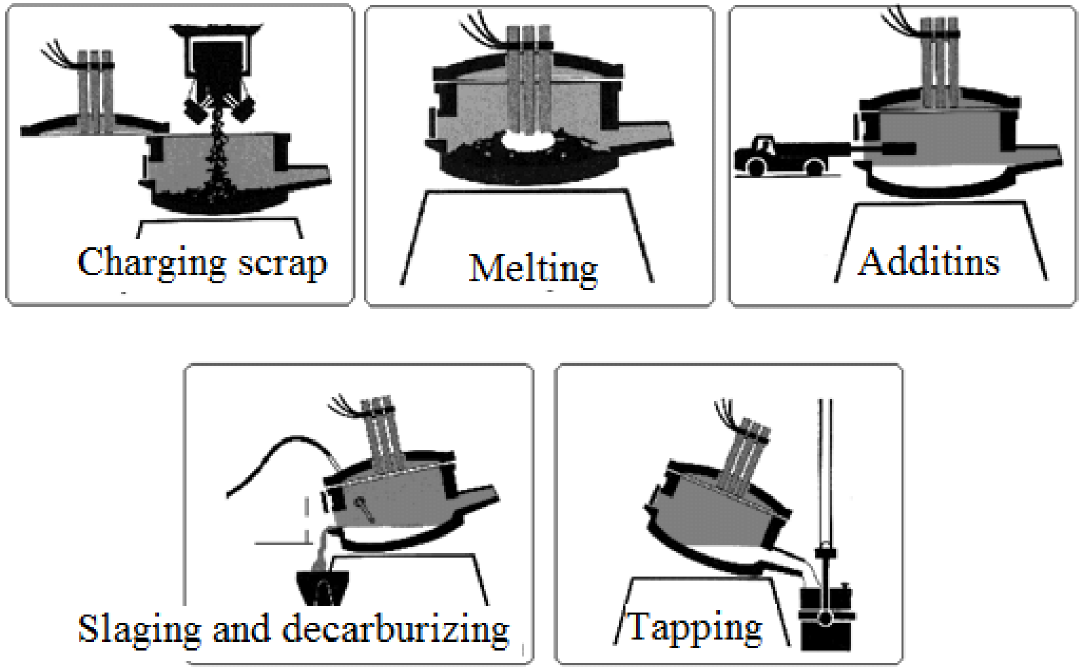
Electric Arc Furnace (EAF) Steelmaking

As the world races towards decarbonization, the steel industry—a major contributor to global carbon emissions—faces immense pressure to adopt greener production methods. With the second-largest steel producer globally, the need for sustainable steel production initiatives in India is critical.

Process flow



The EAF process is a form of secondary steelmaking. It is a batch process, meaning a specific amount of material is processed at a time, unlike the continuous nature of a blast furnace. The process flow is as follows:

1. Scrap Charging: The EAF is charged with steel scrap, which can be anything from old cars to construction waste. Other additives like lime and carbon are also added to form slag and assist in the melting process.

2. Melting: High-voltage electricity is passed through large graphite electrodes, creating powerful electric arcs that generate intense heat (up to 3,500°C or 6,332°F). This heat melts the scrap and turns it into molten steel. Oxygen is often injected to help burn off impurities and create more heat.

3. Refining: Once the scrap is molten, the refining stage begins. The molten steel is stirred, and more lime is added to form a slag layer on top, which absorbs impurities like sulfur and phosphorus. Alloying elements are added at this stage to achieve the desired grade of steel.

4. Tapping: The furnace is tilted to pour the molten steel into a ladle, leaving the slag behind.

5. Secondary Metallurgy: The molten steel in the ladle undergoes further refining and is cast into semi-finished products like billets, blooms, or slabs.

