TransitionAsia
ACCELERATING ASIAN CORPORATE CLIMATE ACTION

HOW LOW-CARBON STEEL DEVELOPMENT ACCELERATES ENERGY-SECTOR DECARBONISATION IN CHINA

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ACHIEVING NEAR-ZERO-CARBON STEEL PRODUCTION IS INSEPARABLE FROM DEEP DECARBONISATION OF THE ENERGY SECTOR

At present, near-zero steel production can be achieved through the green hydrogen-direct reduced iron-electric arc furnace (H_2-DRI-EAF) pathway. Assuming companies adopt on-site renewable energy generation combined with grid-connected hydrogen production, the degree of grid electricity decarbonisation will become a key factor influencing steel production costs.

Given the national average grid emission factor in 2022 (0.52 kgCO_2/kWh), producing near-zero-emission primary steel (0.4 tCO_2 per tonne) means that more than 85% of total emissions would come from grid electricity.[1] Under this constraint, steel producers would need to reduce their reliance on grid power while significantly increasing investment in self-owned renewable generation and associated energy storage facilities to meet the low-carbon electricity requirements of zero-carbon processes.

However, on-site renewable energy generation and energy storage projects generally require high upfront investment, with costs potentially accounting for 15–30% of the total cost of near-zero-carbon steel production. If companies aim to meet the emissions threshold of 0.4 tonnes of CO_2 per tonne of steel while effectively controlling investment scale, they will need to rely heavily on the continued decarbonisation of the grid, specifically through further reductions in the grid emission factor. At present, China's grid emission factor is declining year by year and it is a time-consuming process. For steel producers seeking first-mover advantages to become early deployment of near-zero-carbon steel production, rigourous cost assessment is especially important.

Although on-site renewable power plants involve substantial upfront investment, their long-term operating costs are relatively low. However, due to the intermittent nature of wind and solar output, companies must invest heavily in energy-storage facilities to ensure continuity of production. The upfront investment in energy storage is far from negligible: in general, the cost of a two-hour energy-storage system can account for 8–20% of the initial capital cost of a wind or solar power plant.[2]

1 According to Responsible steel 'cradle to crude' emissions accounting methodology
2 https://assets.kpmg.com/content/dam/kpmg/cn/pdf/zh/2023/03/new-energy-storage-helps-energy-transformation.pdf

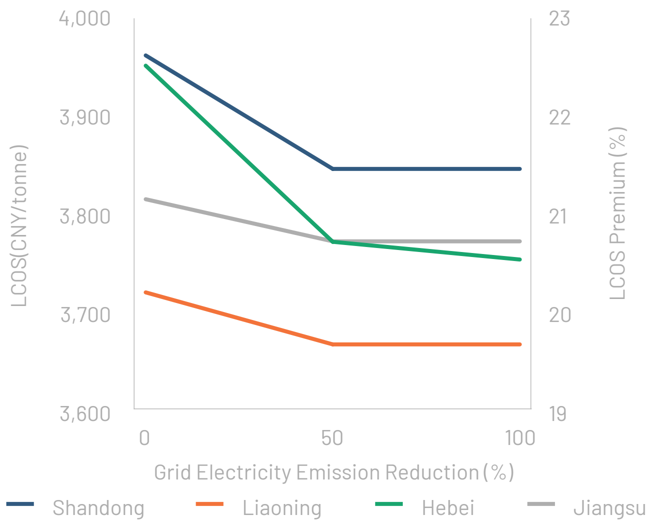
COST DYNAMICS BETWEEN CLEAN ELECTRICITY AND NEAR-ZERO-CARBON STEEL

Considering cost alone, relying on grid electricity is a more attractive alternative than investing in onsite renewable power plants and storage. The key question, however, is how far the carbon intensity of grid electricity must fall in order to reduce the production cost of near-zero-carbon steel.

