Japan's Steel Decarbonization Policy: Mass Balance Approaches, Innovative Electric Arc Furnaces, and the Critical DRI Supply Challenge

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Abstract

This paper provides an integrated analysis of Japan's steel decarbonization policy, combining the MIFUS Project's comparative global research with detailed examination of Japan's unique mass balance certification approach. Primary steelmaking through blast furnaces remains the dominant global production method and a major CO_2 emission source, making rapid decarbonization essential. Japan has developed a distinctive strategy centered on the Japan Iron and Steel Federation (JISF) mass balance guidelines, which pool and allocate emission reductions to create transitional "green steel" products while physical infrastructure transformation proceeds.

The paper examines three major categories of reduction projects: expanded scrap use in basic oxygen furnaces, direct reduced iron (DRI) utilization in blast furnaces, and conversion to innovative electric arc furnaces (EAFs). Government support mechanisms include over ¥300 billion in subsidies for innovative EAF projects, Green Purchasing Act revisions, and enhanced vehicle subsidies.

Critical analysis reveals three fundamental concerns: potential impediment to genuine decarbonization, appropriateness of reduction projects, and scheme reliability. The innovative EAF projects by Nippon Steel and JFE Steel represent Japan's first concrete process transformation steps, but success fundamentally depends on securing adequate DRI supplies. While JFE Steel and Kobe Steel have announced overseas natural gas-based DRI production projects targeting 2030, Nippon Steel lacks a concrete DRI sourcing strategy despite being the largest producer.

The paper argues that mass balance approaches must be clearly time-bound (approximately until 2035), require substantially enhanced transparency and traceability, and should not delay the emergence of authentic near-zero emission steel production. Japan's competitive position in global markets increasingly differentiated by carbon footprint will ultimately depend on leadership in genuine low-emission production rather than sophisticated transitional accounting mechanisms.

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1 Introduction: The Global Context and Japan's Challenge

Primary steelmaking, the process of producing steel by reducing iron ore in blast furnaces, remains the dominant method of steel production globally and is a major source of CO_2 emissions [1, 2]. Rapid decarbonization of this process is therefore essential for meeting global climate targets. Expanding recycling-based steelmaking using scrap represents an important strategy, but global scrap supplies are limited. As a result, maintaining and decarbonizing primary steel production, particularly in blast furnaces, is indispensable for the foreseeable future.[1]

Achieving decarbonization requires not only solving technological challenges but also supporting the supply side through investments and initial operations, given the scale of equipment transformation involved. It is equally crucial to ensure that demand for the produced steel steadily grows. Recognizing and supporting "lower-carbon steel" produced during the decarbonization transition, and promoting its demand, is of significant importance.

1.1 The Ultimate Goal: Near-Zero Emission Steel

In a fully decarbonized era, the ultimate form of steel products is expected to be "near-zero emission" steel, where direct emissions are not entirely eliminated but are very low. According to the International Energy Agency, near-zero emission steel is defined as production with an emission intensity of 0.4 tCO_2e per tonne of crude steel for primary steelmaking (0% scrap) and 0.05 tCO_2e per tonne of crude steel for secondary steelmaking (100% scrap) [8].

However, at present, commercially scaled production of steel products at the near-zero emission level does not exist. The world's first commercial-scale near-zero emission primary steelmaking plant is currently under construction in Sweden by Stegra (formerly H2 Green Steel). Production using hydrogen direct reduced iron (H_2-DRI) is expected to begin as early as 2026 [15]. Similarly, Salzgitter AG in Germany is advancing its SALCOS project for hydrogen-based steelmaking [16].

1.2 Japan's Transitional Approach: Mass Balance Products

During this transitional phase, Japan has commercialized steel products whose virtual emissions are reduced through the use of certificates, and the government has begun supporting their production and supply. Discussions on this topic have continued since 2023, and, following revisions to guidelines by the Japan Iron and Steel Federation (JISF), the matter is now being debated internationally within initiatives such as the Industrial Deep Decarbonisation Initiative (IDDI) [17], the GHG Protocol [18], the Science-Based Targets initiative (SBTi) [19], and the World Steel Association [20].

The Renewable Energy Institute has repeatedly outlined the ideal form of steel products in the decarbonization era, as well as challenges and solutions related to mass balance steel and Japan's Green Purchasing Act [1, 21, 22]. This paper integrates those insights with the MIFUS Project's comparative analysis of steel decarbonization policies across

[1] At the same time, further decarbonization of recycled steelmaking using scrap is essential. Efforts must continue to improve the range and quality of such products and decarbonize the electricity used, promoting measures toward near-zero emission production.

major producing nations [2,3], presenting the current status of efforts toward low-carbon steel products in Japan, highlighting what is critical to promoting production that genuinely contributes to decarbonization, expanding its demand, and clarifying remaining and emerging challenges.

1.3 Document Structure and Methodology

This paper is structured as follows:

- **Section 2** examines the deployment of mass balance steel products in Japan, including the JISF framework and government support mechanisms
- **Section 3** provides critical analysis of three major challenges: transitional nature, project appropriateness, and scheme reliability
- **Section 4** details the three categories of reduction projects being implemented
- **Section 5** analyzes the critical role of DRI supply chains and evaluates each major steelmaker's strategy
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The analysis integrates primary sources from the Renewable Energy Institute's October 2025 detailed examination [1] with the MIFUS Project's comparative international research, providing both depth on Japan's specific circumstances and breadth through global contextualization.

2 Deployment of Mass Balance Steel Products in Japan

2.1 The JISF Mass Balance Framework

The Japan Iron and Steel Federation (JISF) has established guidelines for utilizing "green steel produced under the mass balance approach" (hereafter, JISF Mass Balance Steel) as a substitute for steel products of the decarbonization era that are not yet produced at scale [9]. The Green Steel Guidelines define the framework: the CO_2 reduction achieved through a steelmaker's internal measures is pooled, certified, and allocated to selected steel products. This scheme allows for the carbon footprint (CFP) of any product to be arbitrarily reduced, effectively designating it as zero-emission or low-CO_2 steel.

All three major Japanese blast furnace steelmakers sell products under these guidelines. Key features of this approach include:

- **Flexible Product Assignment**: Within the company boundary (where production sites are physically linked through exchange of semi-finished steel such as slabs and billets), products do not need to originate from the same production process as the CO_2 reduction project; in other words, any product can be designated as low-carbon steel.
- **Certificate-Based CFP Adjustment**: By combining the product's calculated CFP with certified reductions verified by a third party, low-carbon steel with arbitrary emission levels can be created.
- **Project Pooling**: Effects from multiple reduction projects can be pooled to maximize utilization.

2.1.1 Branded Mass Balance Products

Each steelmaker has branded their mass balance products accordingly:

- **Nippon Steel**: NS Carbolex®
- **JFE Steel**: JGreeneX®
- **Kobe Steel**: Kobenable®

2.2 Electric Arc Furnace Producers' Direct Approach

Meanwhile, electric arc furnace (EAF) steelmakers, which focus on recycling steel, have also pursued measures to decarbonize their power sources, producing and selling products with even lower emission intensities through direct operational improvements:

- **Tokyo Steel**: Hobo Zero
- **Chubu Steel Plate**: Sumiles
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These EAF producers achieve lower emissions through renewable energy procurement and operational efficiency improvements, representing more direct emissions reductions compared to certificate-based mass balance systems. This distinction is important: EAF producers' products reflect actual physical production characteristics rather than certificate-based virtual reductions.