Advantages of EAF steelmaking

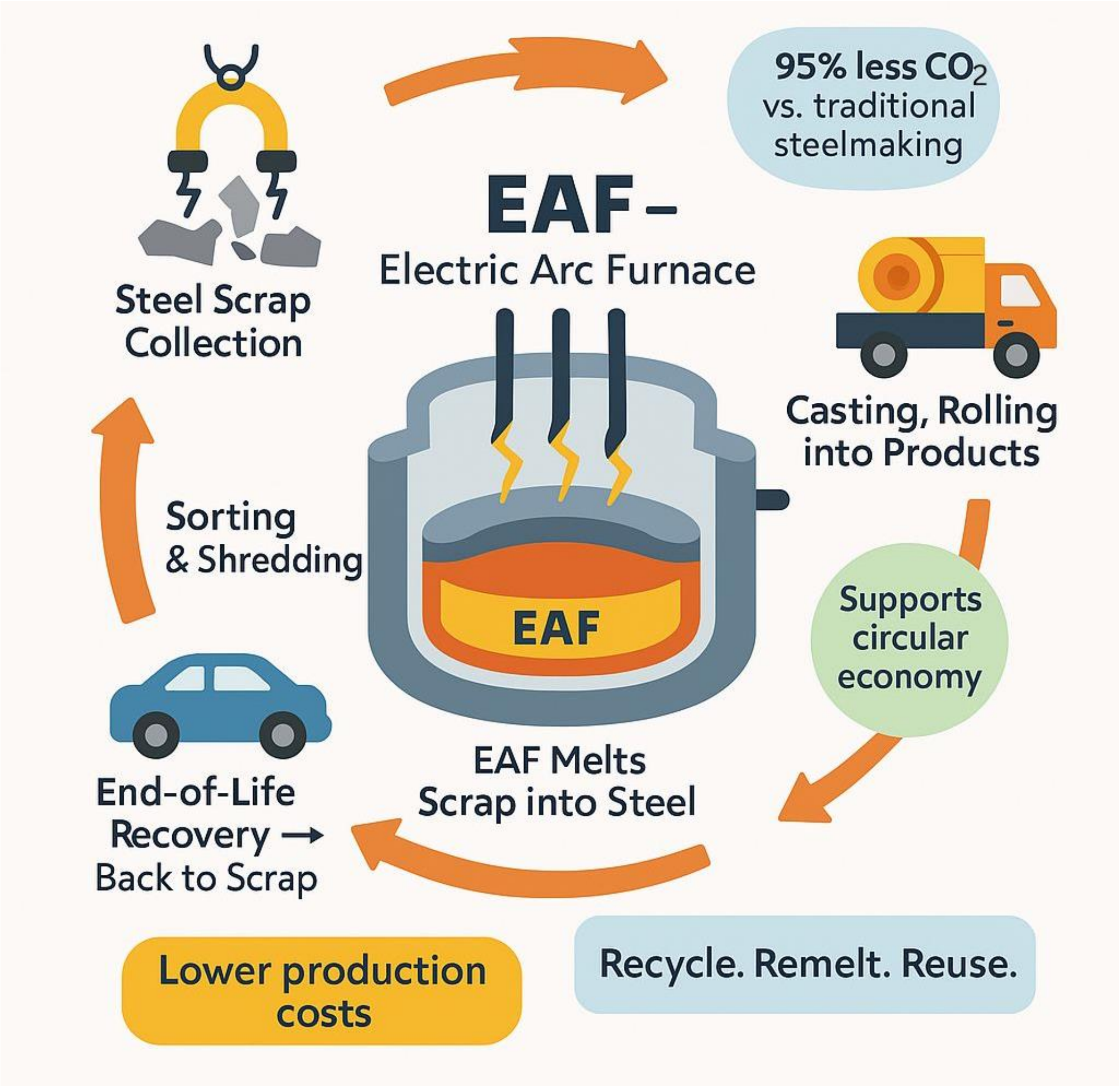
1. Lower direct CO_2 intensity: Scrap-EAF is among the lowest-emitting primary steel routes; combined with renewable electricity it can approach near-zero emissions.

2. Circularity and material efficiency: Uses recycled steel scrap, reducing virgin iron ore demand and landfill/waste.

3. Smaller capital footprint & modularity: Lower up-front capital costs and can be scaled more flexibly than integrated BF-BOF complexes.

4. Faster ramp-up and process flexibility: Shorter campaign/cycle times; easy to switch product grades and batches.

5. Lower coke/coal dependence: Reduces reliance on metallurgical coal and coke making infrastructure.



Disadvantages & constraints

Dependence on Electricity Source: The carbon footprint of an EAF is directly tied to the electricity grid. If the grid is fossil fuel-heavy, the EAF's emissions will still be significant.

Scrap Availability and Quality: The supply of high-quality steel scrap is limited and can fluctuate, impacting production costs. Impurities in scrap can also affect the final product quality.

Alloy/quality limits: Certain ultra-low residual steels may still need BF-BOF or extensive refining.

Need for DRI in some applications: Adds complexity and capital.

Upfront ecosystem changes: Needs logistics, grid upgrades, and investment in new equipment

India's Stand on EAFs and Decarbonization Policies

1. **Steel Scrap Recycling Policy (2019)**

EAFs primarily use scrap steel as their raw material, making the availability of high-quality scrap critical. This policy aims to create a framework for promoting and establishing organized metal scrapping centers across India.

2. "Greening the Steel Sector" Roadmap and Action Plan

The Ministry of Steel has released a comprehensive roadmap that provides a future plan for green steel and sustainability, with a clear focus on achieving the nation's net-zero target by 2070. This roadmap highlights EAFs and induction furnaces (IFs) as key technologies for the transition.

3. Financial Incentives and Missions

The government is preparing a national mission with significant financial support, such as a planned ₹5,000-crore push, to help the steel industry transition to cleaner methods. This mission specifically targets both primary and secondary steel producers.

