

Electrification across the steel value chain

Replacing fossil fuels with electrons for ore reduction and heat generation

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Key Findings

Electrification will be a major theme at COP31, and the steel industry needs to consider all available electrification opportunities to reduce emissions while strengthening long-term cost-effectiveness, supply-chain resilience and energy security.

While much of the focus has been on decarbonising primary steelmaking, significant opportunities exist in secondary steelmaking and the electrification of heat across the value chain, which could further reduce sector emissions.

Flexibility is a key advantage of electrification technologies, allowing steelmakers to reduce energy consumption during peak periods, and shift production towards periods of low-cost, low-emissions electricity.

Hydrogen will be essential for iron ore reduction, but it may not be the preferred alternative for heat generation, where its efficiency is likely to be lower than direct electrification.



Executive summary

Steel production is one of the most energy-intensive industrial processes, and remains heavily reliant on fossil fuels. Energy use in the sector is primarily driven by two requirements: the chemical energy needed to reduce iron ore into iron, and the high-temperature heat required across the steelmaking value chain. Electrification can address both, and should be prioritised as a key pathway to reduce emissions, fossil fuel dependence and exposure to energy supply risks.

As the host of COP31, Türkiye has proposed a “35% by 2035” target to increase the share of electricity in final energy consumption from about 20% today. Greater electrification across industry will be critical to achieving this ambition, particularly in sectors such as steel where fossil fuels remain deeply embedded in production processes.

Electricity accounts for less than 12% of the steel sector’s total energy consumption, highlighting the significant potential for further electrification. In secondary steelmaking, this transition is already well established, with electric arc furnaces using electricity to melt scrap. Further opportunities exist across the downstream steel value chain, particularly through the electrification of process heat supplied by gas and other fossil fuels.

Primary steelmaking presents a more complex challenge. Hydrogen can enable indirect electrification by replacing fossil fuels as a reducing agent in direct reduced iron production, with hydrogen produced using renewable electricity. Hydrogen can also be used to generate process heat when burned, but its relatively low efficiency and high cost compared with direct use of electricity make it less attractive for heating applications. Hydrogen is therefore likely to be most valuable as a reducing agent rather than as a fuel.

Further technology development could eventually allow even greater levels of direct electrification in ironmaking. Electrochemical ironmaking technologies are being developed to use electricity to remove oxygen directly from iron ore, potentially eliminating the need for carbon- or hydrogen-based reductants altogether. However, these technologies remain at an early stage of development, and will require further technological progress, demonstration and commercialisation before they can be deployed at scale.

Unlike other industrial sectors, where highly efficient and relatively low-investment technologies such as industrial heat pumps can be deployed at scale for low-temperature heat, steelmaking presents a particular challenge for electrification because of its reliance on very high-temperature processes. Almost 70% of the sector’s total energy consumption is used to provide process heat at temperatures above 1,000°C. While technologies capable of providing high-temperature electric heat are already available or in development, further investment, demonstration and deployment will be needed before they become mainstream across the steel sector.

The case for electrification extends beyond emissions reduction and energy efficiency. Recent global conflicts and disruptions to major fossil fuel trading routes have highlighted the energy security risks

associated with dependence on imported coal, gas and other fossil fuels. Greater electrification, particularly when supported by domestic renewable electricity, can reduce steelmakers' exposure to global fossil fuel markets and supply disruptions while strengthening the resilience of their energy supply.

Policy support will be essential to accelerate this transition. Increasing scrap use and expanding secondary steelmaking are likely to drive some electrification naturally. However, indirect electrification through green hydrogen and, particularly, the electrification of high-temperature heat in the downstream value chain will require targeted policy support, infrastructure investment and market incentives to overcome higher upfront costs and technology risks.

The steel sector faces higher upfront investment requirements, and often lacks the policy support and incentives available to other sectors. The International Energy Agency forecast the annual investment in electrification to increase from about USD320 billion today to about USD1 trillion in 2035, yet all industrial sectors are expected to account for less than 3% of the total investment, with much larger shares going to transport and construction.

A further challenge is ensuring uninterrupted access to clean electricity. The rapid development of battery storage is improving the ability of electricity systems to provide reliable low-emissions power, but greater flexibility can also play an important role. New electric steelmaking technologies can provide opportunities to adjust electricity consumption in response to system conditions, allowing plants to reduce or shift demand during periods of high electricity prices or peak system demand. This flexibility can improve the economics of electrification while helping integrate higher shares of variable renewable electricity.

Electrification should therefore be viewed not simply as a decarbonisation pathway for steel, but as an opportunity to improve energy efficiency, reduce fossil fuel dependence, strengthen energy security, and increase the flexibility and resilience of steel production.

Introduction

Steel production is one of the most energy-intensive industrial processes. Owing to its heavy reliance on fossil fuels, the sector is responsible for approximately 8% of global greenhouse gas (GHG) emissions.¹ The majority of these emissions arise from the widespread use of the coal-based blast furnace–basic oxygen furnace (BF–BOF) route, where metallurgical (met) coal serves as both the primary reducing agent and the main source of process energy.

While the BF–BOF route remains the dominant source of emissions in the steel industry, alternative ironmaking and steelmaking pathways offer greater flexibility to transition from fossil fuels to electricity.

¹ Global Efficiency Intelligence. [Steel Climate Impact 2025](#). October 2025.

Energy consumption in the steel sector is primarily driven by chemical energy for iron ore reduction and high-temperature process heat. Electrification of both areas is technically possible and should be prioritised to reduce emissions.

Turkiye, as the host of COP31, has proposed a “35% by 2035” target.² The initiative aims for electricity to account for 35% of final energy consumption by 2035, up from 20%, helping to accelerate the transition in various sectors.

The European Union (EU) introduced its Electrification Action Plan in July 2026, which sets an indicative target of increasing the electrification rate to 46% by 2040, up from approximately 23%, where it has remained largely stagnant for more than a decade.³

In 2026, there is no question of the ability of deploying electricity in many areas as it is highly efficient and cost-effective compared with fossil fuel-based alternatives, and with lower carbon emissions.

Electrification is being driven not only by economic and environmental benefits, but also by the need to strengthen supply chain resilience and energy security. Major steelmaking regions such as India and the EU remain highly dependent on external energy supplies. Supply chain disruptions and energy price spikes, exacerbated by recent regional conflicts, have increased operating costs, further squeezed steelmakers' margins already under pressure from declining Chinese steel consumption and global overcapacity and created greater uncertainty for their businesses. A combination of supportive policies and technological advances could create new opportunities for electrification in the steel value chain.

Energy and electricity use across the steel value chain

In 2024, global crude steel production reached 1,885 million tonnes (Mt), consuming approximately 39.5 exajoules (EJ) of energy and generating about 4.1 gigatonnes (Gt) of CO₂e in GHG emissions, including approximately 3.6Gt of CO₂.^{4,5,6}

Approximately 11.6% of the steel sector's total energy consumption comes directly from electricity.⁷ (More recent sources report up to 14%.⁸) While this share may appear relatively small compared with coal, increasing the use of clean electricity could help steelmakers achieve substantial emissions reductions, particularly by replacing fossil fuels with clean electricity, and reducing reliance on vulnerable fossil fuel supply chains.

² United Nations Climate Change. [COP31 Presidency announces new targets on global electrification, cutting waste, resilient cities; press conference transcript](#). 9 June 2026.

³ European Commission. [Commission boosts Europe's competitiveness, decarbonisation and independence with Electrification Action Plan and ETS review](#). 17 July 2026.

⁴ World Steel Association (WSA). [World Steel in Figures 2025](#).

⁵ WSA. [Key sustainability programmes in 2025](#).

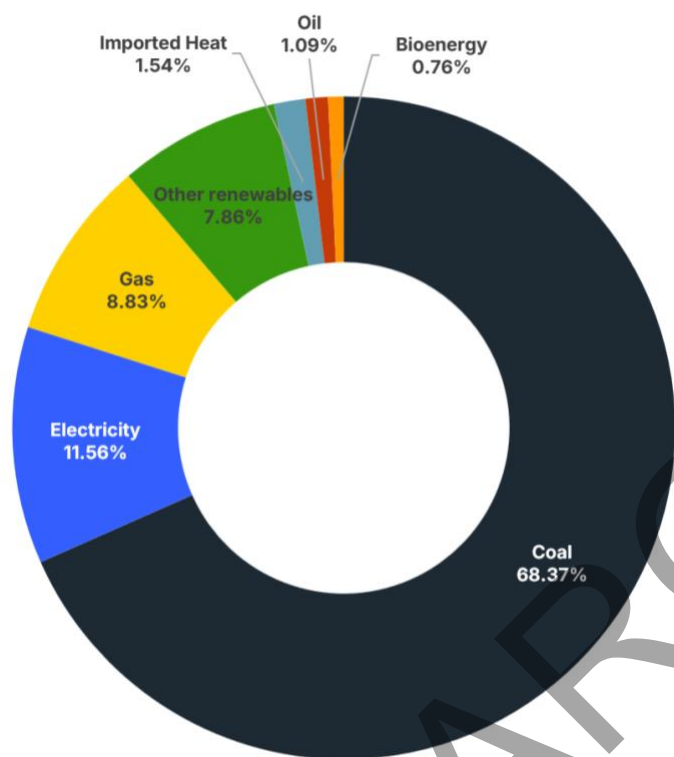
⁶ IEA. [World Energy Outlook 2025](#).

⁷ IEA. [Final energy demand of selected heavy industry sectors by fuel, 2019](#). Last updated 18 September 2020.

⁸ World Economic Forum. [Net-Zero Industry Tracker 2023 Edition](#). November 2023. Page 57.