Scenario analysis based on our proprietary model shows that improvements in grid decarbonisation can meaningfully reduce the production costs of near-zero-carbon steel. For example, if the grid emission factor were to fall by around 50% from current levels, production costs could decline by approximately CNY 49–126 per tonne across provinces.[3] The underlying logic is that a cleaner power grid can act as a form of "virtual storage", replacing the need for companies to invest in on-site renewable generation and storage capacity to ensure continuous operations.

It is worth noting that further reductions in the grid emission factor do not necessarily lead to proportional cost savings. For example, if grid electricity were fully decarbonised, the additional cost reduction compared with a 50% decarbonisation scenario would be limited (see Figure 1). This is because, in most provinces, the cost of self-owned renewable generation is already lower than purchasing electricity from the grid. In such cases, grid electricity mainly substitutes for energy storage by providing backup when renewable output is insufficient, rather than fully replacing companies' own renewable generation capacity.

Figure 1: LCOS Reduction with Declining Grid Emission Factor (Relative to Current Levels)



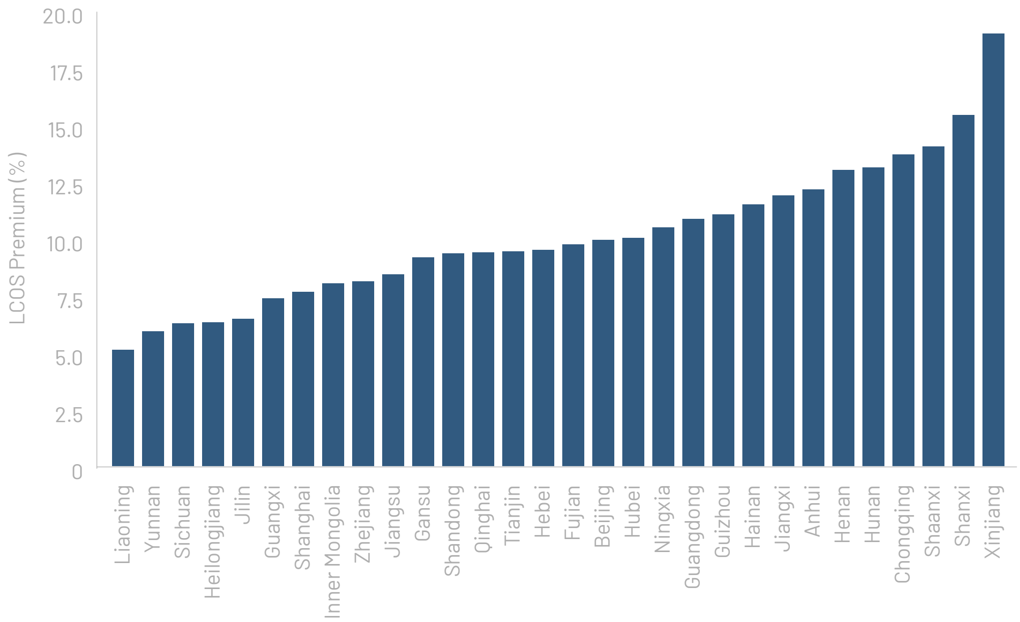
Source: TA analysis

3 Exchange rate conversion reference: According to the announcement of the RMB central parity rate authorized by the China Foreign Exchange Trade System on January 27, 2026, 1 US dollar equals CNY6.9858.

One of the most feasible pathways for producing near-zero-emission steel in China at present is the H_2-DRI-EAF route. However, this pathway remains significantly more expensive than the conventional coal-based blast furnace–basic oxygen furnace process. Based on current grid emission levels and regional renewable resource conditions, the cost premium for near-zero-carbon steel is estimated at around 15–35% relative to the traditional route.[4] This premium varies across regions due to differences in wind and solar resource endowments and grid emission factors.

