe)<sup>50</sup>. Further, the carbon footprint of Indian steel is amongst the highest in the world, at approximately 2.5-2.8 tons CO<sub>2</sub>/ton steel as a result of relatively higher cost of natural gas, limited scrap availability and lower-grade coal<sup>52</sup>, constraining industry to the reliance on coal in both types of primary production processes, the relatively aged stock of BFs in use, and the smaller share of scrap input<sup>28,38</sup>.

Yet as major export markets for Indian steel take steps to meet climate neutrality commitments - and developed economies implement emission-based border taxes - there is an urgent need to assess the economic viability of green steel production in the context of the Global South in order to support rising demand, align with climate commitments, and remain competitive in a rapidly shifting global market. In contrast, the majority of recent work exploring steel decarbonization pathways has largely focused on global, North American, or European contexts<sup>34,6,19</sup>); work on emerging economies has failed to capture the leading position of the H<sub>2</sub>-DRI route for decarbonization of steel production in the near term<sup>38,32</sup>) or has focused solely on policy and regulatory steps to ease adoption<sup>28</sup>.

However, recent studies converge in identifying India among the lowest cost green steel producers and reducing the cost premium of H<sub>2</sub>-DRI-based green steel relative to BF-BOF steel due to the rapid declines in green hydrogen costs<sup>46,60</sup>. Johnson et al (2025)<sup>59</sup> show India as the lowest cost green H<sub>2</sub>DRI producer, starting from a 10% premium in 2025, reaching parity with European BF-BOF by 2030. Devlin et al (2023)<sup>6</sup> also show India among the most competitive global H<sub>2</sub>DRI producers reaching parity with local BF-BOF before 2050. EY-Parthenon et al. (2025)<sup>58</sup> estimate the premium to decline from 32 percent in 2025 to about 1 percent in 2030, reaching a discount of roughly 50 percent by 2050. The Rocky Mountain Institute (RMI, 2023)<sup>57</sup> estimates a cost premium of approximately 5 percent in 2030 under its mid scenario, transitioning to a discount of around 10 percent by 2050. Yadav et al.<sup>56</sup> (2021, CEEW) estimate the premium to fall from approximately 50 percent in 2020 to 20 percent in 2030 and 4 percent by 2040. Taken together, these studies consistently indicate a rapid narrowing of the cost gap through the 2030s; however, none of them incorporate differences in currency exposure and contracting assumptions.

Renewable electricity-driven green hydrogen costs in India remain largely fixed in nominal rupee terms, typically for 25 years, as seen in SECI's green-ammonia auctions (Aug 2025)<sup>46</sup> and SECI solar-plus-storage tenders (Jan 2026)<sup>61</sup>. In contrast, BF-BOF steel relies on imported coking coal priced in United States dollars, causing costs in rupee terms to rise systematically as the Indian rupee depreciates at a historical 3.2% (20-year average)<sup>62</sup> rate. Second, existing analyses have not quantified the scale of the coal import lock-in that a BF-BOF expansion trajectory implies: projected growth would require approximately 161 million tonnes of coking coal imports per year, representing roughly USD 30 billion imports annually and USD 1.2 trillion over a 40-year asset life, alongside a 19.5 Gt CO<sub>2</sub> commitment. Third, prior studies project cost trajectories from modelling assumptions, but India's 2025 and 2026 green hydrogen and ammonia auction outcomes, implying a USD 3.0/kg range, provide contract-level empirical grounding that no previous analysis has incorporated.

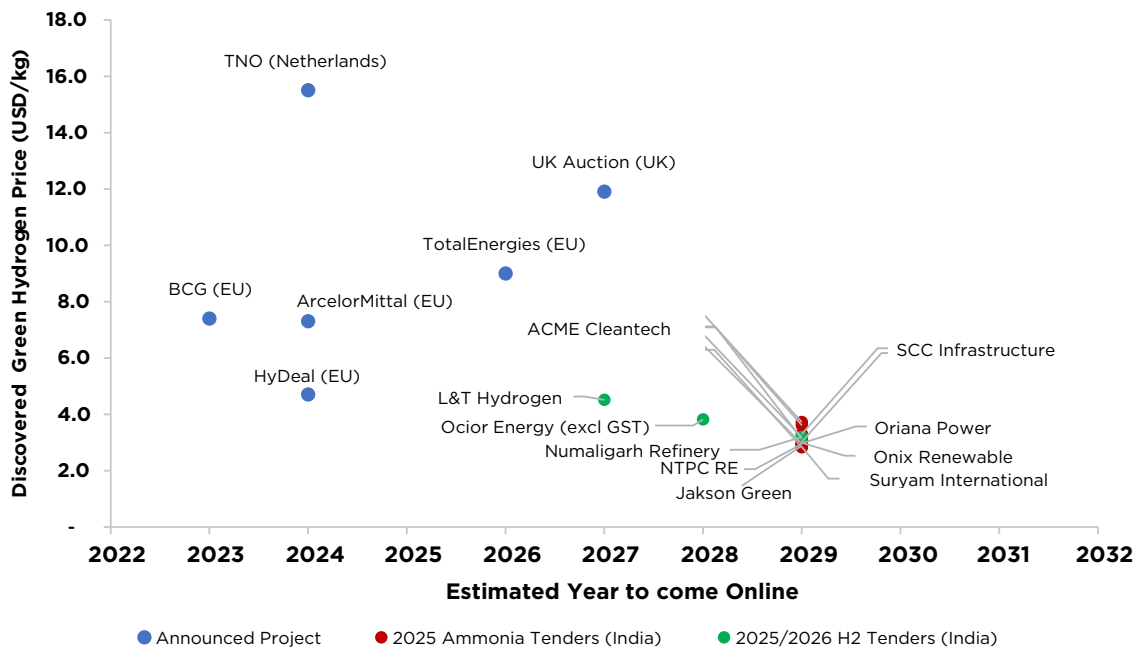
Here we develop a bottom-up cost optimization model anchored in India's current solar resource data, technology costs, and auction-derived prices to show that green hydrogen can be produced at USD 3.0/kg near-term, enabling green steel at under USD 600/t through H<sub>2</sub>-DRI-EAF. We then demonstrate that once currency exposure and coking coal inflation are incorporated into the comparison, H<sub>2</sub>-DRI steel reaches cost parity with BF-BOF steel for plants commissioned around 2030, even under conservative assumptions.

Targeting cost reductions and technological improvements in key areas may further lower the cost of hydrogen to 2.5 US\$/kg H<sub>2</sub> and the cost of green steel to below 500 US\$/ton, which is a highly competitive price locally and with valuable export potential in light of the pending tariffs of the European Union's Carbon Border Adjustment Mechanism. A conducive policy and regulatory framework will be key to deploying green hydrogen and steel production at speed and scale.