Figure 1: Energy source shares in the steel sector (%)

■ Coal ■ Electricity ■ Gas ■ Other renewables ■ Imported Heat ■ Oil ■ Bioenergy



Sources: IEA,⁹ IEEFA

Each steelmaking pathway has a different level of electricity consumption, and offers varying opportunities for electrification. In general, while the BF–BOF pathway relies heavily on coal as an energy source, and has limited flexibility to increase the share of electricity in its energy mix, the scrap-based electric arc furnace (EAF) pathway is already highly electrified. Between them sits gas-based DRI–EAF, which has significant potential for further electrification by replacing gas with green hydrogen. Emerging steelmaking technologies, such as electrochemical ironmaking, also offer significant opportunities for electrification.

⁹ IEA. [Final energy demand of selected heavy industry sectors by fuel, 2019](#). Last updated 18 September 2020.

Table 1: Steelmaking pathways energy intensity (GJ/t) and share of electricity

Pathway	Energy intensity		Electricity share %		Electrification opportunities	
	WSA	IEA*	WSA	IEA	Reduction	Heating
BF–BOF	23.88	23.26	10–15	2.5	Low	Low
Scrap–EAF	9.84	2.35	50–70	72	NA	High
Coal/gas–DRI–EAF	23.3	17.35	25–40	14	Moderate	High
H₂–DRI–EAF	15.12 (4.2MWh/t)		≈100		High	High
Electrochemical + EAF	16.2 (4.5MWh/t)		≈100		High	High

Sources: World Steel Association, *Sustainability indicators 2025* and *Energy use in the steel industry*; Harvey mostly based on IEA data, IEEFA.^{10,11,12} *Note: Figures extracted from Table 8 in the Harvey paper. To understand the differences between the WSA and IEA calculation methodologies, refer to Box 1.3 of the IEA report.¹³

BF–BOF

For the BF–BOF pathway, electricity consumption is estimated as low as 0.1–0.3MWh/t or even 0.4MWh/t.^{14,15,16} Blast furnaces generally require little to no additional electricity from the grid, as both blast furnace gas and coke oven gas can be recovered and used to generate electricity.¹⁷ Consequently, coal serves not only as the primary reducing agent but also as the main energy source for some of the integrated steelmaking process. Approximately 20% of the total energy input is used for the reduction of iron ore, while the remainder is used in various forms, some of which could be recovered and utilised for other purposes.¹⁸

In the BF route, coke, produced from met coal, performs multiple critical functions. In addition to acting as the primary reducing agent for iron ore, it provides the heat required for the process, and maintains the structural integrity and permeability of the burden. As a result, replacing coke solely as a heat source does not represent a practical or scalable decarbonisation solution.¹⁹ Instead, a combination of complementary approaches including using alternative carbon sources, injecting

¹⁰ WSA. [Key sustainability programmes in 2025](#).

¹¹ WSA. [Energy use in the steel industry](#). May 2026.

¹² Energy. [A bottom-up assessment of recent \(2016–20\) energy use by the global iron and steel industry constrained to match a top-down \(International Energy Agency\) assessment](#). Harvey, D. 15 April 2024.

¹³ IEA. [Iron and Steel Technology Roadmap](#). October 2020.

¹⁴ Renewable and Sustainable Energy Reviews. [Flexibility options in a decarbonising iron and steel industry](#). Boldrini, A. et al. January 2024.

¹⁵ Hydrogen Europe. [Steel from Solar Energy](#). May 2022. Page 37.

¹⁶ Resources, Conservation and Recycling. [From coal to green power: Mapping the electrification journey of China's steel sector](#). Tian, S. et al. August 2025.

¹⁷ M Heavy technology. [Using Blast Furnace Gas for Power Production](#).

¹⁸ Applied Thermal Engineering. [Potential for energy savings by heat recovery in an integrated steel supply chain](#). McBrien, M. et al. 25 June 2016.

¹⁹ Agora Industry. [Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU](#). June 2024. Page 46

hydrogen and recycling carbon monoxide, is likely to be required to reduce emissions partially.²⁰ Some new technological solutions, such as plasma torches, are discussed to reduce the BF dependency on coke consumption.²¹

Indirect electrification using hydrogen for both reduction and heating has been pursued for some time by steelmakers such as Nippon Steel via its Super COURSE50 project, which verified 33% reduction in CO₂ emissions.²² However, the technologies in development remain limited in their ability to achieve near-zero-emissions steel production while retaining the conventional BF–BOF pathway.

Scrap–EAF

While blast furnaces are inherently reliant on coal as an energy source, with limited opportunities to substitute it with clean electricity, EAFs can make much greater use of clean electricity to reduce the overall emissions from steelmaking. Although EAFs still use some gas for heating and coke or coal as a carburiser and to facilitate slag formation, electricity provides most of its energy needs.^{23,24} Therefore, this pathway has intrinsic electrification potential.

DRI–EAF

EAFs can also melt direct reduced iron/hot briquetted iron (DRI/HBI) produced using green hydrogen, potentially enabling near-zero-emissions steel production. Gas–DRI–EAF needs about 1MWh/t steel while gas typically provides the rest of the energy.²⁵ However, hydrogen can replace gas as the reducing agent in the process, while electricity (or hydrogen) can be used to generate the heat required for the process.

Regardless of the main power source of production pathways, all steelmaking processes rely to some extent on electricity, which could increasingly be supplied by renewable energy. Table 2 shows the share of different energy sources across the steel value chain. While secondary steelmaking offers the greatest potential for further electrification, substantial opportunities also exist downstream in the value chain, where most energy demand is in the form of heat, and could be electrified.

²⁰ JOM. [Reducing Blast Furnace Dependence on Coke: A Review of Low-Carbon Strategies](#). Wang, Z. et al. 17 August 2026. Volume 78, Pages 9829–9843.

²¹ Hatch. [The use of plasma torches in blast furnace ironmaking](#). ABM Week. September 2016.

²² Nippon Steel. [Verified the World's Highest Level of CO₂ Emissions Reduction at 33% by Heated Hydrogen Injection in the Super COURSE50 Test Furnace](#). 6 February 2024.

²³ Journal of CO₂ Utilization. [Current advances in slag foaming processes toward reduced CO₂ emission for electric arc furnace steelmaking](#). Liu X., Yan, W. et al. December 2024.

²⁴ Metals. [Review on the Use of Alternative Carbon Sources in EAF Steelmaking](#). Echterhof, T. 27 January 2021.

²⁵ Resources, Conservation and Recycling. [From coal to green power: Mapping the electrification journey of China's steel sector](#). Tian, S. et al. August 2025.

Table 2: Net energy use of various processes in the steel value chain (GJ/t material output)

Pathway	Process	Energy input			Electricity	Total	Electricity%	Other fuels%
		Coal/Coke	Gas	Others				
BF-BOF	Coal-pelletising	0.85	0.01	0.04	0.1	1	10	90
	Sintering	1.78	0.02	0.04	0.16	2	8	92
	Coking	41.17	-	0.17	0.03	41.38	0	100
	BF	15.83	0.5	0.8	0.25	17.38	1	99
	BOF	0.55	0.11	0.01	0.13	0.79	16	84
DRI-EAF	Gas-pelletising	-	0.66	-	0.09	0.75	12	88
	Gas-DRI	-	9.42	-	0.34	10	3	97
	Coal-DRI	19.5	-	-	0.36	20	2	98
	EAF (consuming pig iron)	0.58	0.2	0.02	2	2.8	71	29
Scrap-EAF	Scrap-EAF	0.48	0.2	0.02	1.7	2.4	71	29
Downstream	Secondary metallurgy		0.2		0.25	0.45	56	44
	Steel continuous casting		0.75		0.33	1.08	31	69
	Ingot casting (IC)		1.41		1.83	3.23	57	43
	Steel product casting (SPC)		12.82		9.28	22.1	42	58
	Foundry iron casting (FIC)		7.33		6.03	13.36	45	55
	Primary mill		1.22		0.28	1.5	19	81
	Hot rolling		1.39		0.31	1.7	18	82
	Cold rolling		1.13		0.37	1.5	25	75
	Galvanising-hot dip		0.94		0.23	1.17	20	80
	Galvanising-electrolysis		0.68		0.71	1.38	51	49
	Tinning		0.28		0.39	0.66	59	41
	Fabrication		0.2		0.25	0.45	56	44

Source: Harvey,²⁶ IEEFA. Notes: **Coal/Coke** includes all energy from coal-based sources such as coke oven gas, coke oven tar, blast furnace gas and basic oxygen gas. **Others** includes oil products, biomass (org) and waste. Figures for downstream are categorised under fossil fuels in general. Calculations may not sum exactly due to rounding. DRI figures are taken from the attached file, Table OS.9.²⁷ 1kWh=0.0036GJ.

Electrification solutions

Electrification opportunities in the steel sector can generally be grouped into three major areas: iron and scrap melting, process heat and thermal energy, and iron ore reduction. Electricity can directly provide heat for various process steps, replacing fossil fuel-based thermal energy.²⁸ It can also be used to reduce iron ore either directly through electrochemical ironmaking or indirectly by producing green hydrogen through water electrolysis, which can then be used as a reductant.

²⁶ Energy. [A bottom-up assessment of recent \(2016–20\) energy use by the global iron and steel industry constrained to match a top-down \(International Energy Agency\) assessment](#). Harvey, D. 15 April 2024

²⁷ Ibid. [Attached file](#).

²⁸ US Department of Energy. [Improving Process Heating System Performance](#). 2007. Page 25.

Technologies that replace fossil fuel-based thermal energy with electricity are generally more mature and widely deployed in the steel sector than technologies for electrifying iron ore reduction.