On this basis, taking account of provincial wind and solar resource conditions, Transition Asia ("TA") constructed a scenario to reassess the green steel premium across provinces. Key assumptions include 50% reduction of the current grid emission factor and 40% decline in 2021 average industrial electricity prices (0.61 CNY/kWh). The analysis shows that, under the combined effects of multiple factors, both hydrogen production costs and electricity costs for EAF steelmaking fall substantially, significantly narrowing the cost gap with conventional steelmaking routes. Under this scenario, around half of China's provinces are able to keep the green steel premium within 10%, indicating much stronger market competitiveness.

Figure 2: Provincial Green Steel Premium Relative to BF-BOF in 2030, Considering 40% Lower Grid Electricity Price and Half Emission Factor Compared to 2024



Source: TA analysis

Overall, the low-carbon transition of the steel industry is inseparable from decarbonisation efforts in the energy sector. A cleaner energy system is not only a critical foundation for achieving near-zero emissions in steelmaking, but will also become the key to reduce near-zero-carbon steel production cost in the future.

4 Note: Without considering the actual amount of renewable energy electricity the company can obtain, and without considering differences in electricity prices and other costs.

HOW THE SCALE-UP OF NEAR-ZERO-CARBON STEELMAKING CAN ENABLE THE ENERGY SYSTEM TRANSITION

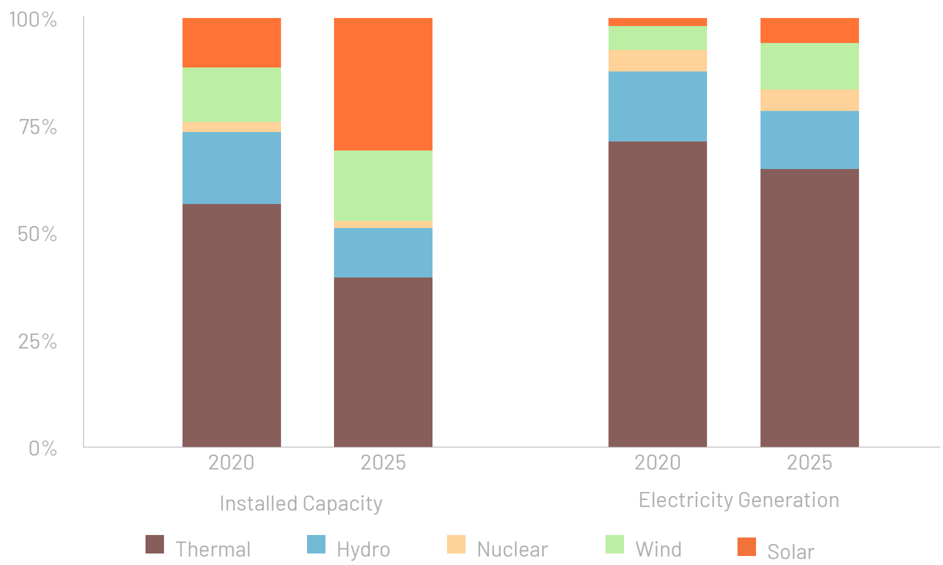
The low-carbon transitions of the energy and steel sectors are closely interconnected and mutually reinforcing. As the steel industry advances process electrification and hydrogen deployment, shifts in its energy-use structure can in turn provide strong support for energy system decarbonisation.

Rapid growth in clean energy capacity, but challenges remain in raising its share of electricity generation

In 2024, China's energy sector reached two major milestones. First, the share of renewable energy capacity exceeded 50% for the first time; second, the cumulative installed capacity of wind and solar energy reached 1,200 GW, meeting the 2030 target six years ahead of schedule. Under the latest medium- and long-term development plans, total wind and solar capacity is projected to expand further to around 3,600 GW by 2035.