2.3 Government Support: Green Steel for GX Promotion

The Japanese government, led by the Ministry of Economy, Trade and Industry (METI), has defined "green steel for GX promotion" (GX referring to "Green Transformation") and is implementing both public and private support measures [10]. Green steel is defined as:

> "Steel that, due to additional direct emission reduction actions at the company level, achieves substantial environmental benefits and, when accounting for the associated costs of these actions, commands a higher price than conventional steel."

Support measures aim to both assist production of these steels and stimulate demand.

2.3.1 Policy Development and Ongoing Debates

The METI-led Green Steel for GX Promotion Study Group issued its summary in January 2025, noting that additional examination is needed before JISF Mass Balance Steel can be formally recognized as GX-promoting green steel [10]. Issues include whether certificates issued by companies, which allow arbitrary allocation of CO_2 reductions in line with sales policies, align with the CFP system and operational rules, as well as harmonization with international standards. These topics have since moved into international discussions.

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The government has implemented several demand-side interventions to create markets for lower-carbon steel products:

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These subsidies cover approximately one-third of initial investment costs for qualifying projects. Additionally, the Strategic Field Domestic Production Promotion Tax System provides corporate tax credits for green steel production meeting specified quality criteria.

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5 Critical Analysis: Three Fundamental Concerns

The mass balance approach adopted by Japan's steel industry, while serving as a transitional mechanism, raises three fundamental concerns that require careful examination: whether it might impede genuine decarbonization, whether the underlying reduction projects are appropriate, and whether the scheme itself is sufficiently reliable and transparent.

5.1 First Concern: Potential Impediment to Genuine Decarbonization

5.1.1 The Risk of Prolonged Transitional Mechanisms

The most fundamental concern regarding mass balance approaches is whether they might delay or prevent the emergence of authentic near-zero emission steel production. While these mechanisms can play a role during the transition period when genuine low-emission production technologies are being developed and scaled, there is a significant risk that they become entrenched as permanent fixtures rather than temporary bridges [1].

The European Union's approach to this challenge offers an instructive contrast. The EU Carbon Border Adjustment Mechanism (CBAM) is designed to recognize only actual embedded emissions in steel products, not certificate-based reductions [24]. This creates strong market incentives for genuine emissions reductions rather than accounting mechanisms. Similarly, the EU's Innovation Fund prioritizes support for breakthrough technologies that achieve near-zero emissions rather than incremental improvements to conventional processes [25].

5.1.2 Market Differentiation and Competitive Dynamics

As global steel markets increasingly differentiate products based on carbon footprint, the competitive position of producers will depend fundamentally on their actual emission intensities rather than virtual reductions. Major steel consumers, particularly in the automotive and construction sectors, are establishing procurement policies that favor demonstrably low-emission steel [23].

The risk for Japan is that extended reliance on mass balance approaches could result in:

- **Delayed infrastructure transformation**: If mass balance products satisfy market demand, investment in genuinely low-emission production capacity may be postponed
- **Technology lock-in**: Continued optimization of conventional blast furnace operations rather than transition to breakthrough technologies
- **Loss of competitive position**: As competitors achieve actual low-emission production, mass balance products may face market rejection
- **Stranded assets**: Major investments in conventional infrastructure that becomes economically obsolete as carbon pricing mechanisms intensify

5.1.3 The Need for Clear Time Boundaries

To address these concerns, mass balance approaches must be clearly time-bound. Based on the development timeline of genuine near-zero emission technologies and the expected availability of critical inputs such as hydrogen-based direct reduced iron (H_2-DRI), a reasonable sunset date for mass balance schemes would be approximately 2035 [1, 8].

This timeframe aligns with:

- Expected commercial availability of H_2-DRI at scale (2026-2030)
- Typical steelmaking equipment lifecycle (20-30 years for blast furnaces)

- International climate commitments requiring substantial emissions reductions by 2035-2040
- Development timelines for the innovative EAF projects currently being implemented in Japan

5.2 Second Concern: Appropriateness of Reduction Projects

The second fundamental concern relates to whether the reduction projects generating certificates under mass balance schemes represent appropriate pathways toward genuine decarbonization or whether they primarily serve to extend the operational life of conventional high-emission infrastructure.

5.2.1 Categories of Reduction Projects in Japan

Japanese steelmakers have implemented three main categories of reduction projects that generate mass balance certificates:

1. **Expanded scrap use in basic oxygen furnaces (BOF)**: Increasing the proportion of scrap metal charged to BOFs reduces virgin iron ore requirements and associated emissions
2. **Direct reduced iron (DRI) utilization in blast furnaces**: Partially substituting iron ore with DRI reduces coke consumption and emissions
3. **Conversion to innovative electric arc furnaces (EAF)**: Complete transformation of production process from blast furnace to EAF route

5.2.2 Evaluating Project Categories

These categories represent very different positions on the spectrum from incremental optimization to genuine transformation:

Expanded Scrap Use in BOF This approach involves optimizing existing blast furnace-BOF operations by increasing scrap ratios in the BOF. While this achieves some emission reductions, it:

- Maintains the fundamental blast furnace infrastructure
- Achieves only modest emission reductions (typically 5-15% depending on scrap availability)
- Does not represent a pathway to near-zero emissions
- May compete with scrap demand for EAF operations
- Faces technical limits on scrap ratio due to steel quality requirements

The primary concern is that this category essentially optimizes the existing high-emission production route rather than transforming it. While such optimization has value during the transition period, it should not be considered equivalent to genuine decarbonization investments [1].

DRI Utilization in Blast Furnaces The use of DRI in blast furnaces represents a more significant step, particularly if the DRI is produced using natural gas or, preferably, hydrogen. However, several considerations apply:

- **Natural gas-based DRI**: Achieves emission reductions of approximately 30-40% compared to conventional blast furnace operation, but does not approach near-zero emissions
- **Hydrogen-based DRI**: Can achieve near-zero emissions if produced with renewable electricity, representing genuine breakthrough technology
- **Infrastructure utilization**: Allows continued use of existing blast furnace capacity during transition period
- **Supply chain development**: Creates market demand that supports development of DRI production capacity

The appropriateness of this category depends critically on the source of DRI. Natural gas-based DRI used in blast furnaces represents an intermediate step but not a final solution. Hydrogen-based DRI, conversely, represents genuine breakthrough technology, though its use in blast furnaces rather than EAFs is suboptimal from an efficiency perspective [8, 26].

Conversion to Innovative Electric Arc Furnaces This category represents genuine process transformation and is clearly appropriate as a decarbonization pathway. The innovative EAF projects being implemented by Nippon Steel and JFE Steel involve:

- Complete replacement of blast furnace infrastructure
- Capability to process 100% DRI feedstock (including H_2-DRI)
- Production of high-quality steel products currently made via blast furnace route
- Long-term viability in a decarbonized steel industry
- Alignment with international best practices and emerging technologies

These projects represent Japan's most significant concrete steps toward genuine steel decarbonization and warrant strong support [11–13].

5.2.3 The Challenge of Project Equivalence

A critical issue within the JISF mass balance framework is that emission reductions from these very different project categories are treated as equivalent and pooled together. This raises significant concerns:

- Projects that merely optimize existing high-emission infrastructure generate certificates of equal value to transformational investments
- There is no mechanism to prioritize or differentiate breakthrough technologies from incremental improvements

- The pooling approach obscures which projects are actually generating the reductions attributed to specific steel products
- Steelmakers can strategically allocate certificates to maximize commercial value rather than transparently represent actual production characteristics

5.3 Third Concern: Scheme Reliability and Transparency

The third fundamental concern relates to the reliability, transparency, and verifiability of the mass balance certification system itself.