Table 3: Key electrification opportunities across the steel value chain

Application	Technology	Maturity	Market adoption	Examples/providers
Melting/ smelting	EAF	Commercial	Widespread	Multiple commercial providers
	Induction furnace			
	Electric smelting furnace (ESF)	Demonstration/early commercial	Early adoption	Metix/SMS Hy4Smelt/Primetals iBLUE/Tenova NeoSmelt/Hatch Metso Outotec
Process heat	Resistance heating	Commercial	Emerging (limited use in iron- and steelmaking/mostly adopted in downstream for reheating)	Tempura/Paul Wurth, Prothal TH/Kanthal, Tutco/SureHeat Midrex
	Induction heating			Elotherm/SMS Inductotherm Various providers
	Plasma torch	Demonstration/early commercial	Early adoption	PyroGenesis EASyMelt/Paul Wurth
	Shockwave heating	Demonstration/early commercial	No/early adoption	Coolbrook RotoDynamic Heater
	Hydrogen combustion	Commercial	Early adoption	OxyFuel/Linde, ZeroFlame HY ² /SMS
Reduction	Indirect (H ₂ -DRI)	Commercial DRI, H ₂ application emerging	Emerging	Midrex, Energiron, HYFOR, HyREX, ZESTY
	H ₂ -flash ironmaking	Early stages	No/early adoption	–
	Direct iron electrolysis - electrowinning - Molten oxide electrolysis - Molten salt electrolysis	Pilot/demonstration	No adoption	Electra Volteron Fortescue DER Boston Metal Element Zero

Source: Agora Industry,²⁹ IEFA. Note: Maturity assessment is for deployment in the steel sector, rather than overall maturity.

Melting/smelting

The most mature electrification technology deployed at scale in the steel sector is the use of electricity to melt scrap and iron metallics in EAFs. In 2025, 30.3% of global steel production came from electric steelmaking routes, predominantly via secondary steelmaking (scrap–EAF).³⁰ About half

²⁹ Agora Industry. [Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU](#). June 2024.

³⁰ WSA. [World Steel in Figures 2026](#).

of global steel sector development is focusing on EAFs, with approximately 110 million tonnes a year (MTPA) of new EAF capacity under construction.^{31,32} While the world is shifting towards lower-emissions electric steelmaking technologies, this transition requires an increased supply of high-quality scrap, alongside access to clean electricity via long-term contracts such as power purchase agreements (PPAs).

In the US, which leads deployment with EAFs accounting for more than 71% of total steel production, renewables accounted for about 24% of electricity generation in 2025.^{33,34}

For EAFs that primarily use DRI as a feedstock, which are concentrated largely in the Middle East, the situation is less promising due to the low renewables penetration. Steelmakers typically power their EAFs with grid electricity, which remains carbon-intensive due to the region's reliance on fossil fuel-based power generation. The average emissions factor in the region was 632kg CO₂/MWh in 2025, approximately 37% higher than the global average.³⁵

Electricity is the primary energy source for EAFs; however, fossil fuels and carbon-containing materials continue to contribute to the process energy input. Modern EAFs also typically use gas burners around the furnace walls to provide supplementary heat. Carbon-containing materials are added for several purposes, including process control, carburisation and the removal of impurities through slag formation, while carbon-based electrodes are also consumed during the process. Electrifying the gas burners, and replacing fossil fuel-based carbon inputs with alternative, low-emissions carbon sources could reduce EAF emissions further, and bring the process closer to near-zero emissions.^{36,37}

EAFs could work with 100% scrap or iron metallics such as DRI/HBI or pig iron. Using more scrap will reduce the electricity consumption as it contains more iron and fewer impurities.

Another key advantage of EAFs is their non-continuous batch operation, which provides greater flexibility in managing electricity consumption, and allows them to better integrate variable renewable energy and other intermittent power sources.

Beyond EAFs, induction furnaces are widely used across the steel sector, particularly in smaller plants for scrap melting.

³¹ Global Energy Monitor (GEM). [Pedal to the Metal 2026](#). May 2026.

³² GEM. [Explore data in the Global Iron and Steel Tracker](#). Accessed 5 October 2026.

³³ WSA. [World Steel in Figures 2026](#).

³⁴ US Energy Information Administration. [Electricity explained Electricity generation, capacity, and sales in the United States](#). Accessed 5 October 2026.

³⁵ Ember. [Electricity Data Explorer. Carbon emissions intensity in Middle East](#).

³⁶ Agora Industry. [Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU](#). June 2024. Page 47.

³⁷ Metals. [Review on the Use of Alternative Carbon Sources in EAF Steelmaking](#). Echterhof, T. 27 January 2021.

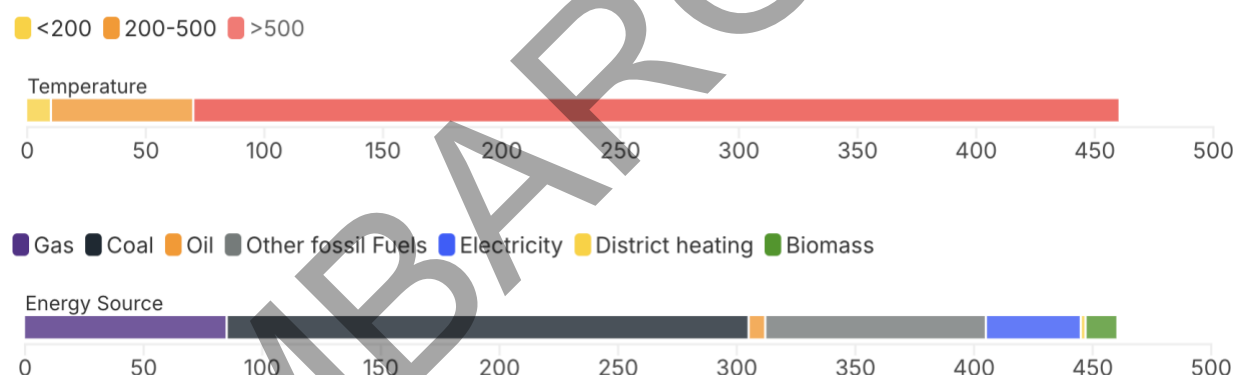
Electric smelting technologies are also under development to address some of the challenges steelmakers face in using lower-grade ores for low-emissions steel production.³⁸

Process heat electrification

Many processes in the steel value chain require temperatures above 1,000°C, beyond the operating range of conventional industrial heat pumps.³⁹ This temperature could be produced via various conventional technologies, such as induction and resistance heating, and newer technologies, such as plasma torches and shockwave heating.

The EU iron and steel sector, which consumed about 460TWh of process heating energy in 2019, was the largest user, accounting for about 25% of total industry process heating energy consumption.⁴⁰ Approximately 85% of this demand was for processes requiring temperatures above 500°C, with the majority of this high-temperature heat demand also being met by fossil fuels, including gas, coal, oil and other sources.

Figure 2: EU iron and steel total energy demand for process heating by temperature and source (TWh)



Sources: Agora Industry,⁴¹ IEEFA

Other studies also provide details on both primary and secondary steelmaking, although they use different calculation methodologies. The data shows about 70% of total energy consumption is used for process heat above 1,000°C.⁴²

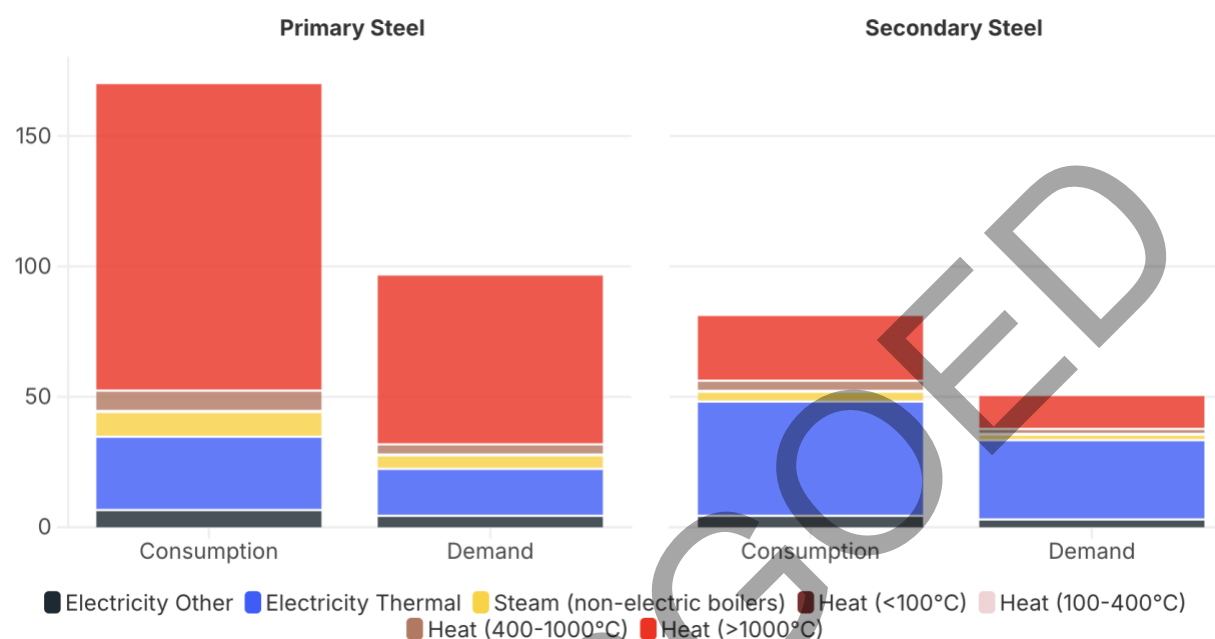
³⁸ IEEFA. [DRI smelters: Promise, progress and barriers](#). 16 June 2026.

³⁹ Applied Thermal Engineering. [Potential for energy savings by heat recovery in an integrated steel supply chain](#). McBrien, M. et al. 25 June 2016.