Despite the rapid growth in capacity, there remains a notable gap between actual wind and solar PV generation and the planning target. By the end of 2025, wind and solar power together accounted for less than 20% of total electricity generation, even though their installed capacity had already doubled compared with 2020. The share of non-fossil-fuel power generation also lags behind the 2025 target of 39%; in 2025, it stood at 35%, leaving a shortfall of around four percentage points. This gap can be attributed to several factors, including the approval of a large number of new coal-power projects, current limitations in the grid's ability to accommodate renewable generation, and the need for upgrades to grid infrastructure.

Figure 3: Share of Installed Capacity and Electricity Generation by Sources in China, 2020–2025



Sources: National Bureau of Statistics, National Energy Administration and TA analysis

Steel sector electrification enhances renewable energy uptake

Large industrial companies are major potential consumers of renewable electricity. For the steel sector, the transition from the blast furnace–basic oxygen furnace route to the electric arc furnace route essentially shifts production processes onto an electricity-based foundation, thereby directly expanding demand for green energy. If companies further deploy renewable-based hydrogen production facilities, green electricity demand will rise even more significantly.

Taking the renewable hydrogen–direct reduced iron–electric arc furnace route as an example, producing one tonne of steel requires on average about 833 kWh of electricity for the DRI and EAF processes, and around 2,971 kWh for hydrogen production. This implies the large-scale process switching in the steel sector would create a major load for newly added renewable capacity, generating stable demand for the energy sector to operate with a high share of clean energy.

Policies are accelerating industry-led renewable energy uptake, strengthening synergies between power-sector transition and steel decarbonisation

National policies are promoting renewable electricity consumption mechanisms centred on energy-intensive industries such as steel. This both raises renewable energy uptake and accelerates process electrification and green transition. By adopting the highly electricity-intensive hydrogen–DRI–EAF route, the steel sector can absorb large volumes of green energy. If companies deploy on-site hydrogen production and consumption, the decarbonisation synergies between the steel and energy sectors will become even more pronounced.

In recent years, China has continuously improved its renewable energy consumption framework, with policies evolving from national renewable electricity consumption quotas to provincial assessments and, more recently, to implementation at the level of key industries. In July 2025, renewable electricity consumption targets were extended to energy-intensive sectors such as steel, cement and polysilicon, requiring heavy industry to meaningfully increase its share of green energy consumption.

In May 2025, the National Development and Reform Commission issued the Notice on Matters Related to the Orderly Promotion of Direct Green Power Connections (《关于有序推动绿电直连发展有关事项的通知》), creating new channels for industrial users to access renewable electricity. The policy encourages dedicated renewable power plants to supply green electricity directly to a single end user via dedicated transmission lines rather than connecting to the public grid. This arrangement ensures source traceability while effectively increasing the share of renewable electricity in industrial consumption. Under this policy, direct-connection renewable projects may be developed by end users themselves or through long-term power purchase agreements (PPAs) between power generators and consumers.

THE GREEN TRANSITION OF THE STEEL SECTOR REQUIRES COORDINATED EFFORTS FROM LOCAL GOVERNMENTS AND COMPANIES

To seize the strategic opportunities presented by near-zero-emission steel and steer the industry steadily towards carbon neutrality, the energy system must continue to play a pivotal supporting role. Provinces need to accelerate renewable energy deployment and improve renewable energy absorption, while actively advancing the development of new power systems. Regions with strong renewable resource endowments should further leverage their advantages by developing supporting green industries such as renewable hydrogen production and equipment manufacturing. A comprehensive green hydrogen value chain will provide a solid foundation for scaling up hydrogen-based DRI, reducing costs, and enhancing international competitiveness.

Against this backdrop, steel companies are advised to closely monitor energy transition policies and update their strategic plans in a timely manner, ensuring their decisions are aligned with evolving decarbonisation pathways and regulatory requirements. Local governments, meanwhile, are expected to tailor policies to regional resource conditions to promote large-scale renewable deployment, and actively respond to national initiatives by providing support for clean and efficient energy use in the steel sector—for example, by refining power market rules and operational arrangements, and exploring mechanisms such as direct green power supply and industrial microgrids. Although green steel currently faces challenges related to market demand, cost competitiveness, and infrastructure, as China's energy sector decarbonisation advances, the focus of achieving the "dual carbon" goals will gradually shift from the energy sector to heavy industries. Only through close alignment with evolving policy frameworks and early strategic positioning can steel companies secure first-mover advantages, stand out in high-quality development, and provide a strong foundation for deep decarbonisation and industrial upgrading in China.