# 1. AFFORDABLE GREEN HYDROGEN IS KEY TO LOW-COST GREEN STEEL

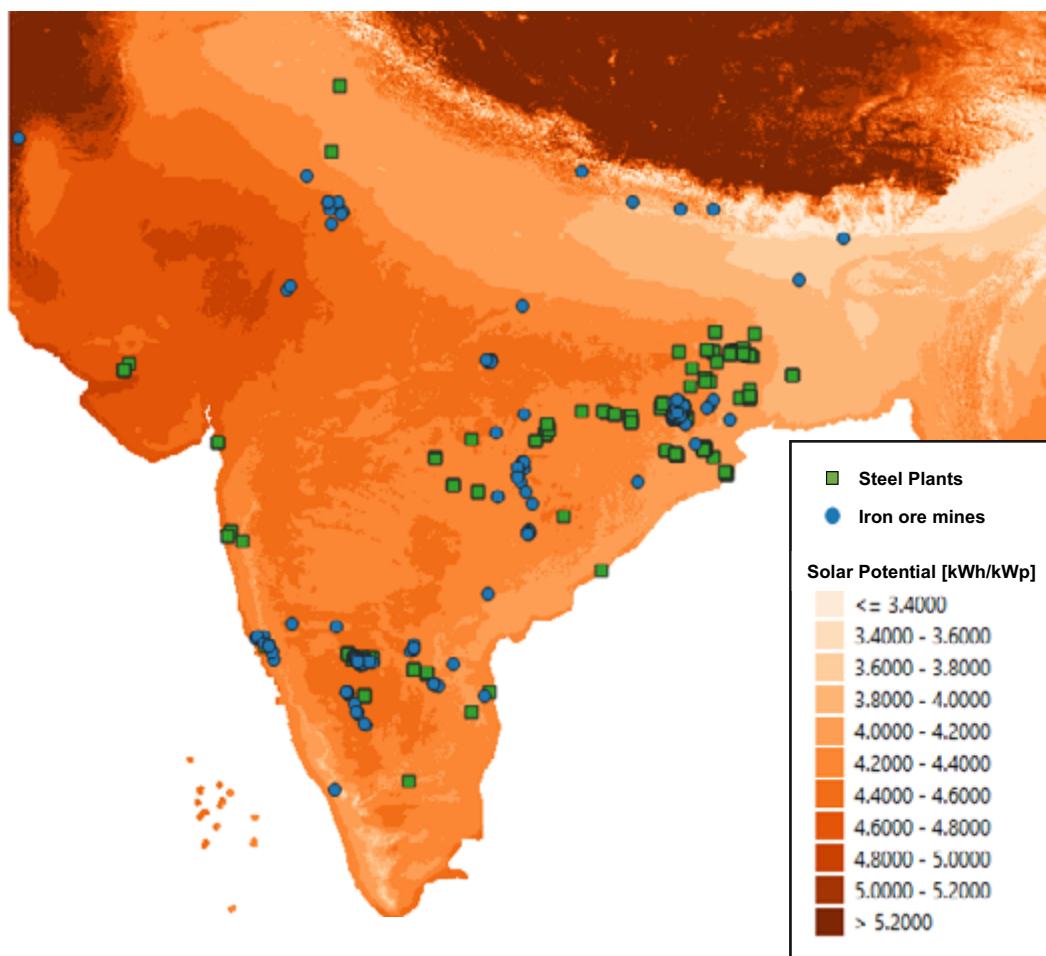
The leading position of the H<sub>2</sub>-DRI-EAF process for green steel production (which we define as steel produced through the H<sub>2</sub>-DRI process with green hydrogen, with less than 2 kg of CO<sub>2</sub> per kg of hydrogen, as defined by Indian regulation<sup>67</sup>) stems from its likeness to the conventional DRI-EAF process. However, there are two key differences: (i) it substitutes the customary fossil-fuel reducing agents like coal or natural gas with green hydrogen, produced from the electrolysis of water using electricity from renewable energy (RE) sources, and (ii) it powers the EAF and associated processes with renewable electricity as well. Therefore, the availability of consistent high-quality RE resources is crucial, as otherwise over-sizing RE capacity and/or integrating energy storage solutions in order to maintain a consistent supply of electricity throughout the day and year may quickly drive up project costs<sup>2</sup>. This is particularly relevant for the production of green hydrogen, which has historically been seen as cost-prohibitive; however, a number of studies have shown that green steel can be economically viable if the cost of green hydrogen feedstock can be reduced to approximately \$1.5-2/kg, particularly in countries with low-cost natural gas <sup>34,31,3,27</sup>.

Given India's import exposure to coking coal, the fuel component of BF-BOF steelmaking looks materially different: seaborne coking coal has averaged 212 US\$/t in fiscal year 2024-25, with 2022 peaks near 344 US\$/t. Using a typical coking-coal consumption of 0.7 t per t crude steel, this implies a coal fuel cost of roughly 148-241 US\$/t-steel under those price bands. This is equivalent to a hydrogen feed cost of roughly 2.5-4.0 USD/kg-H<sub>2</sub> for a mature H<sub>2</sub>-DRI system requiring about 60 kg H<sub>2</sub>/t-steel. This cost range is reflected in India's recent green hydrogen and ammonia auctions. Compared to various proposed projects around the globe, which indicate reference prices of 5-15 \$/kg, India is exhibiting a rapid decline toward 3-4 \$/kg, as seen in Figure 1. This convergence is strategically important for green steel because hydrogen feedstock costs dominate H<sub>2</sub>DRI-EAF economics, with a path toward near-term viability once delivered hydrogen approaches the 3.0 USD/kg threshold.



**FIGURE 1: Discovered prices for renewable hydrogen and ammonia: international reference projects vs. India’s 2025 auction outcomes.** Scatter shows announced international H<sub>2</sub> price discoveries (blue) alongside India’s green Hydrogen tenders (green) and for green ammonia in 2025 (red), plotted by estimated online year and discovered price (US\$/kg H<sub>2</sub>-equivalent), illustrating rapid price convergence toward sub-\$4/kg H<sub>2</sub>-eq via fixed-price, 10-year contracts.<sup>43,44,45,46,73</sup> All monetary figures use an exchange rate of 88 INR per USD for conversion and normalization across datasets; SIGHT scheme incentives were levelized over a 25-year offtake period and expressed as an H<sub>2</sub>-equivalent credit of 0.12 USD/kg-H<sub>2</sub>, which was netted from discovered prices; and renewable ammonia bids were translated to H<sub>2</sub>-equivalent using a conversion of 190kgH<sub>2</sub>/t, then discounted by 50 US\$/t-NH<sub>3</sub> to reflect residual Haber-Bosch CAPEX/OPEX, before reconversion to USD/kg-H<sub>2</sub>-eq for comparability across hydrogen and ammonia tenders. When considering additional benefits such as interstate transmission waivers and energy banking, the lowest unsubsidized costs of electrolytic hydrogen discovered in India auctions are near 3.5 US\$/kg.

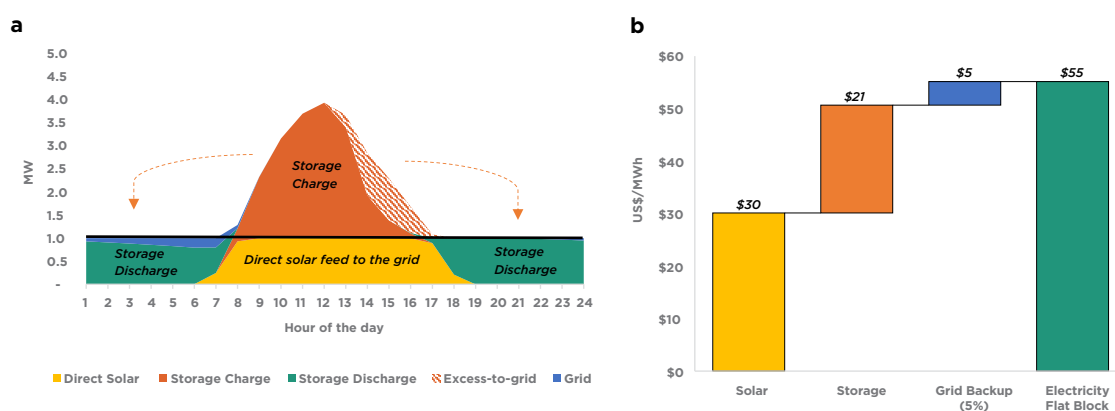
The key to low-cost green hydrogen is high-quality and low-cost solar. Fortunately, India is endowed with high-quality solar resources, as shown in Figure 2. These solar resources are highly consistent throughout the year due to the country’s close proximity to the equator. This dramatically reduces the capacity of long-term energy storage that would otherwise be needed to mediate seasonal solar output fluctuations and ensure a steady supply. This, in turn, decreases the costs of green hydrogen production and makes H<sub>2</sub>-DRI-EAF more economically viable in India, especially compared to other major steel producers like China, Japan, the United States, and Russia, all of which have lower-quality solar potential. India has leveraged these high-quality resources and has achieved some of the lowest prices of solar electricity in the world, in the low \$20s/MWh as of 2021<sup>47</sup>



**FIGURE 2: Solar energy potential and the locations of iron ore mines and steel plants in India.** The map illustrates the solar energy potential across India in terms of kWh per kWp, with darker shades of orange indicating higher potential<sup>13</sup>. Green points represent iron ore mines<sup>5</sup>, while blue points denote the locations of steel plants<sup>12</sup>.