⁴⁰ Agora Industry. [Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU](#). June 2024. Page 18.

⁴¹ Ibid.

⁴² Renewable and Sustainable Energy Reviews. [Electrifying European industrial heat: mapping of heat demand, technologies and applications](#). Gjorgievski, V. et al. January 2027.

Figure 3: EU steel sector final energy consumption and useful energy demand (TWh)

Sources: Gjorgievski et al.,⁴³ IEEFA. Note: Heat refers to non-electric process heat.

The IEA estimates industrial heat demand will increase by about 16EJ between 2025 and 2030, with renewable heat expected to account for 44% of this increase.⁴⁴ Over this period, the share of renewable energy sources is expected to increase only gradually, from 12% in 2024 to 16% in 2030.

In recent years, process gas heating has been one of the key focus areas for technology developers, particularly for direct reduction technologies. In gas-based DRI via shaft furnace, approximately one-quarter of the gas consumption is used for heat generation while the remainder is used for the direct reduction of iron ore.

To reduce emissions further, technology providers are developing high-temperature electric process gas heaters to replace fossil fuel-based heating in DRI plants. This challenge may become even more important in future hydrogen-based DRI operations, as hydrogen reduction is an endothermic process that requires additional heat input compared with conventional gas-based reduction.

Iron ore reduction typically occurs at temperatures of 800–900°C in the Midrex process, and the operating process temperature of the Energiron is 950–1,080°C.^{45,46} Both can use electric gas heaters to reach the process temperature.

⁴³ Renewable and Sustainable Energy Reviews. [Electrifying European industrial heat: mapping of heat demand, technologies and applications](#). Gjorgievski, V. et al. January 2027.

⁴⁴ IEA. [Renewable heat 2025](#).

⁴⁵ Midrex. [MIDREX NG™ with H2 Addition: Moving from natural gas to hydrogen in decarbonizing ironmaking](#). March 2022.

⁴⁶ Tenova. [Energiron](#). Accessed 5 October 2026.

Midrex

Midrex estimates fully decarbonising the DRI pathway using hydrogen, including hydrogen for process heat, would require approximately 900 normal cubic metres (Nm³) of hydrogen per tonne of DRI, equivalent to about 81kg of hydrogen.⁴⁷ Other studies estimate hydrogen consumption at 50kg/t for iron ore reduction and a further 22kg/t for gas heating, although the latter could be electrified.⁴⁸

The Midrex H2 process has been specifically designed to operate with 100% hydrogen.⁴⁹ A key feature of the configuration is an electric heater which replaces the reformer for the recirculating hydrogen stream, representing one of Midrex's latest innovations. The heater was developed and supplied in partnership with Tutco SureHeat, a business unit of Flex-Tek Group, which is part of the UK-based engineering company Smiths Group.⁵⁰

During more than 500 hours of rigorous testing, Midrex successfully derisked this pathway.⁵¹ The gas heaters demonstrated the ability to heat pure hydrogen, hydrogen-gas blends and pure nitrogen to temperatures up to 900°C, using wire elements as the core heating technology.

Kanthal

Kanthal, in collaboration with Nycast AB, has entered into an exclusive licensing agreement to develop high-efficiency, MW-scale electric heaters for high-temperature industrial processes, including direct reduction ironmaking. The technology is being developed under the Prothal TH process gas heater platform, with initial tests demonstrating promising results, achieving gas outlet temperatures of up to 1,050°C.⁵²

Kanthal supplied the process gas heater for HYBRIT's pilot project, where it was used to heat pure green hydrogen to the temperature required for iron ore reduction in the direct reduction furnace.⁵³ The 1MW heater demonstrated an efficiency of approximately 95%, and was capable of heating hydrogen to 950°C.

Kanthal is further advancing the technology's development in partnership with Danieli to deploy it in established gas-based DRI plants as well. The first commercial-scale deployment is scheduled for late 2026 at Emsteel, where the technology will be integrated into an existing DRI facility to provide part of the heat needed in the Energiron shaft furnace.⁵⁴

⁴⁷ Midrex. [Fueling the Future of Ironmaking: MIDREX Flex™](#). March 2024.

⁴⁸ Agora Industry. [Direct electrification of industrial process heat. An assessment of technologies, potentials and future prospects for the EU](#). June 2024. Page 46.

⁴⁹ Midrex. [MIDREX H2](#). Accessed 5 October 2026.

⁵⁰ Tutco. [SureHeat](#). Accessed 5 October 2026.

⁵¹ Midrex. [Developing a Novel Electric Heater for the MIDREX H2 Process](#). June 2026.

⁵² Kanthal. [Prothal® TH: MW-sized Electric Process Gas Heater Charting the Course to Sustainable Industry](#). 8 March 2024.

⁵³ Kanthal. [HYBRIT's fossil-free steel revolution: Powered by Kanthal innovation](#). 10 January 2025.

⁵⁴ Kanthal. [Kanthal and Danieli to supply first electric process gas heater for commercial use in DRI](#). 22 May 2025.

Box 1: Emsteel

The United Arab Emirates steelmaker uses DRI–EAF technology, and has been pursuing decarbonisation across multiple aspects of its operations. The company already gets 86% of its electricity from zero-emissions sources, and has launched initiatives to incorporate green hydrogen and electrified process gas heating to reduce its carbon footprint further.⁵⁵

Emsteel has adopted a formal decarbonisation strategy, targeting 100% zero-emissions electricity supply and a 40% reduction in absolute GHG emissions from its steel business by 2030 compared with 2019 levels.⁵⁶ The company has also committed to achieving net-zero emissions by 2050.

Green hydrogen pilot plant

In 2024, Emsteel successfully commenced green hydrogen production using a 2.1MW electrolyser capable of producing up to 368t of hydrogen a year.⁵⁷ The project, a first-of-a-kind initiative in the Middle East–North Africa (MENA) region, was developed in collaboration with Masdar. The resulting low-emissions steel products were used in the construction of a mosque in Abu Dhabi.⁵⁸

Electric gas heater

In collaboration with Danieli and Kanthal, the company is installing a 1.3MW electric process gas heater (e-PGH) at its DRI facility to reduce its reliance on gas-based heating. The pilot unit, which is the first in commercial use, will deploy Kanthal's Prothal TH technology, and is scheduled to commence operation in late 2026.

Coolbrook

Coolbrook has developed a proprietary shockwave heating technology, the RotoDynamic Heater (RDH), which is designed to deliver high-temperature industrial heat up to 1,700°C.⁵⁹ The technology uses electric motors to spin blades and produce heat directly within gas with 95% energy efficiency, and can be deployed in various processes within the steel industry.⁶⁰

In April 2025, Tenova and Coolbrook announced a strategic partnership to deploy the RDH technology in industrial applications, including initial use in Tenova's acid gas generation systems. Their longer-term ambition is to expand its application across steelmaking and other high-temperature industrial processes.⁶¹

⁵⁵ Emsteel. [Investor Presentation](#). November 2025. Page 17.

⁵⁶ Emsteel. [EMSTEEL Announces Comprehensive Decarbonization Strategy, Aligned with the UAE's Net-Zero by 2050 Strategic Initiative](#). 17 February 2025.

⁵⁷ GMK Center. [Emsteel increased spending on innovation and investment by 127% in 2020-2024](#). 19 April 2025.

⁵⁸ Fuel Cells Works. [EMSTEEL Delivers First Hydrogen-Based Rebar to Develop Abu Dhabi's First Net-Zero Mosque by Aldar](#). 25 August 2025.

⁵⁹ Coolbrook. [Industrial Process Heating: Replacing Fossil Fuels with RotoDynamic Heater](#). Accessed 5 October 2026.

⁶⁰ Coolbrook. [Application of RotoDynamic Technology in Decarbonizing Steel Industry](#). 4 October 2024.

⁶¹ Tenova. [Tenova and Coolbrook for CO2-free Metals Production](#). 16 April 2025.

Tempra

Paul Wurth's Tempra gas heater is another technology designed to electrify industrial heat generation.⁶² Paul Wurth, which is a part of SMS group, has developed a 0.5MW prototype that has demonstrated sustained gas outlet temperatures of 1,080°C. The technology is reported to achieve a process efficiency of more than 95%. With a reported technical readiness level (TRL) of 6, it has successfully completed laboratory-scale validation, and has the potential to supply high-temperature heat for a range of applications across the steel industry.

Plasma torch

Plasma torches are another technology capable of providing very high temperatures, potentially above 3,000°C.⁶³ A plasma generator converts electrical energy into thermal energy, which is transferred to a gas. Depending on the application, different gases can be used as the plasma gas, which carries heat into the furnace.

PyroGenesis is one of the pioneers in this field, and has tested its plasma torch technology in iron ore pelletising applications.⁶⁴ The company is targeting fossil fuel-based energy used in high-temperature industrial processes, estimated at 22MWh annually, with the aim of replacing these applications with electrically powered plasma torches.⁶⁵

Paul Wurth also uses a plasma-based superheating system in its proprietary EASyMelt technology. The system heats synthesis gas (syngas) to 1,700–2,200°C before it is injected into the furnace. This approach can electrify the heat component of the ironmaking process while retaining syngas as the reducing agent.⁶⁶

While these technologies are still in development, there are very few real-world examples to date, and further efforts are required to demonstrate and validate them.

Indirect electrification with hydrogen

While direct electrification has limitations in some steelmaking processes, green hydrogen is often touted as an indirect electrification solution, serving as both a reducing agent for iron ore and a fuel for generating high-temperature heat.

⁶² SMS Group. [Electrifying high-temperature gas heating through proven industrial know-how](#). 8 July 2026.