5.3.1 Verification and Auditing Challenges

The JISF mass balance framework requires third-party verification of reduction projects and certificate issuance. However, several challenges exist:

- **Baseline determination**: Establishing appropriate baselines against which reductions are measured involves subjective judgments
- **Additionality**: Ensuring that certified reductions represent actions beyond business-as-usual requires careful analysis
- **Double counting**: Preventing the same reductions from being claimed under multiple schemes (carbon credits, mass balance certificates, corporate emissions reports) requires coordination
- **Temporal boundaries**: Determining appropriate time periods for certificate validity and preventing banking or borrowing requires clear rules

5.3.2 Transparency and Traceability

A significant limitation of the current JISF framework is limited transparency regarding:

- Which specific reduction projects generated certificates allocated to particular steel products
- The vintage (year of generation) of certificates being used
- The proportion of certificates from different project categories
- Total volumes of certificates issued versus used
- Verification methodologies and audit results

This opacity contrasts sharply with emerging best practices in other certificate schemes, such as renewable energy certificates (RECs), where detailed registry systems track generation, transfer, and retirement of certificates [18, 21].

5.3.3 International Harmonization

The JISF mass balance approach has generated significant international debate, particularly regarding its compatibility with:

- **GHG Protocol**: The Product Standard for calculating and reporting product carbon footprints
- **Science-Based Targets initiative (SBTi)**: Guidance on corporate climate target setting and accounting
- **Industrial Deep Decarbonisation Initiative (IDDI)**: Frameworks for near-zero emission industrial products
- **ISO Standards**: International standards for environmental declarations and carbon footprinting

Without international consensus on the legitimacy and appropriate boundaries of mass balance approaches, Japanese steel products carrying mass balance certificates may face acceptance challenges in global markets [17, 19].

5.3.4 Risk of Greenwashing Perception

Perhaps the most significant reliability concern is the risk that mass balance approaches, particularly when applied to incremental optimization projects, will be perceived as greenwashing rather than genuine decarbonization efforts. This perception risk is heightened when:

- Certificate allocation appears disconnected from physical production characteristics
- Substantial premiums are charged for products whose actual production emissions are unchanged
- Communication emphasizes certificate-based claims rather than actual infrastructure transformation
- Scheme rules and implementation lack transparency

Maintaining credibility requires not only robust technical schemes but also clear communication about what mass balance products represent: transitional mechanisms that facilitate demand for genuinely transformational investments, not permanent solutions to steel sector emissions [1].

5.4 Addressing the Three Concerns: A Pathway Forward

To address these three fundamental concerns while preserving the legitimate transitional role of mass balance approaches, several principles should guide policy development:

1. **Clear sunset provisions**: Mass balance schemes should have explicit end dates (approximately 2035) by which genuine near-zero emission production must predominate

2. **Project differentiation**: Certificate schemes should differentiate between transformational projects (innovative EAFs, H_2-DRI production) and incremental optimization, with preference mechanisms for the former

3. **Enhanced transparency**: Comprehensive registry systems should track certificate generation, allocation, and use, with public reporting on project details

4. **Conservative accounting**: Baseline methodologies should be conservative, additionality requirements strict, and double-counting prevention robust

5. **International alignment**: Schemes should be designed for compatibility with emerging international standards and recognition in global markets

6. **Demand stimulus for breakthrough technologies**: Government procurement and subsidy programs should strongly favor genuine near-zero emission steel over certificate-based products

7. **Investment tracking**: Clear metrics should monitor whether mass balance revenues are actually financing transformational infrastructure investments

6 Reduction Project Implementation: Current Status and Analysis

This section examines the three categories of reduction projects being implemented by Japanese steelmakers, providing detailed analysis of their technical characteristics, emission reduction potential, implementation status, and role in the transition to decarbonized steel production.

6.1 Category 1: Expanded Scrap Use in Basic Oxygen Furnaces

6.1.1 Technical Characteristics

The basic oxygen furnace (BOF) process, also known as the Linz-Donawitz (LD) process, is the dominant secondary steelmaking method used in conjunction with blast furnaces. Conventionally, BOFs are charged with approximately 70-85% hot metal (molten iron from blast furnaces) and 15-30% scrap metal, with the exact ratio depending on steel grade requirements and scrap availability [20].

Expanding scrap use in BOFs involves:

- Increasing the scrap ratio beyond conventional levels, potentially to 35-40%
- Careful scrap quality control to maintain steel product specifications
- Process adjustments to manage thermal balance and chemistry control
- Potential investment in enhanced scrap preparation facilities

6.1.2 Emission Reduction Potential

The emission reduction achieved through expanded scrap use derives from reduced hot metal requirements, which in turn reduces blast furnace operation intensity. Each tonne of scrap substituted for hot metal avoids approximately:

- 1.4-1.6 tonnes of iron ore mining and processing
- 0.6-0.7 tonnes of metallurgical coal consumption
- 1.8-2.2 tonnes of CO_2 emissions from blast furnace operations

However, the overall emission reduction at the integrated steel mill level is more modest, typically 5-15% depending on the extent of scrap ratio increase, because:

- Scrap preparation and handling involves some energy consumption
- BOF process modifications may require additional energy inputs
- Steel quality requirements limit maximum achievable scrap ratios
- Scrap availability constrains implementation scale

6.1.3 Implementation in Japan

All three major Japanese blast furnace steelmakers have implemented expanded scrap use programs:

Nippon Steel Nippon Steel has announced initiatives to increase scrap utilization across its integrated steel mills, with specific focus on:

- Development of advanced scrap sorting and preparation technologies
- Optimization of BOF charging practices to maximize scrap ratios while maintaining product quality
- Collaboration with scrap suppliers to ensure adequate quality material availability

The company has not publicly disclosed specific scrap ratio targets or timelines, but emission reduction certificates generated through these initiatives contribute to the NS Carbolex® mass balance product portfolio [12].

JFE Steel JFE Steel has similarly pursued expanded scrap utilization, particularly at:

- Kurashiki Works (West Japan)
- Keihin Works (East Japan)

The company emphasizes that scrap utilization improvements form part of a broader portfolio of reduction measures, with certificates pooled into the JGreeneX® product system [13].

Kobe Steel Kobe Steel, operating smaller integrated facilities, has implemented scrap expansion programs at:

- Kakogawa Works
- Kobe Works

These initiatives contribute to the Kobenable® mass balance product offerings [14].

6.1.4 Critical Assessment

While expanded scrap use represents rational optimization of existing infrastructure, several critical considerations apply:

1. **Not a pathway to near-zero emissions**: Even maximum feasible scrap ratios in BOFs cannot approach the emission intensity levels required for genuinely decarbonized steel production
2. **Scrap competition**: Increased scrap demand from integrated mills competes with EAF producers, potentially constraining expansion of the more efficient EAF route
3. **Quality constraints**: High-grade steel products, particularly those required for automotive and advanced manufacturing applications, face strict chemistry control requirements that limit scrap utilization
4. **Infrastructure lock-in risk**: Optimizing blast furnace-BOF operations may delay investment in genuinely transformational technologies
5. **Transitional value only**: This category should be recognized as providing modest emission reductions during the transition period but not as a long-term decarbonization strategy

The MIFUS Project's comparative analysis shows that other major steel-producing nations increasingly view scrap-based production through EAF routes, rather than incremental BOF optimization, as the primary pathway for utilizing available scrap resources [2].