We next develop a bottom-up cost optimization model to assess the techno-economics of different configurations for H<sub>2</sub>-DRI-EAF facilities, aiming to minimize the cost of green hydrogen and thus the cost of green steel. Specifically, as depicted in Figure 3, we explore a configuration of co-located solar PV plus battery storage with the hydrogen production optimized to ensure a steady stream of hydrogen into the targeted application; the DRI-EAF process requires continuous operation to ensure efficiency, productivity, and quality consistency.

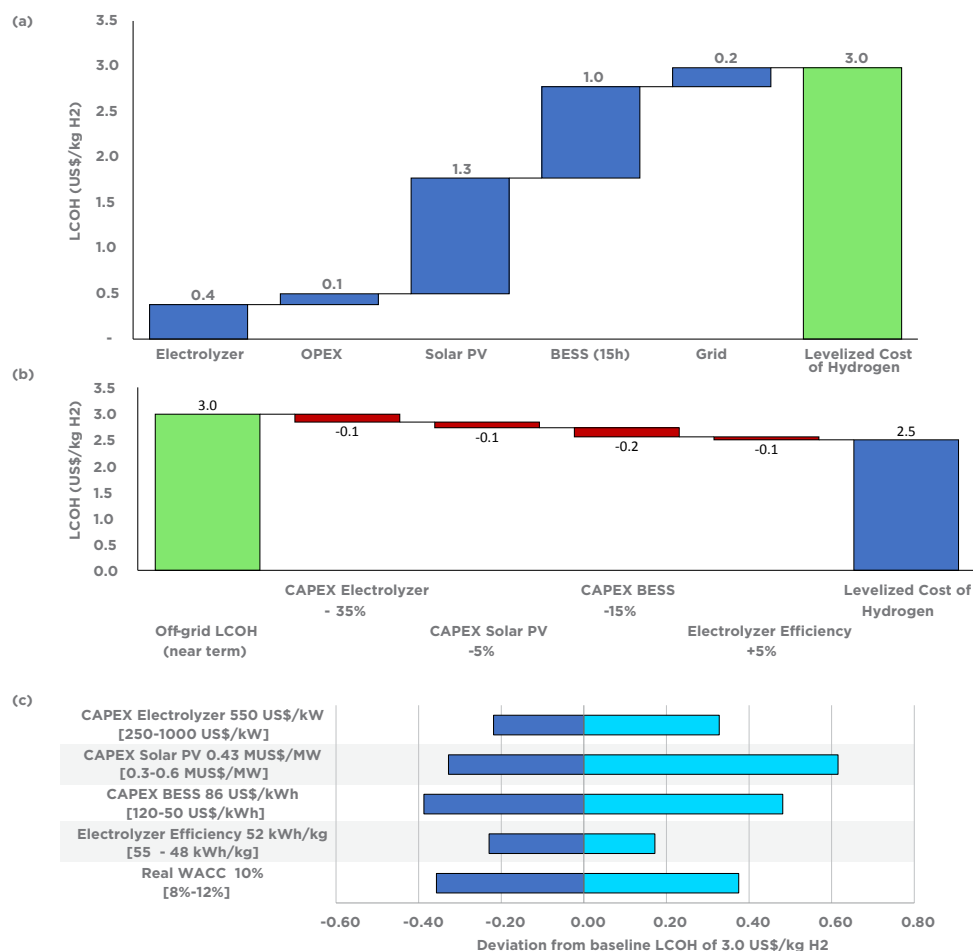
We therefore target an annual capacity factor of 95% for the solar+storage system, achievable through a high electrolyzer load factor, over-building of the solar farm capacity on a location with a typical DC capacity factor of 20%, and sizing battery storage to support 15 hours of daily electricity storage. Electrolyzers would operate continuously to produce hydrogen, requiring grid electricity only 5% of the time of the year to avoid solar drought periods. This results in an annual average load profile as shown in Figure 3a for a 1 MWh per hour continuous load. Figure 3a illustrates how over-building PV and pairing it with approximately 15 hours of battery duration can convert variable solar into a firm, 24/7 flat block of electricity, with batteries charging during the daytime and discharging overnight to sustain a constant output. Building on India’s recent solar+storage auction discoveries and bottom-up cost back-calculations, this configuration can deliver a fully reliable flat block below about 60 USD/MWh today<sup>47</sup>, especially when modest grid backup is used to lift availability from 95% to 100% while selling surplus to the grid (panel b).



**FIGURE 3: Delivering a 24/7 flat block from solar plus storage.** (a) Schematic 24-hour profile: oversized PV charges 15-hour batteries during solar hours and discharges through non-solar hours to provide a constant flat block of electricity; (b) levelized cost build-up for a reliable flat block combining low-cost solar, battery storage, and limited grid backup, yielding sub-60 USD/MWh today in India as documented by recent auction-derived analyses<sup>47</sup>.

Based on India’s solar resource profile, and incorporating technical constraints as well as cost parameters of the solar PV farm, the electrolyzer, and hydrogen storage, Figure 4a shows the resulting build-up of the minimized Levelized Cost of Hydrogen (LCOH) in India. We find that off-grid LCOH is at \$3.0/kg since costs associated with DC/AC conversion equipment can be avoided. Further, although the off-grid case may require a small amount of grid electricity for cold-starting the electrolyzers, the vast majority of electricity needs are supplied by the co-located solar farm, and as a result, this pathway achieves near-zero emissions.

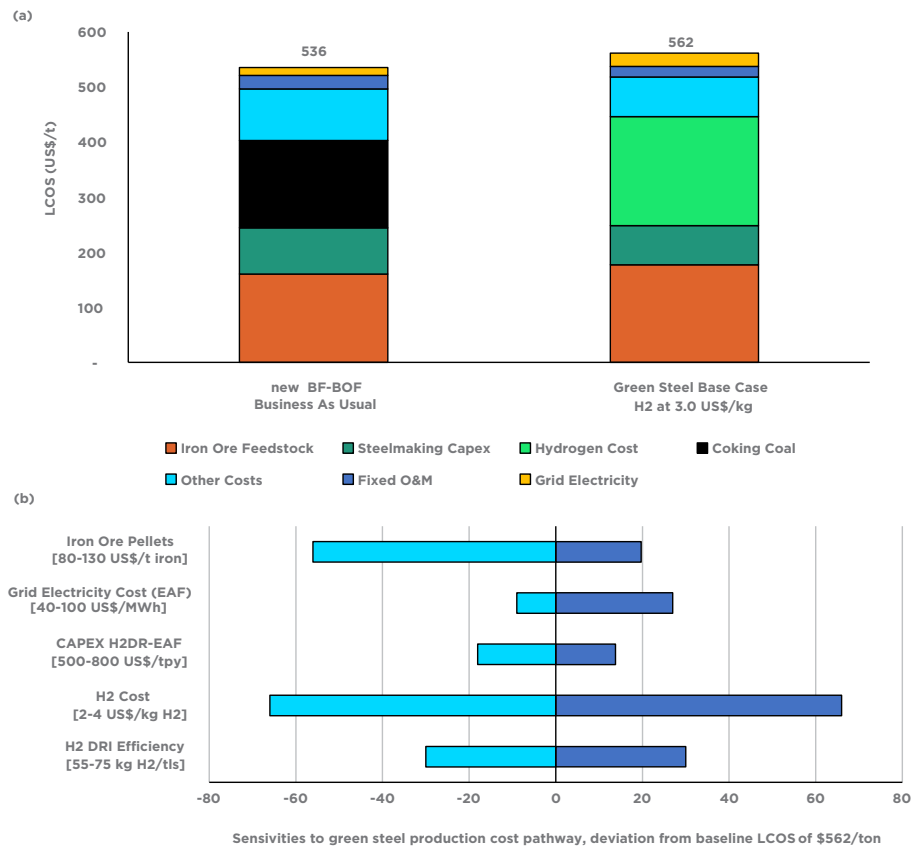
From the base case near-term off-grid hydrogen production, in Figure 4b, we show how additional targeted cost reductions in electrolyzer and hydrogen storage costs, as well as improvements in the technical efficiency of electrolyzers, have the potential to further reduce the LCOH from the near-term \$3.0/kg to \$2.5./kg within the mid-term, i.e., by 2035. In Figure 4c, we further explore the sensitivities of the LCOH of \$3.0/kg to key input assumptions. Potential declines in the capital cost of the electrolyzer have the potential for the largest decrease in LCOH, reinforcing the importance of targeting electrolyzer cost reductions as one of the top policy priorities. Also notable is aiming for a high load factor on the electrolyzer to ensure a steady stream of hydrogen output, maximizing utilization.