⁶³ Thermal Science and Engineering Progress. [A pilot-scale test of plasma torch application for decarbonising the steel reheating furnaces](#). Zaini, I. et al. 1 May 2023.

⁶⁴ PyroGenesis. [PyroGenesis provides update on its iron ore pelletization torch business line](#). 26 January 2023.

⁶⁵ PyroGenesis. [Plasma Torches](#). Accessed 5 October 2026.

⁶⁶ SMS Group. [EASyMelt](#). Accessed 5 October 2026.

Hydrogen for iron ore reduction

The most promising pathway for reducing emissions from primary iron production is to replace fossil fuels with green hydrogen in the iron ore reduction process. The Circored technology was among the first to test hydrogen-based direct reduction at scale.⁶⁷ Since then, numerous direct reduction technologies have sought to incorporate hydrogen into their processes, ranging from shaft furnace technologies, such as Midrex and Energiron, to fluidised-bed technologies, such as HYFOR and HyREX, as well as newer innovative solutions such as Calix's Zesty technology.^{68,69,70,71,72}

Hydrogen for heating

While most attention has focused on using hydrogen as a reducing agent to remove oxygen from iron ore, some technologies are exploring its use as a heat source. Flameless oxyfuel combustion technology — which uses oxygen instead of air for combustion — is one such example, and has been developed to improve the efficiency of thermal heating processes.

Linde has been developing this technology for several years and, following pilot projects and trial operations, delivered the first full-scale reheating furnace powered entirely by hydrogen to the Swedish steelmaker Ovako in 2024 (see Box 2).⁷³ While the new pathway offers several technical benefits, including improved efficiency, better temperature uniformity, and lower carbon emissions, the use of valuable hydrogen for heat generation remains less efficient and more expensive, and must still compete with electricity-based alternatives.

SMS group's ZeroFlame HY² burners provide a similar solution by replacing conventional fossil fuel burners with hydrogen-fired burners for high-temperature industrial heating applications.⁷⁴

Other initiatives are exploring hydrogen combustion for reheating furnaces, such as HYDREAMS, which is demonstrating its H₂ oxy-combustion technology at TRL 7.⁷⁵

⁶⁷ SMS Group. [Circored direct reduction](#). Accessed 5 October 2026.

⁶⁸ Midrex. [MIDREX H₂](#). Accessed 5 October 2026.

⁶⁹ Tenova. [Energiron](#). Accessed 5 October 2026.

⁷⁰ Primetals. [HYFOR®: Hydrogen-Based Fine-Ore Reduction](#). Accessed 5 October 2026.

⁷¹ POSCO. [HyREX® Hydrogen reduction ironmaking technology to reduce carbon emissions](#). Accessed 5 October 2026.

⁷² Calix. [Zesty Green Iron Demonstration Project](#). Accessed 5 October 2026.

⁷³ Linde. [Successful Full-Scale Implementation of Hydrogen as a Fuel](#). December 2025.

⁷⁴ SMS Group. [A burner for all mix ratios of natural gas and hydrogen](#). 15 February 2023.

⁷⁵ HYDREAMS. [Decarbonizing with hydrogen](#). Accessed 5 October 2026.

Box 2: Ovako

The Swedish scrap-based steelmaker is committed to achieving net-zero emissions across its value chain by 2045.⁷⁶ As an interim target, the company aims to reduce its Scope 1, 2, and 3 emissions per tonne of hot-rolled steel by 25% by 2030 and by 75% by 2040, relative to a 2021 baseline. To realise this target, electrification will play a significant role.

In 2024, 43% of Ovako's total energy supply came from nuclear power, 36% fossil fuel-based and a further 20% from renewable sources, resulting in near-zero Scope 2 emissions.

Ovako also became the world's first steel producer to operate a hydrogen-fired reheating furnace for rolling operations.⁷⁷ In collaboration with Linde Gas AB, the company began using green hydrogen produced by a 20MW electrolyser to fuel the reheating furnaces at its Hofors plant, replacing liquefied petroleum gas (LPG) in 2024.

Electrochemical ironmaking

Similar to metals such as aluminium, copper and zinc, iron can also be produced through electrochemical processes, in which oxygen is stripped from iron oxides to produce metallic iron. However, these technologies have been overlooked for decades, and remain at an early stage of development for iron production.

While the electricity consumption of electrochemical ironmaking is broadly comparable with other low-emissions pathways, at about 4MWh/t of iron, DRI-based routes benefit from greater technological maturity, having already been demonstrated and deployed at commercial scale.⁷⁸

Direct iron electrolysis also faces significant scalability challenges, and is more likely to play a niche role in steel decarbonisation over the coming decades.

Flash ironmaking

Flash ironmaking also can use various energy sources to rapidly reduce fine iron ore concentrate particles at high temperatures, producing solid iron powder or molten iron in a matter of seconds.⁷⁹ Flash ironmaking was initially developed at the University of Utah under the leadership of Professor H. Y. Sohn.⁸⁰ Owing to the exceptionally rapid reaction kinetics, the process has been described as exhibiting “explosive” chemical behaviour. When powered by renewable electricity and supplied with

⁷⁶ Oveko. [Sustainability Report Financial Year 2024](#). 2024. Page 9.

⁷⁷ Oveko. [First in the world to heat steel using hydrogen](#). 2020.

⁷⁸ IEEFA. [Electrifying ironmaking: The potential of direct electrolysis of iron ore](#). 26 August 2026.

⁷⁹ Materials. [Research Progress on Low-Carbon Ironmaking Technologies for China's Iron and Steel Industry Under the Carbon Peaking and Carbon Neutrality Goals](#). Liu, W. et al. 23 July 2026.

⁸⁰ Journal of Energy and Power Technology. [Development of the Flash Ironmaking Technology \(FIT\) for Green Ironmaking with Low Energy Consumption](#). Sohn, H. et al. 23 September 2021.

green hydrogen (i.e. hydrogen flash ironmaking), this technology has the potential to substantially reduce carbon emissions from primary iron production.

More recently, the technology has been further investigated by Professor Zhang Wenhai and his research team in China, with promising experimental results.⁸¹ One of the key advantages of the process is its ability to convert iron oxide to molten iron in several seconds, making it one of the fastest direct reduction technologies under development.

Flash ironmaking technology has also attracted interest from major industry players. For example, Fortescue is collaborating with Chinese steelmaker Baowu to advance the development and commercialisation of this pathway. The two parties plan to establish an industrial pilot plant with an annual production capacity of 5,000t of hot metal. The process aims to produce hot metal directly from iron ore concentrate, eliminating the need for conventional ore processing, beneficiation and agglomeration steps.⁸²

Downstream processes

Despite having lower energy requirements than energy-intensive processes such as ironmaking, downstream processes in the steel value chain also present significant opportunities for electrification. These are mostly focused on reheating furnaces for rolling and heat treatment processes such as annealing furnaces.⁸³

The reheating furnace accounts for 15–20% of the total energy consumption of the iron and steel industry and 70% of the total energy consumption of the rolling process.⁸⁴

For reheating, billets/blooms or slabs must be heated to 1,250–1,300°C.⁸⁵ Energy consumption varies considerably depending on factors such as the fuel source, burner type, and whether the furnace uses hot or cold charging. Typically, reheating requires about 1.4–1.8GJ/t of steel for cold charging.⁸⁶ This can range from as low as 0.61GJ/t for hot charging to more than 3GJ/t in some cases, depending on operating conditions and furnace efficiency.⁸⁷

⁸¹ Tech Explorist. [China increases ironmaking productivity by 3,600 times](#). 30 December 2024.

⁸² Hydrogen Insight. [Fortescue to pilot hydrogen-plasma ironmaking with Chinese state-owned steel giant](#). 4 December 2025.

⁸³ Materials. [Continuous Electric Furnace Annealing as a Sustainable Route: Influence on the Microstructure, Texture, and Mechanical Properties of Cold-Rolled Low-Carbon Steels for CO₂ Emission Reduction](#). 17 April 2026.

⁸⁴ Applied Thermal Engineering. [Energy saving study of reheating furnace from structure and oxygen-enriched combustion](#). Lu, B. *et al.* 15 March 2025.

⁸⁵ Steel Research International. [Future Scenarios for Reducing Emissions and Consumption in the Italian Steelmaking Industry](#). Mapelli, C. *et al.* 5 January 2022.

⁸⁶ Journal of Sustainable Metallurgy. [Techno-Economic Analysis of Induction and Hydrogen Reheating of Steel Billet](#). Siyambalapitiya, T. *et al.* 13 June 2026.

⁸⁷ Climate Technology Centre and Network. [Benchmarking Study for Thailand's Iron & Steel Industries](#). Appendix 1. May 2018. Page 6.

Studies indicate the thermal efficiency of gas-fired reheating furnaces is about 60%.⁸⁸ A significant portion of the energy input is lost through waste gases, furnace heat losses and water-cooling systems. This estimate is broadly consistent with industrial data.⁸⁹ For example, one study found that of the 1.55GJ/t of energy supplied to the furnace, only 0.8GJ/t was transferred to the steel, with the remaining energy lost through the furnace.⁹⁰ Other studies also confirmed about 50% of the total energy is absorbed by the steel in the furnace.⁹¹

While technological solutions are trying to increase efficiency, reducing and recovering heat loss in the process, which can be seen in more modern reheating furnaces, electric heaters can replace gas and provide heat more efficiently and sustainably. Hydrogen is another option, although it may not be cost-competitive with gas in the near term.