6.2 Category 2: Direct Reduced Iron Utilization in Blast Furnaces

6.2.1 Technical Characteristics

Direct reduced iron (DRI), also known as sponge iron, is produced by reducing iron ore using reducing gases (typically a mixture of hydrogen and carbon monoxide) at temperatures below the melting point of iron. The product is solid metallic iron with typical metallization rates of 90-95% [27].

Using DRI in blast furnaces involves:

- Charging DRI along with iron ore and coke
- Reduced coke consumption due to DRI's higher metallization
- Modified furnace operation to accommodate different burden characteristics
- Potential improvements in furnace productivity and hot metal quality

6.2.2 DRI Production Methods and Associated Emissions

The emission intensity of DRI production varies dramatically depending on the reduction method:

Natural Gas-Based DRI The dominant commercial DRI production technology uses natural gas as the reducing agent, primarily through:

- **MIDREX process**: Direct reduction using natural gas-reformed synthesis gas
- **HYL/Energiron process**: Direct reduction with similar technology

Natural gas-based DRI production results in CO_2 emissions of approximately 0.6-0.8 tonnes CO_2 per tonne of DRI, significantly lower than the 1.8-2.2 tonnes CO_2 per tonne of hot metal from conventional blast furnaces [8, 27].

Coal-Based DRI Coal-based DRI production, primarily using rotary kiln or rotary hearth furnace technologies, results in higher emissions of approximately 1.2-1.5 tonnes CO_2 per tonne of DRI, offering limited advantage over blast furnace hot metal [20].

Hydrogen-Based DRI Hydrogen direct reduced iron (H_2-DRI) produced using renewable electricity-generated hydrogen represents breakthrough low-emission technology, with emission intensity potentially below 0.1 tonnes CO_2 per tonne of DRI when renewable electricity is used [8, 15].

6.2.3 Emission Reduction Potential

When natural gas-based DRI substitutes for a portion of the iron ore and coke in blast furnaces, the emission reduction depends on:

- DRI substitution rate (typically 5-20% of total metallic charge)
- Specific emission intensity of the DRI source
- Operational adjustments required in the blast furnace

At realistic substitution rates using natural gas-based DRI, integrated steel mill emission reductions of 10-25% can be achieved [26]. Higher substitution rates face technical limitations related to furnace operation and burden distribution.

Use of H_2-DRI could theoretically achieve greater reductions, but optimal utilization of H_2-DRI is in electric arc furnaces rather than blast furnaces, due to:

- Elimination of fossil carbon introduction from coke
- More complete utilization of DRI's metallic iron content
- Simpler process control and operation
- Better economics when renewable electricity is available

6.2.4 Implementation Status in Japan

JFE Steel's DRI Strategy JFE Steel has announced the most concrete DRI utilization plans among Japanese steelmakers:

- **DRI Production Project**: Joint venture in Malaysia to produce natural gas-based DRI, targeting 2030 commencement
- **Production Capacity**: Approximately 2 million tonnes per year
- **Utilization Plan**: Initially for use in blast furnaces at Japanese works, potentially transitioning to EAF feedstock as innovative EAF capacity comes online
- **Supply Chain Integration**: DRI to be shipped to Japan for processing

Kobe Steel's DRI Initiatives Kobe Steel has announced participation in overseas DRI production projects:

- Focus on natural gas-based DRI production in regions with favorable gas availability
- Target timeline similar to JFE Steel (approximately 2030)
- Integration with domestic steel production operations

Nippon Steel's Position Notably, Nippon Steel, Japan's largest steel producer, has not announced concrete DRI sourcing strategies despite planning major innovative EAF installations that will require substantial DRI feedstock. This represents a critical gap in Japan's steel decarbonization strategy, examined in detail in Section 5.

6.2.5 Critical Assessment

DRI utilization in blast furnaces occupies an intermediate position in the decarbonization pathway:

1. **Genuine emission reductions**: Unlike mere scrap expansion, DRI use (particularly with natural gas or hydrogen-based DRI) represents more substantial emission reductions
2. **Supply chain development**: Creating demand for DRI supports development of production capacity and supply chains that will be essential for EAF-based production
3. **Transitional infrastructure use**: Allows continued operation of existing blast furnace capacity while transformational investments mature
4. **Not a final solution**: Even with maximum feasible DRI substitution using natural gas-based material, blast furnace operations cannot approach near-zero emission levels
5. **Suboptimal H_2-DRI utilization**: Using precious H_2-DRI in blast furnaces rather than EAFs represents inefficient use of breakthrough low-emission material

6. **Investment prioritization questions**: Whether investments in blast furnace DRI utilization might delay more fundamental EAF conversion

The appropriateness of this project category depends critically on whether it genuinely represents a transitional step toward EAF-based production or serves primarily to extend blast furnace operational life [1].

6.3 Category 3: Conversion to Innovative Electric Arc Furnaces

6.3.1 Technical Characteristics of Innovative EAFs

The innovative EAF projects being implemented in Japan differ substantially from conventional scrap-based EAFs in several critical aspects:

Feedstock Flexibility Innovative EAFs are designed to process:

- 100% direct reduced iron (DRI) when available
- Variable mixtures of DRI and scrap steel
- 100% scrap when necessary

This flexibility contrasts with conventional EAFs optimized primarily for scrap processing and blast furnace-based facilities designed exclusively for iron ore reduction [12,13].

Product Quality Capability Critical to the Japanese steel industry, innovative EAFs are designed to produce:

- High-strength steel sheets for automotive applications
- Electrical steel for motors and transformers
- High-grade steel products currently produced via blast furnace-BOF route
- Products meeting strict chemistry and property specifications

Achieving this capability requires:

- Advanced process control systems
- Enhanced refining capabilities
- Careful chemistry management
- Integration with sophisticated secondary metallurgy and casting operations

Energy Requirements and Decarbonization Potential Innovative EAFs powered by renewable electricity and processing H_2-DRI can achieve emission intensities approaching the IEA's near-zero threshold of 0.4 tonnes CO_2e per tonne of crude steel [8]. Key considerations include:

- Electricity consumption: 400-500 kWh per tonne of steel when processing 100% DRI
- Electricity emission intensity: Critical determinant of overall carbon footprint
- Electrode consumption and associated emissions
- Process gases and auxiliary energy requirements

When renewable electricity is available and H_2-DRI is used as primary feedstock, emission intensities below 0.2 tonnes CO_2e per tonne of steel are achievable, representing genuine near-zero emission steel production [15, 26].

6.3.2 Major Innovative EAF Projects in Japan

Nippon Steel's Projects Nippon Steel has announced two major innovative EAF projects representing Japan's largest steel decarbonization investments:

Hirohata Area Project (Hyogo Prefecture)

- **Capacity**: Approximately 2 million tonnes per year
- **Timeline**: Construction commencing 2024, operation targeted 2027-2028
- **Government Support**: ¥42.8 billion subsidy approved
- **Replacing**: Aging blast furnace infrastructure at Hirohata Works
- **Products**: High-grade steel sheet products

Yawata/Shunan Project (Kyushu Region)

- **Capacity**: Approximately 5 million tonnes per year combined
- **Timeline**: Phased implementation 2025-2030
- **Government Support**: ¥208.7 billion subsidy approved (largest single industrial decarbonization subsidy in Japanese history)
- **Significance**: Represents complete transformation of major integrated steel production complex
- **Integration**: Coordinated development of both Yawata Works (Fukuoka) and Shunan Works (Yamaguchi)

Combined, these projects represent approximately 7 million tonnes of annual steel production capacity transitioning from blast furnace to innovative EAF operation, equivalent to approximately 15% of Japan's total crude steel production [11, 12].