The initiative aims to provide financial tools like concessional loans, risk guarantees, and targeted incentives to reduce the barriers for steelmakers who are investing in sustainable practices and technologies, including EAFs. The Production-Linked Incentive (PLI) scheme for specialty steel also supports investments in technologies that improve energy efficiency and reduce imports.

4. Duty Exemptions and Tariff Policies

To make scrap more affordable and accessible for EAF-based production, the government has taken measures to reduce the cost of raw materials.

Global Status of EAF Adoption

Global Electric Arc Furnace Market Segmentation by Region (in value %)

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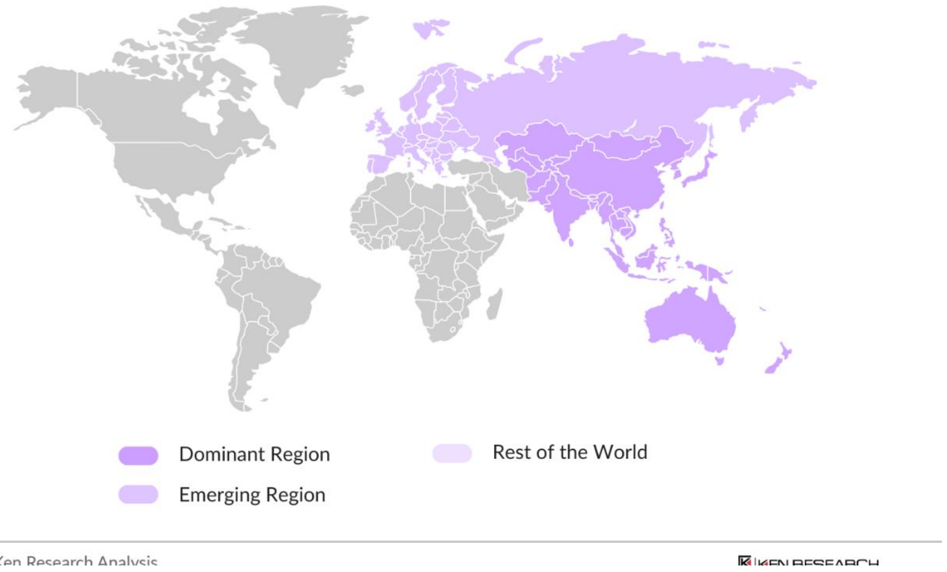

- The global electric arc furnace market size was valued at USD 794.3 million in 2024 and is projected to grow from USD 868.6 million in 2025 to USD 1,891.1 million by 2032, exhibiting a CAGR of 11.8% during the forecast period. Asia Pacific dominated the global market with a share of 52.47% in 2024.

- The global electric arc furnace market is expected to witness substantial growth in the coming years. The increasing demand for green steel, combined with technological advancements and government support for reducing carbon emissions, is driving the market forward. Additionally, rising global infrastructure demand, especially in emerging economies, will further bolster the need for steel, indirectly promoting the growth of electric arc furnace market

Advancements in EAF technology

1. Efficiency and Energy Savings

- Advanced Process Control (APC): Systems that use real-time data to optimize furnace operations, adjust power input, and manage raw material feed rates, significantly reducing energy consumption.
- Waste Heat Recovery: Technologies that capture and reuse waste heat from the furnace, lowering overall energy consumption and costs.
- Improved Electrodes: High-performance electrodes are being developed to extend their lifespan and improve the furnace's energy efficiency.
- Enhanced Magnetic Stirring (EMS): This technology improves heat and mass transfer within the furnace, reducing energy and electrode consumption while increasing productivity

2. Environmental Performance
Advanced Filtration Systems:

- High-efficiency baghouses and electrostatic precipitators are implemented to effectively capture dust and particulate matter emissions.
- Cleaner Scrap Processing: New techniques for sorting and cleaning scrap metal ensure only high-quality scrap enters the furnace, which helps reduce impurities and emissions.
- Renewable Energy: There is a growing trend to power EAFs using electricity from renewable sources like wind and solar power, which drastically reduces the carbon footprint of the steelmaking process.
- Carbon Capture: Technologies for capturing $CO2$ emissions from the EAF process and either storing them or utilizing them in other applications are being developed.

3. Digitalization and Automation

- AI and Machine Learning: These technologies analyze real-time data to optimize process control, predict maintenance needs, and enhance energy efficiency, thereby improving productivity and extending component lifespan.
- Digital Twins: Creating virtual replicas of the furnace allows operators to simulate processes, optimize performance, and predict maintenance, leading to greater efficiency and reduced downtime.
- Automated Monitoring and Control: Advanced sensors and automation systems provide real-time data on internal furnace conditions, allowing for precise adjustments, reduced energy waste, and more consistent product quality.