FURTHER READING: AN OVERVIEW OF GREEN STEEL PRODUCTION COMPETITIVENESS

As China accelerates its progress in both energy and industrial decarbonisation, the spatial distribution of renewable resources is becoming a key determinant of the cost competitiveness of green steel production. Provinces differ widely in renewable energy potential, grid carbon intensity, and hydrogen development strategies, all of which affect the economics of the H_2–DRI–EAF route. Regions that combine steelmaking capacity with abundant renewable resource potentials and clean power infrastructure are well positioned to take a leading role in low-carbon steel production. Other resource-rich regions with limited existing steel capacity may also attract the relocation of low-carbon production.

Differences in renewable resource endowments, grid decarbonisation levels, and hydrogen development progress across regions shape their respective green steel production potential in distinct ways.

The provincial cost model developed by Transition Asia for H_2-DRI indicates that Liaoning, the fourth largest steel producing province, offers the lowest green premium, largely due to its abundant wind power potentials.[5] The high complementarity between wind and solar in the region also helps to minimize energy storage requirements.

Over the past four years, Liaoning has been a top runner in clean power generation, experiencing a 22% increase. In 2024, both clean energy capacity and generation in Liaoning surpassed 50%, with targets to raise these shares to 55% and 53% respectively.[6] The province further aims to deploy 14 GW of nuclear capacity by 2030 to further decarbonise its grid. These clean energy developments create opportunities for green hydrogen. In 2024, China's largest off-grid wind-to-hydrogen production project commenced commercial operation in Liaoning, featuring 25 MW wind power installation, 5 MW energy storage, and three electrolyzers, each capable of producing 1000 nm^3 of hydrogen per hour. [7]

These clean energy developments have created fertile ground for green hydrogen initiatives in Liaoning. For instance, Angang Group recently completed a pilot project for green hydrogen-based DRI production powered by wind electricity, marking full process integration of a green H_2–DRI–EAF route in Yingkou, Liaoning province. The company plans to scale up toward an industrial demonstration project with an annual capacity of 500 thousand tonnes.[8]

Jiangsu, Hebei, and Shandong, all significant steel-producing provinces, demonstrate strong potential for cost-competitive green steel production. Jiangsu, in particular, benefits from its advanced solar PV industry, which has fueled substantial growth in solar energy. The province ranks second in solar PV capacity nationally, with 84 GW installed, and led in capacity additions during the first half of 2025, adding 22 GW.[9] Jiangsu also excels in grid flexibility, ranking fourth in new energy storage capacity by 2024 and achieving a remarkable 99% renewable energy utilisation ratio.[10] The Jiangsu provincial government plans to accelerate the development of its hydrogen industry over the next five years, with green hydrogen targeted to be the primary driver of new capacity by 2030.[11]

Hebei and Shandong are also at the forefront of clean power generation in China, demonstrating significant increases in renewable electricity share from 2020-2024 (16% and 13% respectively). This growth is primarily driven by substantial solar capacity additions, with 50 GW in Hebei and 53 GW in Shandong. Shandong has been a pioneer in enhancing renewable electricity consumption. It was among the first regions to implement an electricity spot market, and by 2022, solar power dominated its electricity