JFE Steel's Kurashiki Project JFE Steel's innovative EAF project at Kurashiki Works represents the second major transformation initiative:

- **Capacity**: Approximately 2-2.5 million tonnes per year
- **Timeline**: Construction phasing 2024-2029
- **Government Support**: ¥104.5 billion subsidy approved
- **Replacing**: Existing blast furnace capacity at Kurashiki Works
- **Products**: High-grade steel products for automotive and industrial applications
- **Integration**: Coordinated with company's DRI supply chain development

Kobe Steel's Position Kobe Steel, operating at smaller scale, has not announced innovative EAF projects comparable to Nippon Steel and JFE Steel, instead focusing on:

- Incremental improvements to existing EAF operations
- DRI supply chain participation
- Optimization of existing integrated facilities

6.3.3 Economic and Policy Support Framework

The innovative EAF projects benefit from comprehensive government support:

Capital Investment Support Through the "Support Project for Energy and Process Conversion in Hard-to-Abate Industries" (Green Innovation Fund):

- Subsidies covering approximately 30-35% of initial investment costs
- Total commitment exceeding ¥300 billion for innovative EAF projects
- Focus on projects demonstrating genuine technological breakthrough
- Requirements for detailed emission reduction verification

Operational Support Additional support mechanisms include:

- **Strategic Field Domestic Production Promotion Tax System**: Corporate tax credits for qualifying green steel production
- **Enhanced vehicle subsidies**: Additional ¥50,000 subsidy for vehicles using innovative EAF steel
- **Green Purchasing Act**: Priority procurement of lower-carbon steel in government projects

Electricity Supply Considerations Critical to innovative EAF success is renewable electricity availability:

- Japan's renewable electricity share remains relatively low (approximately 22% in 2024)
- Renewable energy procurement mechanisms under development
- Regional electricity grid capacity constraints in some areas
- Need for coordinated renewable energy expansion and steel sector decarbonization

6.3.4 Critical Assessment and Success Factors

Genuine Transformation Innovative EAF projects represent authentic process transformation rather than incremental optimization:

1. **Infrastructure replacement**: Complete replacement of blast furnace infrastructure with fundamentally different technology
2. **Long-term viability**: EAF-based production remains competitive and appropriate in fully decarbonized economy
3. **Technology alignment**: Consistent with international best practices and breakthrough technologies (Stegra, SALCOS, etc.)
4. **Product capability**: Designed to maintain Japan's competitive position in high-value steel markets
5. **Scale significance**: Projects collectively represent approximately 9-9.5 million tonnes capacity, roughly 20% of Japan's crude steel production

Critical Success Factor: DRI Supply The fundamental challenge for innovative EAF success is securing adequate DRI feedstock. Section 5 examines this critical dependency in detail, but key considerations include:

- **Volume requirements**: 9-9.5 million tonnes of innovative EAF capacity requires comparable DRI volumes when operating at 100% DRI charge
- **Quality specifications**: High-grade steel production requires high-quality DRI with strict chemistry control
- **Supply reliability**: Long-term supply contracts and infrastructure essential
- **Transition path**: How DRI availability scales to match EAF capacity commissioning
- **Cost competitiveness**: DRI pricing relative to scrap and blast furnace hot metal

Renewable Electricity Requirement The decarbonization benefit of innovative EAFs depends fundamentally on electricity source:

- With Japan's current electricity mix (approximately 75% fossil fuels), EAF emission intensity remains 0.6-0.8 tonnes CO_2 per tonne steel
- Achieving near-zero emissions requires renewable electricity at approximately 0.02-0.05 tonnes CO_2 per MWh
- Requires coordinated development of renewable electricity generation capacity and steel sector transformation

Timeline and Transition Management Successfully implementing innovative EAF projects while maintaining production continuity requires:

- Phased blast furnace decommissioning coordinated with EAF commissioning
- Interim production arrangements using remaining blast furnace capacity and external sourcing
- Workforce transition and retraining programs
- Customer communication and product transition management
- Supply chain adjustments for both inputs (DRI, electricity, electrodes) and outputs

7 The Critical DRI Supply Challenge

7.1 DRI's Central Role in Steel Decarbonization

Direct reduced iron has emerged as the critical enabler of steel sector decarbonization globally. The innovative EAF pathway, recognized internationally as the most technically and economically viable route to near-zero emission steel production

8 Critical Analysis: Three Fundamental Concerns

The mass balance approach adopted by Japan's steel industry, while serving as a transitional mechanism, raises three fundamental concerns that require careful examination: whether it might impede genuine decarbonization, whether the underlying reduction projects are appropriate, and whether the scheme itself is sufficiently reliable and transparent.

8.1 First Concern: Potential Impediment to Genuine Decarbonization

8.1.1 The Risk of Prolonged Transitional Mechanisms

The most fundamental concern regarding mass balance approaches is whether they might delay or prevent the emergence of authentic near-zero emission steel production. While these mechanisms can play a role during the transition period when genuine low-emission production technologies are being developed and scaled, there is a significant risk that they become entrenched as permanent fixtures rather than temporary bridges [1].

The European Union's approach to this challenge offers an instructive contrast. The EU Carbon Border Adjustment Mechanism (CBAM) is designed to recognize only actual embedded emissions in steel products, not certificate-based reductions [24]. This creates strong market incentives for genuine emissions reductions rather than accounting mechanisms. Similarly, the EU's Innovation Fund prioritizes support for breakthrough technologies that achieve near-zero emissions rather than incremental improvements to conventional processes [25].

8.1.2 Market Differentiation and Competitive Dynamics

As global steel markets increasingly differentiate products based on carbon footprint, the competitive position of producers will depend fundamentally on their actual emission intensities rather than virtual reductions. Major steel consumers, particularly in the automotive and construction sectors, are establishing procurement policies that favor demonstrably low-emission steel [23].

The risk for Japan is that extended reliance on mass balance approaches could result in:

- **Delayed infrastructure transformation**: If mass balance products satisfy market demand, investment in genuinely low-emission production capacity may be postponed
- **Technology lock-in**: Continued optimization of conventional blast furnace operations rather than transition to breakthrough technologies
- **Loss of competitive position**: As competitors achieve actual low-emission production, mass balance products may face market rejection
- **Stranded assets**: Major investments in conventional infrastructure that becomes economically obsolete as carbon pricing mechanisms intensify

8.1.3 The Need for Clear Time Boundaries

To address these concerns, mass balance approaches must be clearly time-bound. Based on the development timeline of genuine near-zero emission technologies and the expected availability of critical inputs such as hydrogen-based direct reduced iron (H_2-DRI), a reasonable sunset date for mass balance schemes would be approximately 2035 [1, 8].

This timeframe aligns with:

- Expected commercial availability of H_2-DRI at scale (2026-2030)
- Typical steelmaking equipment lifecycle (20-30 years for blast furnaces)
- International climate commitments requiring substantial emissions reductions by 2035-2040
- Development timelines for the innovative EAF projects currently being implemented in Japan

8.2 Second Concern: Appropriateness of Reduction Projects

The second fundamental concern relates to whether the reduction projects generating certificates under mass balance schemes represent appropriate pathways toward genuine decarbonization or whether they primarily serve to extend the operational life of conventional high-emission infrastructure.