**FIGURE 4: Levelized Cost of Hydrogen (LCOH) in India.** (a) LCOH cost build-up of off-grid hydrogen production with limited grid backup. (b) LCOH can be reduced from the near-term \$3.0/kg to \$2.5/kg in the mid-term (2035) through projected reductions in electrolyzer, battery, and solar PV costs, as well as improvements in the technical efficiency of electrolyzers. (c) Sensitivities to key input assumptions from the baseline LCOH of \$3.0/kg. Baseline assumptions include an alkaline electrolyzer capex of \$550/kW, solar PV capex of 0.43M\$/MW, an integrated BESS CAPEX of 86 \$/kWh, an electrolyzer efficiency of 52 kWh/kg, and a Weighted Average Cost of Capital (WACC) of 10%. Green bars depict an increase in annualized peaker cost while blue bars depict a decrease in annualized peaker costs, relative to baseline assumptions. Costs are in 2025 US\$.

## 2. LEVERAGING COMPETITIVE H<sub>2</sub> AND IRON ORE FOR INDIA'S H<sub>2</sub>DRI PRODUCTION

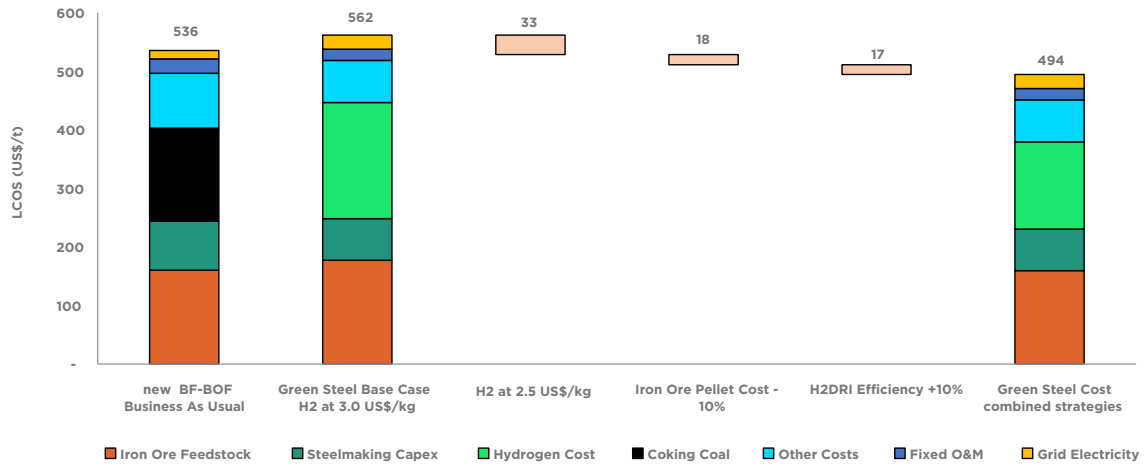
We next assess the Levelized Cost of Steel (LCOS) in Figure 5. With an LCOH of \$3.0/kg for our base case in the near term (2030), the LCOS comes out to \$562/ton. These figures are obtained using the estimated hydrogen costs and levelized values with a WACC of 10% for a 2 MTPA nth-of-a-kind steel facility. Comparatively, the historical average cost of steel in India over the past three years (between January 2021 and December 2023) was \$575/ton<sup>26</sup>. As can be seen, the cost of hydrogen plays a driving role in determining the final cost of steel. The other major driver of steel cost is the cost of iron ore pellets, which are lower in the international context, given India's mid-to-high ore quality<sup>51</sup>. We assume 117 US\$/t for high-grade pellets (66%Fe, including Iron ore fines 80 US\$/t<sup>48</sup> beneficiation, pelletization, and transportation at 37 US\$/t ore, which is substantially lower compared to international market references at 101 US\$/t<sup>49</sup> for 62%Fe content iron ore and above 150 US\$/t<sup>50</sup> for DR quality pellets. Figure 5 shows a potential near-term scenario (2030) for the Levelized Cost of Steel, where the Hydrogen cost is 3.0 US\$/kg, compared to a Business as Usual (new BF-BOF) facility.



**FIGURE 5: Levelized Cost of Steel (LCOS) in India.** (a) LCOS cost build-up of steelmaking through a new BF-BOF facility compared to an H<sub>2</sub>-DRI facility with a H<sub>2</sub> price of 3.0 US\$/kg. (b) Sensitivities to key input assumptions from the baseline LCOS of \$562/ton. Baseline assumptions include a hydrogen cost of \$3.0/kg, H<sub>2</sub>-DRI-EAF capex of \$670/tpy, grid electricity cost of \$60/MWh for EAF, and iron ore pellets cost of \$117/ton. Dark blue bars depict an increase in LCOS while light blue bars depict a decrease in LCOS, relative to baseline assumptions. Costs are in nominal US\$.

It is relevant to note that these two main pathway comparisons are made in nominal US\$, which confront different cost dynamics in terms of inflation and currency devaluation over the life of the assets. Such analysis is shown in the following section.

Figure 6 shows potential pathways for Levelized Cost of Green Steel reduction beyond BF-BOF levels. Iron Ore 10% cost reductions are achievable by integration along the value chain, i.e., steel production facilities can be located in close proximity to captive iron ore mines, saving on costs associated with transportation, logistics, intermediate mark-ups, and/or transactional costs if vertically integrated and/or use of captive mines. Further cost reductions can be brought by increasing by 10% the efficiency of the H<sub>2</sub>-DRI process from the assumed starting case of 66 kg H<sub>2</sub>/ton steel and reducing the capital costs (-10%) by scaling of manufacturing.

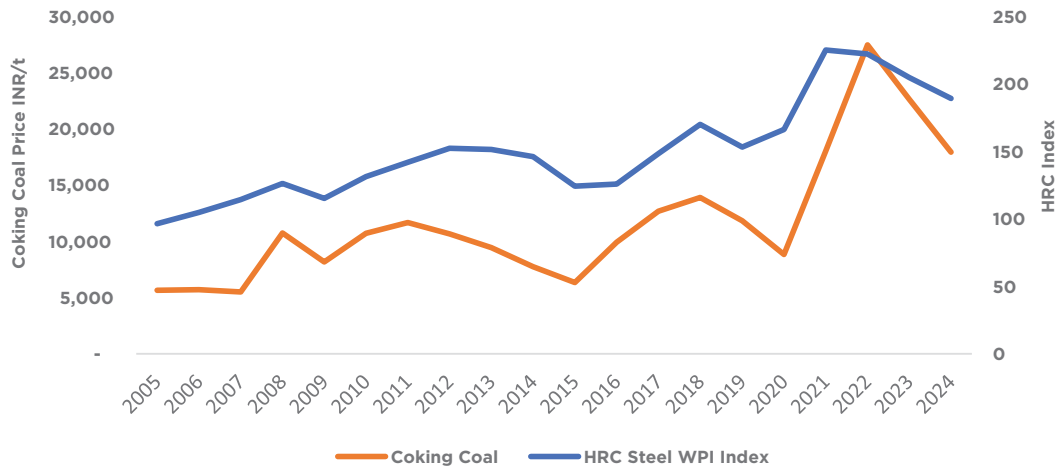


**FIGURE 6: Pathways for reducing the Levelized Cost of Steel (LCOS) in India.** LCOS cost build-up of steelmaking through a new BF-BOF facility compared to an H<sub>2</sub>-DRI facility with a varied H<sub>2</sub> price and further efficiency improvements in Iron Ore Pellets costs, H<sub>2</sub> DRI process efficiency, and Capital Expenditures reductions (CAPEX).

Further technological gains are possible by using an H<sub>2</sub>--DRI + Smelter + BOF configuration to process lower-grade ores, which can reduce beneficiation needs; this pathway was not evaluated in this analysis<sup>52</sup>.