Technology providers

A range of technologies are able to provide the required temperature for these processes. One example is SMS group's Elotherm induction heating furnace, which replaces conventional gas-fired billet reheating furnaces at the Feralpi Group rebar mill.⁹²

Kanthal in collaboration with the Swedish metals research institute Swerim is developing a hybrid system that combines induction and resistance heating for reheating applications. As part of the ELROS project, which is focused on modernising the reheating process for billets and slabs, the company tested the replacement of gas-fired heaters with electric heaters at the Swerim facility.⁹³

A new generation of mills are also seeking to integrate production with clean electricity. Greensteel Australia has announced plans to establish a fossil fuel-free rolling mill in Australia that will use an electric induction furnace (EIF) to produce 0.6MTPA of reinforcing bar.⁹⁴ The technology provider is Danieli.⁹⁵

Economics of electrifying heat

While hydrogen could be used as a heat source for reheating applications, direct electric heating remains more efficient.⁹⁶ Water electrolysis has an efficiency of about 72% using the best European

⁸⁸ Renewable and Sustainable Energy Reviews. [Energy efficiency assessment by process heating assessment and survey tool \(PHAST\) and feasibility analysis of waste heat recovery in the reheat furnace at a steel company](#). Si, M. et al. August 2011.

⁸⁹ Climate Technology Centre and Network. [Benchmarking Study for Thailand's Iron & Steel Industries](#). Appendix 1. May 2018. Page 21.

⁹⁰ European Commission. [Reference Document on Best Available Techniques in the Ferrous Metals Processing Industry](#). December 2001. Page 64.

⁹¹ 18th Brazilian Congress of Thermal Sciences and Engineering. [Reheating furnaces in the steel industry: determination of the thermal powers in the combustion of coke oven gas, Linz-Donawitz gas and blast furnace gas](#). November 2020. Page 2.

⁹² SMS Group. [Electrification: A key pathway to decarbonizing downstream processes](#). 18 September 2024.

⁹³ Kanthal. [ELROS project: Kanthal and Swerim's push for sustainable steel](#). 30 October 2024.

⁹⁴ Greensteel Australia. [Greensteel Australia's \\$500M Investment Returns Steelmaking to the NSW Hunter Region](#). 7 July 2026.

⁹⁵ Danieli. [World-first rolling mill to be 100% gas-free operated](#). 21 October 2024.

⁹⁶ Future Cleantech Architects. [Decarbonizing high-temperature heat in industry](#). October 2024. Page 2.

technologies available.⁹⁷ Assuming an 85% efficiency for hydrogen combustion and factoring in another 90% for transportation, storage and losses, the overall efficiency of converting electricity into heat through hydrogen is about 55%.⁹⁸ Direct electric heating therefore offers a more efficient pathway by avoiding these additional conversion losses. An RMI study shows that using hydrogen to generate heat in a DRI facility requires more than 50% more electricity than an electric gas heater.⁹⁹

Replacing gas with hydrogen as a heat source in a scrap-based EAF facility in Italy was assessed in one study.¹⁰⁰ It found the cost of thermal energy would increase by approximately 230% when switching from gas to hydrogen. The study also found that, at a carbon price of €100/tCO₂ and gas prices ranging from €0.05–0.30/kWh, hydrogen becomes cost-competitive when electricity prices are 40–60% lower than the gas price.

This condition is difficult to achieve in many EU markets, where electricity prices are typically two to four times higher than gas prices. The Electrification Action Plan aims to narrow this price gap through reforms to energy taxation and network charges, with the goal of bringing the ratio closer to two for industrial users.¹⁰¹

Another study analysed three options (gas, hydrogen and electricity) for reheating billets, and calculated the levellised cost of heat (LCOH).¹⁰² It found hydrogen was unlikely to be competitive with the other two pathways, with cost parity estimated about USD1.75/kg H₂. This price may not be achievable in many jurisdictions around the world in the near future. Electricity appears to be a more promising option. Although its cost remains higher than gas in this study, electric heating can be more competitive in locations with very high gas prices.

Figure 4 shows that even without a carbon cost, induction heating could reach cost parity with gas about USD54/MWh, a level that could be within reach for many producers in the near future. At a carbon price of USD130/tCO₂, the costs of the two options become broadly comparable.

⁹⁷ IEEFA. [Less is more – Efficient electrolyzers vital for competitive Australian green iron](#). 4 June 2026. Page 3.

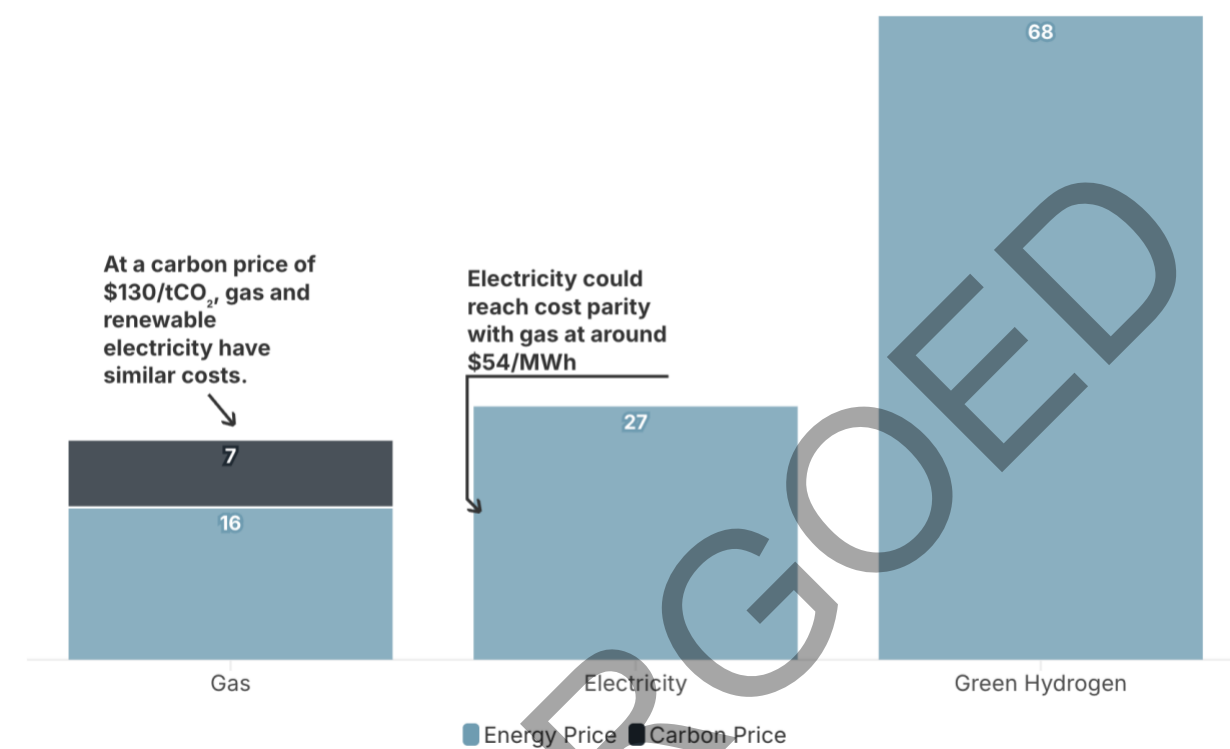
⁹⁸ European Commission. [Hydrogen for Heating: Technologies, Challenges, and Opportunities](#). 28 May 2025.

⁹⁹ RMI. [Steel Production After Coal and Beyond Gas](#). 13 July 2026.

¹⁰⁰ Journal of Cleaner Production. [Assessment of the role of hydrogen to produce high-temperature heat in the steel industry](#). Marocco, P. et al. 15 February 2023.

¹⁰¹ European Commission. [Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions. electrification action plan](#). 17 July 2026.

¹⁰² Journal of Sustainable Metallurgy. [Techno-Economic Analysis of Induction and Hydrogen Reheating of Steel Billet](#). Siyambalapitiya, T. et al. 13 June 2026.

Figure 4: Energy cost in various reheating technologies (USD/t)

Source: IEEFA. Note: Gas/hydrogen furnace efficiency 50%; induction furnace total efficiency 75%; gas price USD10/GJ; green hydrogen USD6/kg; firm renewables USD90/MWh; minimum heat for heating up cold billet 222kWh/t (excluding losses); carbon price USD85/tCO₂.

Beyond the technical challenges associated with switching to 100% hydrogen burners, some studies suggest blending hydrogen with gas could be an alternative that avoids the need for a complete burner upgrade.^{103,104} However, studies indicate the capital cost of hydrogen burner systems, including upgrades to valves and piping, could be four to eight times higher than gas burner systems.¹⁰⁵ Further technological advances are needed to reduce the capital expenditure of hydrogen-based heating and improve its economic viability. In the near term, hydrogen-based reheating is unlikely to be economically viable, while direct electrification could challenge the future role of gas heating.

Electrification as a pathway to greater energy security

Beyond the economic and environmental benefits, recent global conflicts have exposed the serious energy security risks of fossil fuel dependence in the steel sector. Disruptions to global fuel supplies can rapidly translate into higher energy costs, supply shortages and production risks. This makes

¹⁰³ Fluor. [Decarbonization of industrial fired heaters by using hydrogen fuel](#). 29 September 2022. Page 15.