8.2.1 Categories of Reduction Projects in Japan

Japanese steelmakers have implemented three main categories of reduction projects that generate mass balance certificates:

1. **Expanded scrap use in basic oxygen furnaces (BOF)**: Increasing the proportion of scrap metal charged to BOFs reduces virgin iron ore requirements and associated emissions

2. **Direct reduced iron (DRI) utilization in blast furnaces**: Partially substituting iron ore with DRI reduces coke consumption and emissions

3. **Conversion to innovative electric arc furnaces (EAF)**: Complete transformation of production process from blast furnace to EAF route

8.2.2 Evaluating Project Categories

These categories represent very different positions on the spectrum from incremental optimization to genuine transformation:

Expanded Scrap Use in BOF This approach involves optimizing existing blast furnace-BOF operations by increasing scrap ratios in the BOF. While this achieves some emission reductions, it:

- Maintains the fundamental blast furnace infrastructure
- Achieves only modest emission reductions (typically 5-15% depending on scrap availability)
- Does not represent a pathway to near-zero emissions
- May compete with scrap demand for EAF operations
- Faces technical limits on scrap ratio due to steel quality requirements

The primary concern is that this category essentially optimizes the existing high-emission production route rather than transforming it. While such optimization has value during the transition period, it should not be considered equivalent to genuine decarbonization investments [1].

DRI Utilization in Blast Furnaces The use of DRI in blast furnaces represents a more significant step, particularly if the DRI is produced using natural gas or, preferably, hydrogen. However, several considerations apply:

- **Natural gas-based DRI**: Achieves emission reductions of approximately 30-40% compared to conventional blast furnace operation, but does not approach near-zero emissions
- **Hydrogen-based DRI**: Can achieve near-zero emissions if produced with renewable electricity, representing genuine breakthrough technology
- **Infrastructure utilization**: Allows continued use of existing blast furnace capacity during transition period
- **Supply chain development**: Creates market demand that supports development of DRI production capacity

The appropriateness of this category depends critically on the source of DRI. Natural gas-based DRI used in blast furnaces represents an intermediate step but not a final solution. Hydrogen-based DRI, conversely, represents genuine breakthrough technology, though its use in blast furnaces rather than EAFs is suboptimal from an efficiency perspective [8, 26].

Conversion to Innovative Electric Arc Furnaces This category represents genuine process transformation and is clearly appropriate as a decarbonization pathway. The innovative EAF projects being implemented by Nippon Steel and JFE Steel involve:

- Complete replacement of blast furnace infrastructure
- Capability to process 100% DRI feedstock (including H_2-DRI)
- Production of high-quality steel products currently made via blast furnace route
- Long-term viability in a decarbonized steel industry
- Alignment with international best practices and emerging technologies

These projects represent Japan's most significant concrete steps toward genuine steel decarbonization and warrant strong support [11–13].

8.2.3 The Challenge of Project Equivalence

A critical issue within the JISF mass balance framework is that emission reductions from these very different project categories are treated as equivalent and pooled together. This raises significant concerns:

- Projects that merely optimize existing high-emission infrastructure generate certificates of equal value to transformational investments
- There is no mechanism to prioritize or differentiate breakthrough technologies from incremental improvements

- The pooling approach obscures which projects are actually generating the reductions attributed to specific steel products
- Steelmakers can strategically allocate certificates to maximize commercial value rather than transparently represent actual production characteristics

8.3 Third Concern: Scheme Reliability and Transparency

The third fundamental concern relates to the reliability, transparency, and verifiability of the mass balance certification system itself.

8.3.1 Verification and Auditing Challenges

The JISF mass balance framework requires third-party verification of reduction projects and certificate issuance. However, several challenges exist:

- **Baseline determination**: Establishing appropriate baselines against which reductions are measured involves subjective judgments
- **Additionality**: Ensuring that certified reductions represent actions beyond business-as-usual requires careful analysis
- **Double counting**: Preventing the same reductions from being claimed under multiple schemes (carbon credits, mass balance certificates, corporate emissions reports) requires coordination
- **Temporal boundaries**: Determining appropriate time periods for certificate validity and preventing banking or borrowing requires clear rules

8.3.2 Transparency and Traceability

A significant limitation of the current JISF framework is limited transparency regarding:

- Which specific reduction projects generated certificates allocated to particular steel products
- The vintage (year of generation) of certificates being used
- The proportion of certificates from different project categories
- Total volumes of certificates issued versus used
- Verification methodologies and audit results

This opacity contrasts sharply with emerging best practices in other certificate schemes, such as renewable energy certificates (RECs), where detailed registry systems track generation, transfer, and retirement of certificates [18, 21].

8.3.3 International Harmonization

The JISF mass balance approach has generated significant international debate, particularly regarding its compatibility with:

- **GHG Protocol**: The Product Standard for calculating and reporting product carbon footprints
- **Science-Based Targets initiative (SBTi)**: Guidance on corporate climate target setting and accounting
- **Industrial Deep Decarbonisation Initiative (IDDI)**: Frameworks for near-zero emission industrial products
- **ISO Standards**: International standards for environmental declarations and carbon footprinting

Without international consensus on the legitimacy and appropriate boundaries of mass balance approaches, Japanese steel products carrying mass balance certificates may face acceptance challenges in global markets [17, 19].

8.3.4 Risk of Greenwashing Perception

Perhaps the most significant reliability concern is the risk that mass balance approaches, particularly when applied to incremental optimization projects, will be perceived as greenwashing rather than genuine decarbonization efforts. This perception risk is heightened when:

- Certificate allocation appears disconnected from physical production characteristics
- Substantial premiums are charged for products whose actual production emissions are unchanged
- Communication emphasizes certificate-based claims rather than actual infrastructure transformation
- Scheme rules and implementation lack transparency

Maintaining credibility requires not only robust technical schemes but also clear communication about what mass balance products represent: transitional mechanisms that facilitate demand for genuinely transformational investments, not permanent solutions to steel sector emissions [1].

8.4 Addressing the Three Concerns: A Pathway Forward

To address these three fundamental concerns while preserving the legitimate transitional role of mass balance approaches, several principles should guide policy development:

1. **Clear sunset provisions**: Mass balance schemes should have explicit end dates (approximately 2035) by which genuine near-zero emission production must predominate

2. **Project differentiation**: Certificate schemes should differentiate between transformational projects (innovative EAFs, H_2-DRI production) and incremental optimization, with preference mechanisms for the former
3. **Enhanced transparency**: Comprehensive registry systems should track certificate generation, allocation, and use, with public reporting on project details
4. **Conservative accounting**: Baseline methodologies should be conservative, additionality requirements strict, and double-counting prevention robust
5. **International alignment**: Schemes should be designed for compatibility with emerging international standards and recognition in global markets
6. **Demand stimulus for breakthrough technologies**: Government procurement and subsidy programs should strongly favor genuine near-zero emission steel over certificate-based products
7. **Investment tracking**: Clear metrics should monitor whether mass balance revenues are actually financing transformational infrastructure investments

9 Reduction Project Implementation: Current Status and Analysis

This section examines the three categories of reduction projects being implemented by Japanese steelmakers, providing detailed analysis of their technical characteristics, emission reduction potential, implementation status, and role in the transition to decarbonized steel production.

9.1 Category 1: Expanded Scrap Use in Basic Oxygen Furnaces

9.1.1 Technical Characteristics

The basic oxygen furnace (BOF) process, also known as the Linz-Donawitz (LD) process, is the dominant secondary steelmaking method used in conjunction with blast furnaces. Conventionally, BOFs are charged with approximately 70-85% hot metal (molten iron from blast furnaces) and 15-30% scrap metal, with the exact ratio depending on steel grade requirements and scrap availability [20].