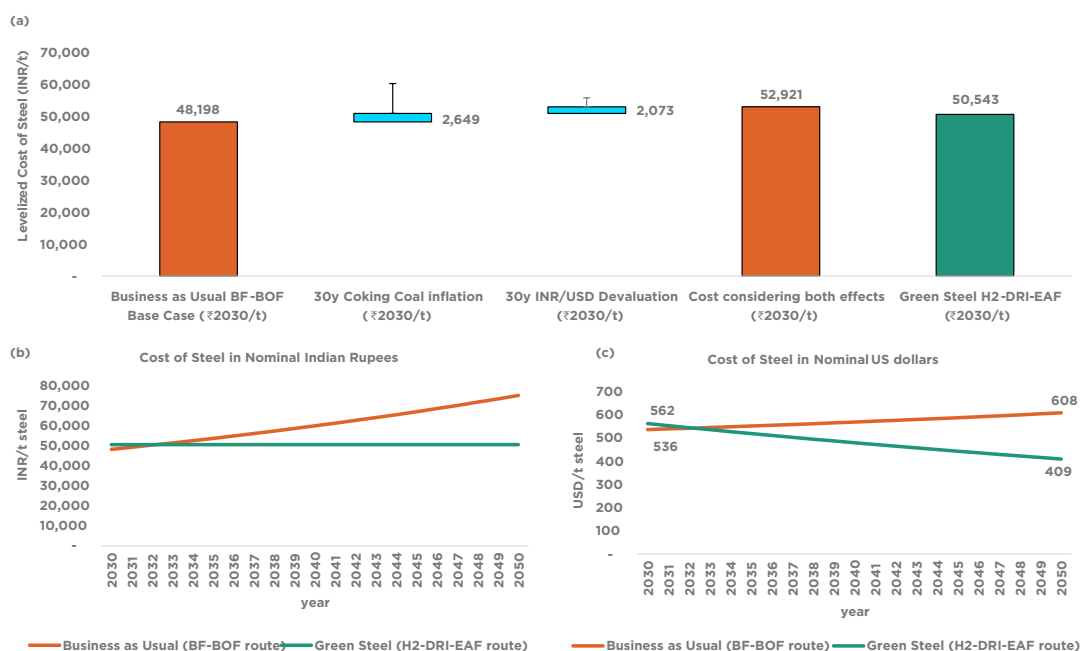
### 3. INFLATION AND INTERNATIONAL DEPENDENCE

BF-BOF steel is structurally exposed to rising coking coal over multi-decade asset lives, so capacity commissioned in the 2030s could remain exposed well into a period of tightening carbon constraints, currency devaluation, and inflation of scarce imported goods. Figure 7 shows the strong historical correlation between coking coal import prices (INR/ton) and the price index of Indian domestic Hot Rolled Coil (HRC) from 2005 to 2024, implying that global coal-market volatility transmits directly into Indian steelmaking costs.



**FIGURE 7: Coking Coal Import Prices (INR/t) and HRC Steel Wholesale Price Index, 2005–2024.** The left axis shows landed coking coal prices (INR/ton); the right axis shows the HRC Steel Wholesale Price Index. The close co-movement of the two series illustrates the structural pass-through of imported coal costs to domestic steel prices, highlighting the FX and input-cost exposure embedded in the BF-BOF production route. Sources: Coking coal import prices (INR/t) derived from Ministry of Commerce import data<sup>63,64,65</sup> and RBI exchange-rate series; HRC Steel WPI from the Office of the Economic Adviser, Ministry of Commerce and Industry<sup>74</sup>.

In contrast, Renewable electricity-driven green hydrogen costs in India remain largely fixed in nominal rupee terms because electricity, the dominant input, can be secured through long-term power purchase agreements denominated in Indian rupees, typically for 25 years. Parity of Indian Rupee denominated H<sub>2</sub>-DRI, and BF-BOF can be reached earlier when incorporating currency and import exposure. BF-BOF steel relies on imported coking coal priced in United States dollars, causing costs in rupee terms to rise systematically as the Indian rupee depreciates. Historical depreciation of the rupee vs the US dollar is 3.2% on average over the last 20 years<sup>62</sup>. Additionally, coking coal has shown an average inflation of 4.2% in nominal US dollars over the same period<sup>63,64,65</sup>. Considering both effects, rupee-denominated coking coal has increased at a rate of 7.4% on average over the last 20 years. Figure 8 shows that even if the rupee depreciates at only half its historical rate (1.6%/y) and coking coal inflation in USD is halved (2%/y), the levelized cost of H<sub>2</sub>-DRI steel converges with BF-BOF steel by the early 2030s. If depreciation continues at historical rates, H<sub>2</sub>-DRI steel becomes lower cost for plants commencing operation around 2030, while BF-BOF plants remain exposed to imported coal costs through the 40+-year life of assets, approximately 2060.



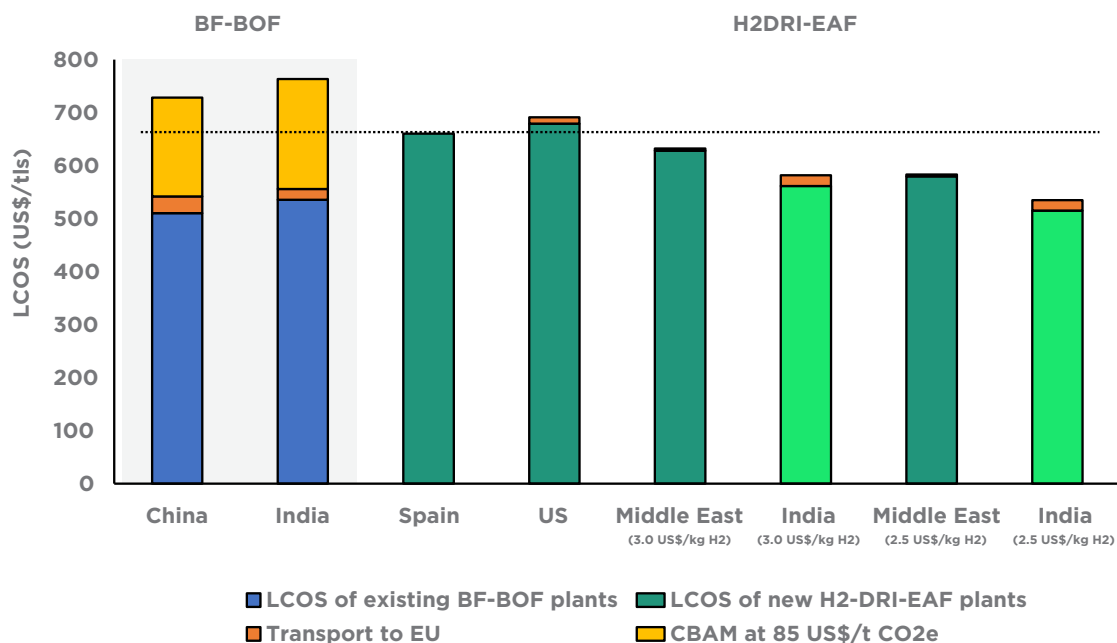
**FIGURE 8: Levelized Cost of Steel Production Pathways Accounting for Coking Coal Inflation and Currency Devaluation.** A panel compares levelized costs of BF-BOF steel (orange) versus H2-DRI/EAF steel (green) in 2030 INR terms, incorporating half the historical 20-year average increases in coking coal prices (2.0%) and INR/USD devaluation (1.6%) over a 30-year timeframe. BF-BOF costs reach Rs 52,921/tonne, exceeding H2-DRI/EAF at Rs 50,543/tonne, with bar ranges reflecting the highest average increase ranges over 20-, 10-, and 5-year periods. Lower panels (B and C) depict nominal costs per tonne over 2030–2050: Panel B in INR shows inflation-proof green H2-DRI/EAF (green) remaining flat while BF-BOF (orange) rises due to coking coal inflation; Panel C in USD highlights BF-BOF growth from coal effects despite INR devaluation benefits for H2-DRI/EAF.