5 https://transitionasia.org/enabling-chinas-green-steel-transition/
6 https://www.ln.gov.cn/web/ywdt/jrln/wzxx2018/2025032708530347556/index.shtml
7 http://www.sasac.gov.cn/n2588025/n2588124/c30616778/content.html
8 https://www.ln.gov.cn/web/ywdt/jrln/tpxw/2025082909214342140/index.shtml
9 https://www.nationalee.com/newsinfo/8718775.html
10 https://www.stdaily.com/web/gdxw/2025-03/25/content_314509.html
11 http://www.jsjnw.org/dangjian_1/624.html

market, driving prices below zero. Both provinces prioritise energy storage; Shandong ranked third in new energy storage capacity by 2024, while Hebei leads in pumped hydro, which boosts grid flexibility and decarbonisation.[12] Regarding hydrogen production, Hebei's largest green hydrogen production base in Zhangjiakou city produces 22 tonnes daily. Shandong also has hydrogen production on its policy agenda, though its application is more geared towards transport fuels than industrial feedstock. Both Hebei and Shandong now have pilot projects using H_2-DRI-EAF for steel production. Even though these projects are running on hydrogen produced from natural gas or coke oven gases, they are designed to be "green hydrogen-ready".

Provinces with low-cost green steel production potential, even those without existing steel hubs, could become vital hydrogen production centers, supplying industrial regions downstream. For instance, Sichuan, Yunnan, Jilin, and Heilongjiang are ideal for new H2-DRI facilities, enabling capacity transfers from provinces with high hydrogen costs like Henan and Jiangxi. Yunnan and Sichuan, leading in hydropower with 95 GW and 80 GW capacity respectively in 2023, benefit from exceptionally clean grid electricity with an emission intensity of only 0.1 kgCO2/kWh.[13] This abundance of hydropower has already attracted various industries, including aluminum, solar PV, and battery manufacturing, to Yunnan.

Jilin and Heilongjiang provinces present significant potential for green hydrogen development due to their strong renewable resources, boasting wind capacity factors of 25% and 27% respectively, and solar capacity factors of 17% and 18%. This makes them ideal locations for future green hydrogen hubs. Currently, Jilin hosts the world's largest integrated green electricity-green hydrogen-green ammonia project, producing 180 thousand tonnes of ammonia annually from 320 thousand tonnes of green hydrogen, powered by 800 MW of green electricity.[14] Similarly, Heilongjiang is developing a green hydrogen project that will produce 164 thousand tonnes annually, utilising 3.5 GW of wind power. [15] Both projects are focused on producing sustainable aviation fuel and green methanol for the transport sector.

In conclusion, renewable resource endowments, as reflected in renewable hydrogen production potential, play a pivotal role in low-carbon steel production and are a key consideration in capacity planning. Regions with strong and complementary wind and solar resources are best positioned to serve as stable bases for renewable hydrogen production and are likely to deliver cost-competitive solutions for the steel sector's low-carbon transition at an early stage.

Click the link for details in our report: *Enabling China's Green Steel Transition: CAPEX development, grid decarbonisation and subsidy support*

12 https://www.nea.gov.cn/20250731/1d40d09f75714280a9218d5bea178fbd/202507311d40d09f75714280a9218d5bea178fbd_453d9a0609da1d4456a8b12d843bd256cf.pdf
13 Data from China Electricity Council, China Electric Power Yearbook 2024
14 http://www.daan.gov.cn/tzda/xmjs/202412/t20241223_1004736.html
15 https://www.hlj.gov.cn/hlj/c116382/202312/c00_31692643.shtml

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Founded in 2021, Transition Asia is a non-profit think tank dedicated to accelerating decarbonisation in Asia's materials and heavy industries to achieve the 1.5°C climate goal. Our multidisciplinary team combines diverse perspectives, experience and expertise, underpinned by a strong research foundation in Asia and a nuanced understanding of the region. Using analytical models and in-depth assessments, we evaluate and monitor corporations' decarbonisation efforts and actions. By engaging with stakeholders across sectors—including corporates, investors, policymakers and civil society organisations—we facilitate informed and impactful discussions that drive sustainable, low-carbon transitions aligned with a 1.5°C future.

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