Expanding scrap use in BOFs involves:

- Increasing the scrap ratio beyond conventional levels, potentially to 35-40%
- Careful scrap quality control to maintain steel product specifications
- Process adjustments to manage thermal balance and chemistry control
- Potential investment in enhanced scrap preparation facilities

9.1.2 Emission Reduction Potential

The emission reduction achieved through expanded scrap use derives from reduced hot metal requirements, which in turn reduces blast furnace operation intensity. Each tonne of scrap substituted for hot metal avoids approximately:

- 1.4-1.6 tonnes of iron ore mining and processing
- 0.6-0.7 tonnes of metallurgical coal consumption
- 1.8-2.2 tonnes of CO_2 emissions from blast furnace operations

However, the overall emission reduction at the integrated steel mill level is more modest, typically 5-15% depending on the extent of scrap ratio increase, because:

- Scrap preparation and handling involves some energy consumption
- BOF process modifications may require additional energy inputs
- Steel quality requirements limit maximum achievable scrap ratios
- Scrap availability constrains implementation scale

9.1.3 Implementation in Japan

All three major Japanese blast furnace steelmakers have implemented expanded scrap use programs:

Nippon Steel Nippon Steel has announced initiatives to increase scrap utilization across its integrated steel mills, with specific focus on:

- Development of advanced scrap sorting and preparation technologies
- Optimization of BOF charging practices to maximize scrap ratios while maintaining product quality
- Collaboration with scrap suppliers to ensure adequate quality material availability

The company has not publicly disclosed specific scrap ratio targets or timelines, but emission reduction certificates generated through these initiatives contribute to the NS Carbolex® mass balance product portfolio [12].

JFE Steel JFE Steel has similarly pursued expanded scrap utilization, particularly at:

- Kurashiki Works (West Japan)
- Keihin Works (East Japan)

The company emphasizes that scrap utilization improvements form part of a broader portfolio of reduction measures, with certificates pooled into the JGreeneX® product system [13].

Kobe Steel Kobe Steel, operating smaller integrated facilities, has implemented scrap expansion programs at:

- Kakogawa Works
- Kobe Works

These initiatives contribute to the Kobenable® mass balance product offerings [14].

9.1.4 Critical Assessment

While expanded scrap use represents rational optimization of existing infrastructure, several critical considerations apply:

1. **Not a pathway to near-zero emissions**: Even maximum feasible scrap ratios in BOFs cannot approach the emission intensity levels required for genuinely decarbonized steel production
2. **Scrap competition**: Increased scrap demand from integrated mills competes with EAF producers, potentially constraining expansion of the more efficient EAF route
3. **Quality constraints**: High-grade steel products, particularly those required for automotive and advanced manufacturing applications, face strict chemistry control requirements that limit scrap utilization
4. **Infrastructure lock-in risk**: Optimizing blast furnace-BOF operations may delay investment in genuinely transformational technologies
5. **Transitional value only**: This category should be recognized as providing modest emission reductions during the transition period but not as a long-term decarbonization strategy

The MIFUS Project's comparative analysis shows that other major steel-producing nations increasingly view scrap-based production through EAF routes, rather than incremental BOF optimization, as the primary pathway for utilizing available scrap resources [2].

9.2 Category 2: Direct Reduced Iron Utilization in Blast Furnaces

9.2.1 Technical Characteristics

Direct reduced iron (DRI), also known as sponge iron, is produced by reducing iron ore using reducing gases (typically a mixture of hydrogen and carbon monoxide) at temperatures below the melting point of iron. The product is solid metallic iron with typical metallization rates of 90-95% [27].

Using DRI in blast furnaces involves:

- Charging DRI along with iron ore and coke
- Reduced coke consumption due to DRI's higher metallization
- Modified furnace operation to accommodate different burden characteristics
- Potential improvements in furnace productivity and hot metal quality

9.2.2 DRI Production Methods and Associated Emissions

The emission intensity of DRI production varies dramatically depending on the reduction method:

Natural Gas-Based DRI The dominant commercial DRI production technology uses natural gas as the reducing agent, primarily through:

- **MIDREX process**: Direct reduction using natural gas-reformed synthesis gas
- **HYL/Energiron process**: Direct reduction with similar technology

Natural gas-based DRI production results in CO_2 emissions of approximately 0.6-0.8 tonnes CO_2 per tonne of DRI, significantly lower than the 1.8-2.2 tonnes CO_2 per tonne of hot metal from conventional blast furnaces [8, 27].

Coal-Based DRI Coal-based DRI production, primarily using rotary kiln or rotary hearth furnace technologies, results in higher emissions of approximately 1.2-1.5 tonnes CO_2 per tonne of DRI, offering limited advantage over blast furnace hot metal [20].

Hydrogen-Based DRI Hydrogen direct reduced iron (H_2-DRI) produced using renewable electricity-generated hydrogen represents breakthrough low-emission technology, with emission intensity potentially below 0.1 tonnes CO_2 per tonne of DRI when renewable electricity is used [8, 15].

9.2.3 Emission Reduction Potential

When natural gas-based DRI substitutes for a portion of the iron ore and coke in blast furnaces, the emission reduction depends on:

- DRI substitution rate (typically 5-20% of total metallic charge)
- Specific emission intensity of the DRI source
- Operational adjustments required in the blast furnace

At realistic substitution rates using natural gas-based DRI, integrated steel mill emission reductions of 10-25% can be achieved [26]. Higher substitution rates face technical limitations related to furnace operation and burden distribution.

Use of H_2-DRI could theoretically achieve greater reductions, but optimal utilization of H_2-DRI is in electric arc furnaces rather than blast furnaces, due to:

- Elimination of fossil carbon introduction from coke
- More complete utilization of DRI's metallic iron content
- Simpler process control and operation
- Better economics when renewable electricity is available

9.2.4 Implementation Status in Japan

JFE Steel's DRI Strategy JFE Steel has announced the most concrete DRI utilization plans among Japanese steelmakers:

- **DRI Production Project**: Joint venture in Malaysia to produce natural gas-based DRI, targeting 2030 commencement
- **Production Capacity**: Approximately 2 million tonnes per year
- **Utilization Plan**: Initially for use in blast furnaces at Japanese works, potentially transitioning to EAF feedstock as innovative EAF capacity comes online
- **Supply Chain Integration**: DRI to be shipped to Japan for processing

Kobe Steel's DRI Initiatives Kobe Steel has announced participation in overseas DRI production projects:

- Focus on natural gas-based DRI production in regions with favorable gas availability
- Target timeline similar to JFE Steel (approximately 2030)
- Integration with domestic steel production operations

Nippon Steel's Position Notably, Nippon Steel, Japan's largest steel producer, has not announced concrete DRI sourcing strategies despite planning major innovative EAF installations that will require substantial DRI feedstock. This represents a critical gap in Japan's steel decarbonization strategy, examined in detail in Section 5.

9.2.5 Critical Assessment

DRI utilization in blast furnaces occupies an intermediate position in the decarbonization pathway:

1. **Genuine emission reductions**: Unlike mere scrap expansion, DRI use (particularly with natural gas or hydrogen-based DRI) represents more substantial emission reductions
2. **Supply chain development**: Creating demand for DRI supports development of production capacity and supply chains that will be essential for EAF-based production
3. **Transitional infrastructure use**: Allows continued operation of existing blast furnace capacity while transformational investments mature
4. **Not a final solution**: Even with maximum feasible DRI substitution using natural gas-based material, blast furnace operations cannot approach near-zero emission levels
5. **Suboptimal H_2-DRI utilization**: Using precious H_2-DRI in blast furnaces rather than EAFs represents inefficient use of breakthrough low-emission material

6. **Investment prioritization questions**: Whether investments in blast furnace DRI utilization might delay more fundamental EAF conversion

The appropriateness of this project category depends critically on whether it genuinely represents a transitional step toward EAF-based production or serves primarily to extend blast furnace operational life [1].