## 4. COMPETITIVENESS OF INDIA'S GREEN STEEL IN A CHANGING GLOBAL MARKET

While the EU is a key market for Indian steel today - the bloc annually imports about \$5.5 billion worth or around 27% of India's total iron and steel exports<sup>16</sup> - the pending CBAM is likely to increasingly erode the competitiveness of imported highly-carbon-intensive steel, absent additional action. Specifically, the CBAM is set to levy carbon tariffs on imported steel that does not meet the bloc's carbon emission standards to prevent carbon leakage, beginning in 2026 and ramping up with the phase-out of free allowances by 2035<sup>7</sup>. Therefore, whereas Indian and Chinese BF-BOF steel may have previously enjoyed a competitive advantage stemming from lower production costs as a result of less stringent environmental regulations, the impending carbon tariffs may make it less competitive within the European market compared to domestically produced steel or steel from countries with comparable carbon pricing policies. Other previous work has shown that CBAM could pull down the profits of Indian steel exports to the EU by 60-165 US\$/MT between 2026 and 2034, as Indian steel production has a significantly higher carbon footprint than competing suppliers to the EU<sup>20</sup>. With the competitiveness of India's steel industry at stake, we assess steel production costs post-CBAM in major production countries and their respective production processes based on input energy costs, forecast CBAM tariffs, and sea-based transportation to the EU market.

In Figure 9, we show how a CBAM tariff of 85 US\$/t CO<sub>2</sub>e will make India's and China's BF-BOF steel approximately 15% more expensive than steel that is produced within the EU through H<sub>2</sub>-DRI-EAF. Spain - the home of many announced H<sub>2</sub>-DRI projects, leveraging the country's abundant wind and solar - is able to produce green steel at brownfield sites at approximately 660 US\$/ton of crude steel<sup>9, 8</sup>. Meanwhile, US producers leveraging lower input energy costs are capable of producing H<sub>2</sub>-DRI-EAF at brownfield sites at approximately 693 US\$/t<sup>8</sup>. Yet producing steel in India via H<sub>2</sub>-DRI-EAF emerges as the cheapest option at approximately 582 US\$/t, inclusive of delivery to the EU, driven by high-quality and low-cost solar and lower labor costs. With further cost reductions in the cost of hydrogen to 2.5 US\$/kg H<sub>2</sub>, steel produced via H<sub>2</sub>-DRI-EAF in India would come at a steep discount to both steel produced via the conventional BF-BOF process as well as green steel produced domestically within the EU. Considering that EU carbon prices are projected to rise from the recent historical average of 85 US\$/t CO<sub>2</sub>e up to higher, as simultaneously free allowances are phased out, the cost advantage of green steel will grow correspondingly. In EY-Parthenon et al., 2025<sup>58</sup>, this translates into a material border-cost exposure for EU-bound Indian steel: the implied additional CBAM charge is approximately -US\$237/t in 2030 and -US\$638/t in 2040. These levels of carbon-related charges can

materially erode the competitiveness of high-emissions BF-BOF steel in EU markets, whereas H<sub>2</sub>-DRI/EAF supplied with low-carbon hydrogen and electricity materially reduces embedded emissions, and therefore reduces exposure to both domestic carbon-cost pass-through and CBAM-related charges. This demonstrates that Indian producers who invest in cleaner steel production technologies in the present day would likely retain, if not even additionally boost, their competitiveness within the EU steel market, compared to the conventional BF-BOF production pathway.

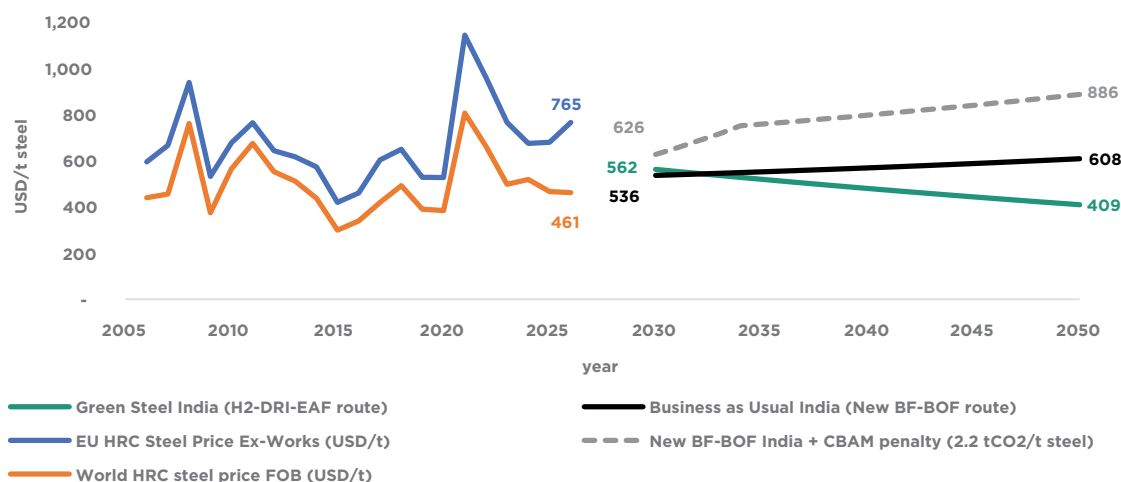


**FIGURE 9: Costs of steel in major steel-producing countries, inclusive of a CBAM tariff of 85 US\$/t CO<sub>2</sub>e.** Color corresponds to the cost component; the dashed line reflects the average global market price of steel, at 650 US\$/t HRC. CBAM tariff calculation assumes an emissions intensity of 2.6 t CO<sub>2</sub>/tcs in India and 2.3 t CO<sub>2</sub>/tcs in China<sup>11,35,36</sup>.

These calculations show consistency with recent studies<sup>59</sup> with India emerging among the lowest cost of green H<sub>2</sub> DRI, but also facing the highest penalties from CBAM. Further, approximately 100 MT capacity investment in H<sub>2</sub>DRI is anticipated by the year 2035.

Moreover, Figure 10 contrasts the historical price record against the cost trajectories of two steelmaking projects commissioned in 2030. A new BF-BOF plant remains exposed to imported coking coal priced in dollars, so its production costs drift upward over time with global inflation and rupee depreciation. Moreover, CBAM exposure widens the gap further as EU free allowances phase out through the 2030s. A H<sub>2</sub>-DRI/EAF project follows the opposite path: renewable electricity locked in through long-term INR-denominated PPAs

makes green hydrogen costs fall from roughly US\$3.00/kg in 2030 toward US\$1.90/kg by mid-century, so its costs stay effectively fixed in rupee terms and decline when expressed in nominal USD. The two trajectories cross within the asset-life window, marking the point at which green steel ceases to be a premium product and becomes the lower-cost route to serve both local and carbon-exposed export markets. Investment decisions that fail to internalize long-term cost trajectories risk a prolonged lock-in of uncompetitive, high-cost assets.



**FIGURE 10:** Steel: Historical Market Prices and Production Cost Projections by Route (Nominal USD/t), 2005–2050. Historical series show realized market prices, while forward series show levelized production costs for new plants commissioned in 2030. The BF-BOF + CBAM line is illustrative; actual exposure will depend on verified embedded emissions, the prevailing EU ETS price, and any crediting of carbon prices paid in the country of origin. CBAM cost calculation assumes 2.2 tCO<sub>2</sub> per ton of BF-BOF steel, an EU ETS carbon price starting at approximately US\$85/tCO<sub>2</sub> in 2030 and growing at 2% p.a. (nominal), with the effective CBAM cost adjusted for the legislated free-allowance phase-out schedule (Regulation (EU) 2023/956: 48.5% in 2030, rising to 100% by 2034). Green steel costs decline as green hydrogen costs in nominal USD fall from approximately US\$3.00/kg in 2030 toward approximately US\$1.90/kg by mid-century, with renewable electricity locked in via long-term INR-denominated PPAs. Sources: EU HRC ex-works price and World HRC FOB price (historical) from SteelBenchmark75.

## 5. DISCUSSION

Steel production contributes a major share of greenhouse gas emissions, yet the majority of planned projects - particularly in rapidly growing emerging economies - are based on conventional fossil-fuel-based technology. However, these results suggest that the window for cost-effective green steel deployment in India is open today, not in the late 2030s as previously assumed. Moreover, capital allocation decisions that fail to consider input-cost and carbon-price exposure, risk becoming structurally uncompetitive well within their economic lifetime.