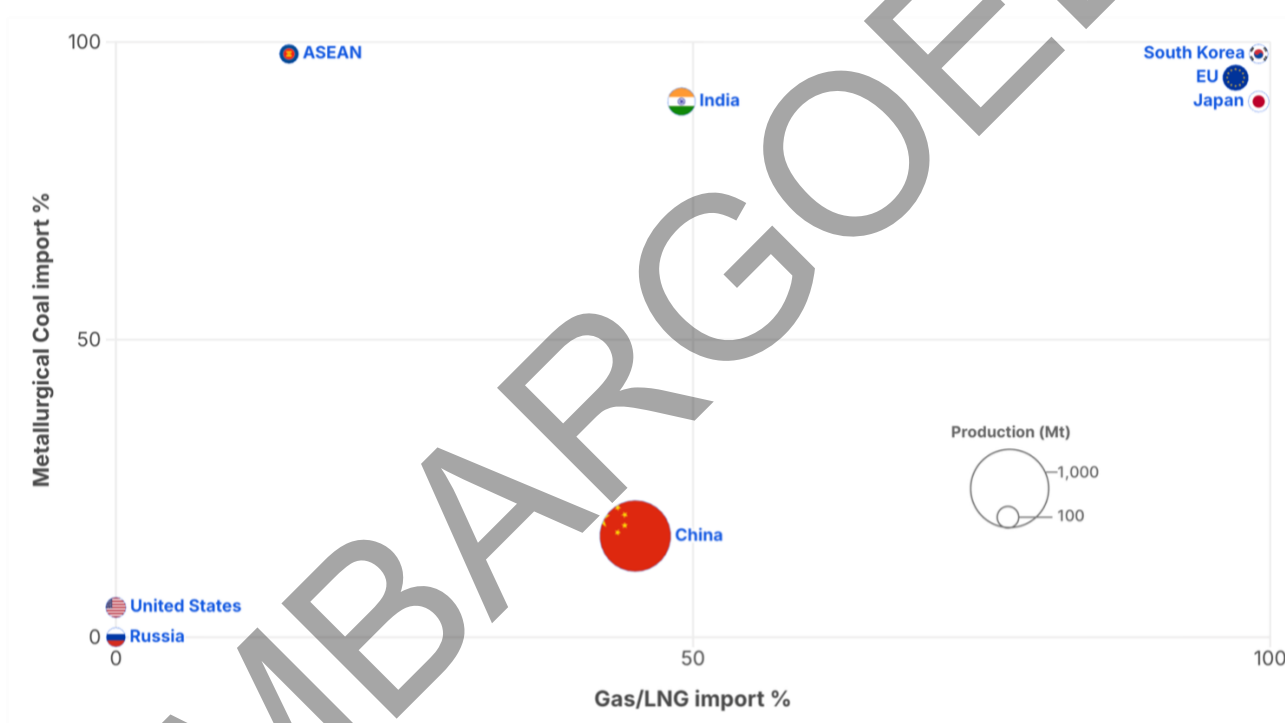
¹⁰⁴ Energy Solutions. [Industrial Hydrogen Blending: Retrofitting Gas Furnaces for the H2 Economy](#). 28 January 2025.

¹⁰⁵ Australian Hydrogen Council. [Bringing the heat. Hydrogen's role in decarbonising Australian industrial process heat](#). August 2023. Page 19.

reducing fossil fuel dependence not only a decarbonisation priority, but also a strategic imperative to strengthen domestic energy security, increase self-sufficiency and build more resilient industrial supply chains.

Not all steelmakers around the world have reliable access to the energy sources required for domestic steelmaking. Met coal and gas/LNG, two major fossil fuels used in the steel sector, are highly concentrated among a limited number of producers, making their global value chains vulnerable to disruption.

Figure 5: Fossil fuel dependence across major steelmaking regions and countries



Sources: IEA Coal 2025¹⁰⁶ and World Energy Balances Highlights 2025;¹⁰⁷ IEEFA.¹⁰⁸ Note: Gas/LNG figures show the percentage of total imports rather than consumption specifically attributable to the steel sector. The countries and regions shown accounted for about 90% of global steel production in 2025. In ASEAN, Thailand is the only major steelmaking country that imports gas/LNG. Indonesia and Malaysia are both gas/LNG exporters. Both the US and Russia are net exporters of met coal and gas/LNG. South Korea, Japan and the EU have the highest dependence on fossil fuels for energy demand of the countries and regions shown.

The disruption of major fossil fuel trading routes is prompting energy-intensive industries to rethink their energy supply strategies, with greater electrification emerging as a potential way to reduce exposure to global energy supply shocks.¹⁰⁹

¹⁰⁶ IEA. [Coal 2025](#).

¹⁰⁷ IEA. [World Energy Balances Highlights](#). October 2025.

¹⁰⁸ IEEFA. [Data Dive: A breakdown of gas and LNG demand in Asia](#). Accessed 5 October 2026.

¹⁰⁹ IEA. [Impacts of Middle East conflict set to reshape energy investment plans as disruptions put focus on security](#). 28 May 2026.

India

India is a clear example, having been significantly affected by the conflict in the Middle East.¹¹⁰ It produces almost half of its gas domestically, and remains dependent on imports for its gas-based ironmaking.¹¹¹ ArcelorMittal Nippon Steel and JSW are among the major steelmakers most exposed to this dependency, and were particularly affected by the conflict in the Middle East.^{112,113} The steel sector also relies on other fuels, including oil and LPG, particularly among smaller steelmakers.

The situation is even more challenging for met coal, with India importing almost 90% of its demand from the global market.¹¹⁴ As with oil and gas, surges in met coal prices driven by global conflicts can increase costs and expose steelmakers to greater market volatility. These uncertainties could undermine the country's long-term plans to increase steel production capacity to 604MTPA.¹¹⁵

EU

Europe is highly reliant on both imported gas and metallurgical coal from various suppliers. The region experienced one of its most severe energy challenges following Russia's expanded invasion of Ukraine in 2022, as pipeline gas supplies from Russia were progressively replaced by gas from Norway and LNG imports mainly from the US.¹¹⁶ However, the region has only shifted from one supply chain to another without fully mitigating its underlying energy security risks.

This dependency has again been tested by the conflict in the Middle East, highlighting the vulnerability associated with continued reliance on imported fossil fuels. Reducing this exposure requires greater electrification of power generation and industrial processes, alongside increased reliance on domestic and diversified energy sources.¹¹⁷ The power sector remains particularly exposed to fuel price fluctuations, as electricity prices are closely linked to the cost of the fuels used for generation.¹¹⁸ Steelmakers in the EU are not immune to these market volatilities, with rising energy costs further eroding the already narrow margins of steel manufacturing.¹¹⁹ The conflict appears to be prolonged, with increasingly significant economic impacts on the EU.¹²⁰

These conflicts are becoming more frequent, lasting longer and having more severe global impacts, affecting not only energy supply but also prices, regardless of whether energy is sourced

¹¹⁰ World Economic Forum. [How the Iran war is disrupting India's steel production amid fuel shortages and rising costs](#). 21 April 2026.

¹¹¹ IEA. [India Gas Market Report](#). 12 February 2025. Page 7.

¹¹² Argus Media. [India's steel sector sounds alarm on gas supply crunch](#). 13 March 2026.

¹¹³ GMK Center. [JSW is asking the Indian government to intervene due to a gas shortage for the steel industry](#). 20 March 2026.

¹¹⁴ IEEFA. [India's steel sector confronts growing coal risks](#). 4 December 2025.

¹¹⁵ Reuters. [India unveils steel policy aiming for 604 million tons capacity by 2047](#). 11 October 2026.

¹¹⁶ IEEFA. [EU gas flows tracker](#). Accessed 5 October 2026.

¹¹⁷ Ember. [Latest energy shock reminds Europe of its risky gas reliance](#). 13 March 2026.

¹¹⁸ Ember. [European electricity prices and costs](#). Accessed 5 October 2026.

¹¹⁹ The Guardian. ['Very damaging': how the Iran war is hitting energy-intensive industries](#). 17 March 2026.

¹²⁰ European Commission. [How a prolonged Middle East crisis would impact energy prices and the EU economy](#). 27 May 2026.

domestically or imported.¹²¹ However, energy-importing countries are more exposed to these shocks, and therefore have greater incentives to reduce their dependence on external supplies.

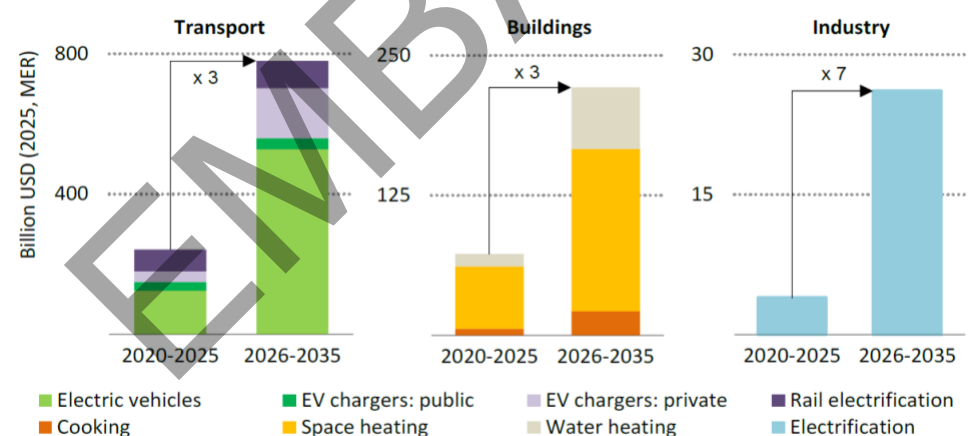
Electrification of different sectors could reduce energy import costs by more than USD400 billion by 2035 compared with 2025 across major energy-importing countries.¹²² Amid two ongoing energy supply shocks triggered by regional conflicts, alongside persistent concerns over energy affordability, many countries are turning to electrification to strengthen energy security, with 25 announcing new electrification-related policies since February 2026.