Several methodological choices merit discussion. First, our system configuration relies on solar-plus-battery storage with limited grid backup to deliver a flat-block electricity supply, because of its ubiquity, rather than optimising across wind-solar hybrid configurations or dynamic DRI operation. These alternatives could reduce LCOS further in some locations, and surplus electricity exports to the grid could improve project economics; both would favour the H<sub>2</sub>-DRI pathway. Second, we model a single representative solar site rather than conducting site-specific analysis across India's diverse solar resource zones; costs would be lower at the best sites (e.g., Rajasthan, Gujarat) and higher at marginal ones. Third, we do not assess the potential for exporting Hot Briquetted Iron (HBI) directly to the EU, which could leverage India's low-cost green hydrogen and iron ore advantages while utilising existing European EAF steelmaking capacity – a mutually beneficial trade pathway that warrants dedicated analysis. Finally, we do not model the H<sub>2</sub>-DRI + Smelter + BOF configuration that could process lower-grade ores and reduce beneficiation costs, nor do we assess the potential for hot-charging DRI into the EAF to reduce electricity consumption – both of which represent additional cost reduction pathways not captured here.

A conducive policy and regulatory framework will be essential to deploy green hydrogen-DRI/EAF steelmaking in India at speed and scale. However, improving economics does not automatically translate into deployment at scale: early projects face a bankability gap, as buyers and financiers need contractible near-zero definitions and Measurement, Reporting, and Verification (MRV)<sup>71</sup>, multi-year offtake at meaningful scale (with payment security)<sup>72</sup>, and coordinated enabling actions, alongside risk-reduction for first plants and DR-grade ore/pellet readiness. Building on India's Green Steel Taxonomy<sup>70</sup>, these constraints could be addressed by demand signals such as, public procurement and tenders. These demand signals should be complemented by enabling measures that lower first-plant risk and accelerate execution, including standardised contracting and performance-guarantee templates, limited first-of-a-kind risk cover, an ore-and-pellet strategy to improve DR-grade feedstock readiness, and alignment with clean-power and green-hydrogen certification/contracting under the National Green Hydrogen Mission.<sup>68</sup>

This targeted policy can help spur India to not only become a leader in green steel production, but likewise an expert in the H2-DRI-EAF process itself. Compared to the top producer, China, where nearly 90% of steel is made via the BF-BOF route, India produces only approximately 46% of its steel via BF-BOF, with a majority of steelmaking done through electric pathways<sup>17,15</sup>. India can leverage its current position as a top steel producer already, including corresponding know-how and skilled labor, to become a global leader in steelmaking via H2-DRI-EAF. Future analysis can be conducted to assess the cost and benefit trade-offs of siting green hydrogen and steel production in the highest-quality solar areas, i.e., in the west of India, where limited steel production takes place today, versus closer to existing iron ore mines and existing steel plants, which tend to be found in the east of India.

Given its substantial industrial output and carbon footprint, urgent action is required to safeguard the competitiveness of the Indian steel industry, particularly given that impending policies - namely the EU's CBAM - are phased in. However, the near-term deployment of green steel production at scale may also deliver other economic and environmental benefits, not explicitly studied here. For example, because Indian coal has a high ash content, most of the coking coal required for steel production via the conventional BF-BOF route - over 80% - must be imported. This leaves India heavily exposed to fluctuations in international energy markets and coal prices, which in turn have a major impact on India's industrial energy costs, consumer inflation, and foreign trade balance/currency<sup>1</sup>. In fact, projections of BF-BOF steel production will demand 161 MT of coking coal (90% imported), approximately 30 billion US\$ annually, locking in approximately 6 billion tons and 1.2 trillion US\$ imports over a 40-year period. With an average of 2.6 tCO<sub>2</sub> per tonne of steel, this will represent 19.5 Gt CO<sub>2</sub> over the same period. In contrast, the H2-DRI-EAF pathway would leverage India's abundant solar for green hydrogen production as well as high-quality iron ore resources, reducing the country's coke import dependency and shielding Indian steel production from the coal price volatility that has driven up steel production costs in recent years<sup>30</sup>. Further, whereas the low availability of domestic scrap steel limits secondary steel production in India today, substantial infrastructure is set to reach the end of its lifespan in the coming years; complementary policy promoting the recovery of domestic scrap steel may also help to reduce the resource inputs and energy intensity of steel production within existing pathways in a cost effective manner<sup>1</sup>.

# METHODS

## COSTS OF HYDROGEN PRODUCTION

We use hourly-resolution solar energy resource data from the Global Solar Atlas<sup>13</sup> to estimate the amount of solar energy that is available at a representative (Gujarat or Rajasthan) 20% capacity factor DC-solar site in India in one year<sup>47</sup>. This data was used to calculate the amount of hydrogen that could be produced through electrolysis at each site, as well as the corresponding hydrogen storage requirement, potential curtailment, and cost of hydrogen. For the electrolyzer, we assume alkaline technology as it is the lowest-cost today, with costs and technical parameters based on the literature<sup>4,43</sup>. We then size the hydrogen production (solar, electrolyzer, and storage) by minimizing the LCOH, targeting a desired output capacity factor defined as the quantity of hydrogen input to the H<sub>2</sub>-DRI facility per hour divided by the total hours in a year. The LCOH methodology is based on NREL Capital Recovery Factor<sup>53</sup>, using a plant life of 25 years<sup>8</sup>, stack replacement every 10 years and a Weighted Average Cost of Capital (WACC) of 10%<sup>47</sup>. A full list of cost assumptions for energy costs and electrolyzers is provided in Table S1.

$$\text{LCOH}(\text{US\$/kg}) = \frac{\text{Annualized CAPEX} + \text{LCOE} + \text{OPEX} + \text{Grid use}}{\eta_e * 365 * \text{Availability}}$$

Levelized Cost of Hydrogen (LCOH) estimated with Hydrogen production equipment considered in annualized Capital Expenditures(CAPEX), flat block electricity considered in LCOE<sup>47</sup>, annual Operational Expenditures (OPEX) estimated as 2% of CAPEX, Grid use as 5% of year hours at 90 US\$/MWh,  $\eta_e$  referring to the electrolyzer efficiency and availability as 95%.

## COSTS OF STEEL PRODUCTION

We then use the LCOH and resource data to estimate the Levelized Cost of Steel of producing green steel at a typical plant in India, incorporating capital and operating costs, renewable energy resource availability, and hydrogen storage requirements. As the H<sub>2</sub>-DRI technology is under development and not fully mature, we used multiple sources to conservatively estimate the production efficiencies and energy use to produce a ton of

green steel. All costs are estimated for a large steel plant, i.e., with a production capacity of 2 MT/yr, equivalent to a demand for 16 tons H<sub>2</sub>/hr. Table S2 provides an overview of input assumptions from various sources and the conservative values we assumed for this analysis.

$$\begin{aligned}
 \text{LCOS (US\$/t)} &= \frac{\text{Annualized CAPEX}}{\text{Annual Steel Output}} + \text{OPEX} + \text{EAF electricity} + \text{LCOH} * \eta_s \\
 &+ \frac{\text{Iron Ore cost}}{\text{Fe\%}}
 \end{aligned}$$

Levelized Cost of Steel (LCOS) estimated with H<sub>2</sub>DRI-EAF production equipment considered in annualized Capital Expenditures(CAPEX), WACC of 10%, annual Operational Expenditures (OPEX) estimated as 34 US\$/t, EAF electricity estimated as 0.6 MWh/t steel at 55 US\$/MWh, LCOH as Levelized cost of hydrogen,  $\eta_s$  referring H<sub>2</sub>DRI efficiency in kilograms of Hydrogen per tonne of steel output and Iron ore pellet cost at 117 US\$/t with 66%Fe content, and a Steel Output of 2.0 MTPA.

## CBAM COMPARISON

We take costs for steel production in existing BF-BOF plants in India and China from <sup>29</sup> and add costs of delivery to the EU of 20 US\$/t<sup>36</sup> assuming China-EU distance of 16,000 km and India-EU distance of 10,000 km. We further add the cost of the CBAM tariff, calculated by taking the recent historical average EUA price of 85 US\$/t CO<sub>2</sub>e<sup>54</sup> and multiplying by the average carbon emissions intensity of steel production in India and China<sup>11,35</sup>. We take costs for steel production in new H<sub>2</sub>-DRI-EAF plants in Spain and the US<sup>8</sup> based on present-day production costs of H<sub>2</sub>-DRI-EAF plants located at brownfield sites; for the US, we add costs of delivery to the EU of 20 US\$/t<sup>36</sup> assuming a US-EU distance of 6,000 km. The LCOS of India's H<sub>2</sub>-DRI-EAF production is obtained from our preceding analysis.

## CURRENCY AND IMPORT EXPOSURE COMPARISON

To compare the two steelmaking pathways on a like-for-like basis over a 30-year timeframe, we construct levelized cost trajectories in Indian rupee terms for plants commissioned in 2030. For BF-BOF steel, we escalate the coking coal input cost annually at two rates applied simultaneously: (i) the historical average nominal USD inflation of coking coal prices<sup>63,64,65</sup>, and (ii) the historical average depreciation of the Indian rupee against the US dollar<sup>62</sup>, both computed over a 20-year period (2005–2025). We then compute the levelized cost of each pathway as the net present value of all annual costs over the 30-year asset life, discounted

at a nominal WACC of 10% and divided by the steel output. To test robustness, we present three scenarios: (i) historical average rates for both coal inflation and rupee depreciation, (ii) coal inflation halved to 2.0%/year with historical depreciation, and (iii) historical coal inflation with depreciation halved to 1.6%/year. These scenarios correspond to the panels in Figure 8.



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# SUPPLEMENTARY INFORMATION

**TABLE S-1: Cost assumptions for electricity production.**

| Electricity Production                  | Unit       | Base case value (2030) | Mid Term Scenario (2035) |
|---|------------|------------------------|--------------------------|
| Weighted Average Cost of Capital (WACC) | %          | 10%                    | 10%                      |
| Lifespan                                | years      | 25                     | 25                       |
| CAPEX Solar PV AC                       | MUS\$/MW   | 0.43                   | 0.41                     |
| BESS CAPEX                              | US\$/kWh   | 86                     | 74                       |
| Solar Capacity Factor (AC)              | %          | 25%                    | 25%                      |
| OPEX (PV and BESS)                      | % of CAPEX | 2%                     | 2%                       |
| Grid electricity (dry hours)            | US\$/MWh   | 90                     | 90                       |

**TABLE S-2: Cost assumptions for hydrogen production.**

| Electricity Production                     | Unit       | Base case value (2030) | Mid term Scenario |
|--|------------|------------------------|-------------------|
| Weighted Average Cost of Capital (WACC)    | %          | 10%                    | 10%               |
| Lifespan                                   | years      | 25                     | 25                |
| CAPEX Electrolyzer                         | MUS\$/MW   | 0.55                   | 0.35              |
| Electrolyzer efficiency                    | kWh/kg     | 52                     | 50                |
| OPEX Electrolyzer (inc. stack replacement) | % of CAPEX | 3.5%                   | 3.5%              |
| OPEX Electrolyzer                          | % of CAPEX | 2%                     | 2%                |

**TABLE S-3: Cost assumptions for green steel production.**

| Value/Source                                 | BloombergNEF | RMI <sup>32</sup> | (Rosner et al., 2023) | (Bhaskar et al., 2022) | Base Case value | Unit                       |
|--|--------------|-------------------|-----------------------|------------------------|-----------------|----------------------------|
| Iron ore pellets required H <sub>2</sub> DRI | 1.6          | 1.6               | 1.6                   | 1.5                    | <b>1.52</b>     | t iron/t steel             |
| Electricity EAF                              | 0.53         | 0.78              | 0.55                  | -0.6                   | <b>0.6</b>      | MWh/t steel                |
| Electricity other                            | -            | -                 | -                     | -0.5                   |                 | MWh/t steel                |
| Total Electricity use                        | 0.53         | 0.78              | 0.55                  | 1.10                   | <b>0.60</b>     | MWh/t steel                |
| Cost of iron ore pellets                     | 125          |                   | 130                   | 120                    | <b>117</b>      | US\$/t iron                |
| H <sub>2</sub> -DRI-EAF efficiency           | 73.3         | 56.7              | 67-76                 | 59.5                   | <b>66</b>       | kg H <sub>2</sub> /t steel |
| H <sub>2</sub> DRI CAPEX                     | 670          |                   |                       |                        | <b>670</b>      | US\$/t                     |

**TABLE S-4: Cost assumptions for BF-BOF steel production.**

| Item             | Value       | Unit         |
|------------------|-------------|--------------|
| BF-BOF CAPEX     | <b>800</b>  | US\$/t       |
| Coking Coal Cost | <b>200</b>  | US\$/t       |
| Iron Ore use     | <b>1.58</b> | tons/t-steel |
| Coking Coal use  | <b>0.7</b>  | tons/t steel |
| Thermal Coal use | <b>0.1</b>  | tons/t steel |

**TABLE S-5: Discovered prices for renewable hydrogen and ammonia: international reference projects vs. India’s 2025 auction outcomes.**

Methodological note: All monetary figures use an exchange rate of 88 INR per USD for conversion and normalization across datasets; SIGHT scheme incentives were levelized over a 25-year offtake period and expressed as an H<sub>2</sub>-equivalent credit of 0.12 USD/kg-H<sub>2</sub>, which was netted from discovered prices; and renewable ammonia bids were translated to H<sub>2</sub>-equivalent using a conversion of 190kgH<sub>2</sub>/t, then discounted by 50 US\$/t-NH<sub>3</sub> to reflect residual Haber-Bosch CAPEX/OPEX, before reconversion to USD/kg-H<sub>2</sub>-eq for comparability across hydrogen and ammonia tenders. Commercial Operations Date (COD) is either obtained from references or estimated as 3 years after auction.

| Announced Project       | COD  | Hydrogen Eq Price (\$/ kg) | Ammonia Price in Rs | Hydrogen Price in Rs | Source |
|-------------------------|------|----------------------------|---------------------|----------------------|--------|
| TNO (Netherlands)       | 2024 | 15.5                       |                     |                      | 43     |
| BCG (EU)                | 2023 | 7.4                        |                     |                      | 43     |
| UK Auction (UK)         | 2027 | 11.9                       |                     |                      | 43     |
| TotalEnergies (EU)      | 2026 | 9.0                        |                     |                      | 43     |
| ArcelorMittal (EU)      | 2024 | 7.3                        |                     |                      | 43     |
| HyDeal (EU)             | 2024 | 4.7                        |                     |                      | 43     |
| L&T Hydrogen            | 2027 | 4.5                        |                     | 397                  | 44     |
| Ocior Energy (excl GST) | 2028 | 3.8                        |                     | 328                  | 45     |
| Numaligarh Refinery     | 2029 | 3.2                        |                     | 279                  | 73     |
| ACME Cleantech          | 2029 | 3.0                        | 51.9                |                      | 46     |
| ACME Cleantech          | 2029 | 3.1                        | 54.7                |                      | 46     |
| ACME Cleantech          | 2029 | 3.2                        | 55.8                |                      | 46     |
| ACME Cleantech          | 2029 | 3.7                        | 64.7                |                      | 46     |
| ACME Cleantech          | 2029 | 2.8                        | 49.8                |                      | 46     |
| ACME Cleantech          | 2029 | 3.6                        | 62.8                |                      | 46     |
| Jakson Green            | 2029 | 2.9                        | 50.8                |                      | 46     |
| SCC Infrastructure      | 2029 | 3.0                        | 53.1                |                      | 46     |
| SCC Infrastructure      | 2029 | 3.3                        | 57.7                |                      | 46     |
| NTPC RE                 | 2029 | 3.0                        | 51.8                |                      | 46     |
| Oriana Power            | 2029 | 3.0                        | 52.3                |                      | 46     |
| Onix Renewable          | 2029 | 3.0                        | 52.5                |                      | 46     |
| Suryam International    | 2029 | 2.8                        | 50.0                |                      | 46     |