Investment and policy support for steel electrification

Despite the rapid growth in global electricity demand, electricity accounts for only 23% of the world's final energy consumption. While some sectors, particularly transport through electric vehicles and low-temperature heating through heat pumps in buildings, are advancing rapidly, industrial electrification has lagged. Industrial sectors face higher upfront investment requirements, and often lack the policy support and incentives available to other sectors. A review of electrification policies and regulations around the world reinforces this gap, highlighting the need for greater government support to accelerate investment and overcome initial cost barriers.¹²³

This is also reflected in projected electrification investment to over the next decade. To meet a 35% electrification target, annual investment is expected to increase from about USD320 billion today to about USD1 trillion in 2035. However, all industrial sectors are expected to account for less than 3% of the total investment, with much larger shares going to transport and buildings (Figure 6).¹²⁴

Figure 6: Average annual electrification investment in high electrification scenario



Source: IEA¹²⁵

¹²¹ IEEFA. [Tempering risk: Steelmakers count costs of fossil fuel price volatility](#). 31 March 2026.

¹²² IEA. [Electrification Special Report](#). 22 September 2026. Page 17.

¹²³ Ibid. Page 41.

¹²⁴ Ibid. Page 144.

¹²⁵ Ibid. Page 145.

Historical data also shows industry has never attracted a significant share of total electrification investment.¹²⁶ Moreover, the industrial sector investment in 2025 was about 30% lower than in 2015.¹²⁷ Several factors contribute to this trend, including high capital expenditure, volatile electricity markets and low manufacturing margins, which make industrial electrification projects less attractive to investors.

In 2025, global energy transition investment reached USD2.3 trillion, while investment in clean steel amounted to USD25.3 billion, accounting for about 1% of the total.¹²⁸

These figures pale in comparison with the investment required to decarbonise the steel sector, estimated at US\$1.4 trillion, with some estimates as high as US\$4.4 trillion.^{129,130}

The European Commission estimates the technical potential for industrial electrification could reach 1,400TWh by 2030 and exceed 2,000TWh by 2040, provided supportive policies are in place to accelerate the transition. Across different modelling scenarios, the iron and steel sector could require 113–444TWh of electricity by 2040, although hydrogen is expected to remain the primary energy carrier for much of the sector's decarbonisation.¹³¹

Despite this potential, renewable electricity accounted for less than 20% of industrial electricity consumption across most of Europe in 2023.

Large-scale electrification requires several key preconditions, with sufficient renewable electricity generation and adequate grid capacity among the most important. Supportive policies, reductions in the cost of electric steel production, and increasing the cost of continued reliance on fossil fuels — such as through the EU emissions trading scheme (ETS) — can further improve the economics of electrification. Together, these factors can shift the balance in favour of replacing fossil fuels with electricity, and make electrification a more attractive option for iron and steel producers.

Flexibility opportunities from steel electrification

While electrification opens the door to reducing emissions in the steel sector, providing reliable 24/7 electricity remains a challenge for many steelmakers around the world. The transition to clean electricity will happen gradually, making it increasingly important to develop more flexible technologies that can operate with intermittent supplies of renewable electricity.

New electric-based technologies can also provide a degree of flexibility, enabling plants to operate more efficiently and economically by avoiding or reducing electricity consumption during peak-

¹²⁶ IEA. [World Energy Investment 2026](#). June 2026. Page 105.

¹²⁷ Ibid. Page 127.

¹²⁸ Bloomberg NEF. [BNEF Energy Transition Investment Trends 2026](#). 26 January 2026. Proprietary.

¹²⁹ IEA. [Iron and Steel Technology Roadmap](#). Page 111.

¹³⁰ McKinsey Sustainability. [Steel](#). 1 August 2022.

¹³¹ European Commission. [Study on pathways and policies for accelerating electrification and use of renewables in industry](#). December 2025. Pages 96–97.

demand periods. A range of incentives are available around the world, particularly in the EU, to encourage demand reduction and peak shaving. Technologies with greater responsiveness are therefore better positioned to capture these opportunities.

As EAFs benefit from batch production systems, which give them greater flexibility. In scrap-based EAFs, shifting the timing of batch melting to periods of lower electricity prices can reduce operating costs by 5–46% without affecting steel production. Similar flexibility is possible in H₂–DRI–EAF plants, where 5–40% of electricity demand can be shifted by adjusting electrolyser operation to reduce average monthly electricity costs by 5–35%. Hydrogen storage can also provide greater flexibility at scale.¹³²

The EU steel sector estimated to have an annual theoretically shiftable volume of about 270GWh of upward flexibility, referring to the ability to reduce or shift electricity consumption to relieve grid stress. It also has an annual shiftable volume exceeding 40GWh of downward flexibility, referring to the ability to increase electricity consumption on demand and absorb excess generation.¹³³

Table 3 provides the flexibility characteristics of technologies relevant to the green iron and steel sector, including their potential for load shifting and demand response.

¹³² Renewable and Sustainable Energy Reviews. [Flexibility options in a decarbonising iron and steel industry](#). Boldarini, A. et al. January 2024.

¹³³ European Commission. [Study on pathways and policies for accelerating electrification and use of renewables in industry](#). December 2025. Page 109.

Table 4: Technical characteristics of flexibility assets across the steel industry

Process/asset		Asset operation	Power-on-time	Time-shifting potential	Ramp-up/ ramp-down rate	Load reduction potential	Energy flexibility potential	Flexibility events	Electricity use – EU level
Electric arc furnaces		Year-round, downtime in summer possible	80–90% (batch duty)	10–30 minutes (intra-heat), 1–3h by rescheduling heats	Seconds to minutes	30–80% (full-off between heats)	10s–100MWh per event	40–45pa	24–30TWh/ year (28–35TWh/year by 2030)
Induction furnaces		Year-round, batch scheduling	60–90% (batch duty)	15–60 min (inrabatch), 1–2h by rescheduling/ holding	Seconds to minutes	50–100%	Up to 10s of MWh per event	50–150pa	1–3TWh/ year (2030)
DRI buffer		Year-round operation	Continuous (shaft)	2–6h (depending on buffer size & product)	Limited on shaft, use buffer to avoid trips	Indirect (shifts EAF load)	Indirect	10–30pa	N.A. (indirect)
Cryogenic air separation units		Year-round, maintenance windows	90–95%	1–6h (via LOX/LIN tanks & cold storage)	~3%/min	50–60% (with liquid stock), brief full off on parallel trains	10s–100MWh per event	10s to >100pa	1–3TWh/ year (2030)
E-boiler		Follows steam demand	High (duty cycled)	Minutes to hours (with steam accumulators)	Seconds to minutes	0–100% (storage aided)	Up to 10s of MWh per event	100–300 per year	<0.5TWh/ year (2030)
High-temperature heat pump		Follows waste-heat availability	High (when sinks/ sources align)	Minutes to hours (thermal buffers)	Minutes	20–100%	Up to 10s of MWh per event	20–100 per year	<0.5TWh/ year (2030)
Mechanical vapor recompression		Follows wet-process duty	High (continuous)	≤1–2h (with tankage)	Minutes	30–100%	Up to 10s of MWh per event	50–150pa	<0.2TWh/ year (2030)
Hydrogen electrolyser	Alkaline	Continuous, year-round operation	95%	Minutes	Up to 20%/s (*FCR simulations)	60–90%	10s of MWh per event	10s to >100pa	0.4–0.5TWh/ year (15–60TWh/ year by 2030)
	PEM	Continuous, year-round operation	95%	Minutes (with buffer: 9–10h)	0–100% in <1 min (<10s at HyBalance)	100% for short durations (min. load ~20%)	10s of MWh per event	10s to >100pa	20–50TWh/ year (2030)
	Chlor alkali	Continuous, year-round operation	~60–100%	Minutes to hours	Minutes	50–100% (60–100% for safety/ quality)	10s of MWh per event	10s to 50pa	14.5–17.4TWh/ year (2030)
Electrochemical metal processing	Aluminium	Year-round, no strong seasonal downtime	98–99%	Minutes	2–4%/min	25–65%	100s of MWh per event	26–27pa (max 3 per month)	35–60TWh/ year (2030)
	Zinc	Year-round, minor maintenance stops	~95%	Minutes to hours (via tank house load redistribution)	<1 minute	10–20% (higher if duration in minutes)	10s to 100s MWh/day	10–150pa	6–6.5TWh/ year (2030)

Source: European Commission,¹³⁴ IEEFA. *Note: FCR = frequency containment reserve. The hydrogen electrolyser section draws on data from the petrochemical sector. While detailed information on the flexibility of electrochemical ironmaking is not yet available, aluminum and zinc production can provide useful proxies and insights into the potential flexibility of these processes in the future.

¹³⁴ European Commission. [Study on pathways and policies for accelerating electrification and use of renewables in industry](#). December 2025. Page 205.

Conclusion

Electrification is widely recognised as one of the most efficient pathways for the energy transition, with sectors seeking to electrify as many processes as technically feasible. The steel sector is no exception.

There are opportunities to accelerate electrification across the steel sector. Electrification through secondary steelmaking in EAFs represents a relatively low-hanging fruit, but still requires an appropriate policy framework across different jurisdictions, particularly to secure long-term clean electricity supply. Electrification of high-temperature heat, particularly in the downstream steel value chain, and indirect electrification through hydrogen for ironmaking are less mature and may require additional support to move beyond the early adoption stage. Such support is needed to help technologies progress from first-of-a-kind commercial plants to *n*th-of-a-kind deployment and achieve widespread adoption at scale.

As President of Negotiations for COP31, Australia has an unprecedented opportunity to push for industrial electrification, including of iron- and steelmaking, to contribute to the ambitious 35% by 2035 target. While this target could be achievable, electrification is unlikely to progress evenly across all sectors. Buildings and transport are the main drivers of this target, as mature and efficient technologies such as heat pumps and batteries are already available. These technologies continue to improve, and their advantages over fossil-fuel alternatives are increasingly recognised, making the transition in these sectors more likely to progress steadily. By contrast, industrial electrification appears to be lagging, despite the sector's significant contribution to global emissions. This gap should not be overlooked.

Without stronger action, the iron and steel sector risks falling behind.

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