9.3 Category 3: Conversion to Innovative Electric Arc Furnaces

9.3.1 Technical Characteristics of Innovative EAFs

The innovative EAF projects being implemented in Japan differ substantially from conventional scrap-based EAFs in several critical aspects:

Feedstock Flexibility Innovative EAFs are designed to process:

- 100% direct reduced iron (DRI) when available
- Variable mixtures of DRI and scrap steel
- 100% scrap when necessary

This flexibility contrasts with conventional EAFs optimized primarily for scrap processing and blast furnace-based facilities designed exclusively for iron ore reduction [12,13].

Product Quality Capability Critical to the Japanese steel industry, innovative EAFs are designed to produce:

- High-strength steel sheets for automotive applications
- Electrical steel for motors and transformers
- High-grade steel products currently produced via blast furnace-BOF route
- Products meeting strict chemistry and property specifications

Achieving this capability requires:

- Advanced process control systems
- Enhanced refining capabilities
- Careful chemistry management
- Integration with sophisticated secondary metallurgy and casting operations

Energy Requirements and Decarbonization Potential Innovative EAFs powered by renewable electricity and processing H_2-DRI can achieve emission intensities approaching the IEA's near-zero threshold of 0.4 tonnes CO_2e per tonne of crude steel [8]. Key considerations include:

- Electricity consumption: 400-500 kWh per tonne of steel when processing 100% DRI
- Electricity emission intensity: Critical determinant of overall carbon footprint
- Electrode consumption and associated emissions
- Process gases and auxiliary energy requirements

When renewable electricity is available and H_2-DRI is used as primary feedstock, emission intensities below 0.2 tonnes CO_2e per tonne of steel are achievable, representing genuine near-zero emission steel production [15, 26].

9.3.2 Major Innovative EAF Projects in Japan

Nippon Steel's Projects Nippon Steel has announced two major innovative EAF projects representing Japan's largest steel decarbonization investments:

Hirohata Area Project (Hyogo Prefecture)

- **Capacity**: Approximately 2 million tonnes per year
- **Timeline**: Construction commencing 2024, operation targeted 2027-2028
- **Government Support**: ¥42.8 billion subsidy approved
- **Replacing**: Aging blast furnace infrastructure at Hirohata Works
- **Products**: High-grade steel sheet products

Yawata/Shunan Project (Kyushu Region)

- **Capacity**: Approximately 5 million tonnes per year combined
- **Timeline**: Phased implementation 2025-2030
- **Government Support**: ¥208.7 billion subsidy approved (largest single industrial decarbonization subsidy in Japanese history)
- **Significance**: Represents complete transformation of major integrated steel production complex
- **Integration**: Coordinated development of both Yawata Works (Fukuoka) and Shunan Works (Yamaguchi)

Combined, these projects represent approximately 7 million tonnes of annual steel production capacity transitioning from blast furnace to innovative EAF operation, equivalent to approximately 15% of Japan's total crude steel production [11, 12].

JFE Steel's Kurashiki Project JFE Steel's innovative EAF project at Kurashiki Works represents the second major transformation initiative:

- **Capacity**: Approximately 2-2.5 million tonnes per year
- **Timeline**: Construction phasing 2024-2029
- **Government Support**: ¥104.5 billion subsidy approved
- **Replacing**: Existing blast furnace capacity at Kurashiki Works
- **Products**: High-grade steel products for automotive and industrial applications
- **Integration**: Coordinated with company's DRI supply chain development

Kobe Steel's Position Kobe Steel, operating at smaller scale, has not announced innovative EAF projects comparable to Nippon Steel and JFE Steel, instead focusing on:

- Incremental improvements to existing EAF operations
- DRI supply chain participation
- Optimization of existing integrated facilities

9.3.3 Economic and Policy Support Framework

The innovative EAF projects benefit from comprehensive government support:

Capital Investment Support Through the "Support Project for Energy and Process Conversion in Hard-to-Abate Industries" (Green Innovation Fund):

- Subsidies covering approximately 30-35% of initial investment costs
- Total commitment exceeding ¥300 billion for innovative EAF projects
- Focus on projects demonstrating genuine technological breakthrough
- Requirements for detailed emission reduction verification

Operational Support Additional support mechanisms include:

- **Strategic Field Domestic Production Promotion Tax System**: Corporate tax credits for qualifying green steel production
- **Enhanced vehicle subsidies**: Additional ¥50,000 subsidy for vehicles using innovative EAF steel
- **Green Purchasing Act**: Priority procurement of lower-carbon steel in government projects

Electricity Supply Considerations Critical to innovative EAF success is renewable electricity availability:

- Japan's renewable electricity share remains relatively low (approximately 22% in 2024)
- Renewable energy procurement mechanisms under development
- Regional electricity grid capacity constraints in some areas
- Need for coordinated renewable energy expansion and steel sector decarbonization

9.3.4 Critical Assessment and Success Factors

Genuine Transformation Innovative EAF projects represent authentic process transformation rather than incremental optimization:

1. **Infrastructure replacement**: Complete replacement of blast furnace infrastructure with fundamentally different technology
2. **Long-term viability**: EAF-based production remains competitive and appropriate in fully decarbonized economy
3. **Technology alignment**: Consistent with international best practices and breakthrough technologies (Stegra, SALCOS, etc.)
4. **Product capability**: Designed to maintain Japan's competitive position in high-value steel markets
5. **Scale significance**: Projects collectively represent approximately 9-9.5 million tonnes capacity, roughly 20% of Japan's crude steel production

Critical Success Factor: DRI Supply The fundamental challenge for innovative EAF success is securing adequate DRI feedstock. Section 5 examines this critical dependency in detail, but key considerations include:

- **Volume requirements**: 9-9.5 million tonnes of innovative EAF capacity requires comparable DRI volumes when operating at 100% DRI charge
- **Quality specifications**: High-grade steel production requires high-quality DRI with strict chemistry control
- **Supply reliability**: Long-term supply contracts and infrastructure essential
- **Transition path**: How DRI availability scales to match EAF capacity commissioning
- **Cost competitiveness**: DRI pricing relative to scrap and blast furnace hot metal

Renewable Electricity Requirement The decarbonization benefit of innovative EAFs depends fundamentally on electricity source:

- With Japan's current electricity mix (approximately 75% fossil fuels), EAF emission intensity remains 0.6-0.8 tonnes CO_2 per tonne steel
- Achieving near-zero emissions requires renewable electricity at approximately 0.02-0.05 tonnes CO_2 per MWh
- Requires coordinated development of renewable electricity generation capacity and steel sector transformation

Timeline and Transition Management Successfully implementing innovative EAF projects while maintaining production continuity requires:

- Phased blast furnace decommissioning coordinated with EAF commissioning
- Interim production arrangements using remaining blast furnace capacity and external sourcing
- Workforce transition and retraining programs
- Customer communication and product transition management
- Supply chain adjustments for both inputs (DRI, electricity, electrodes) and outputs

10 The Critical DRI Supply Challenge

10.1 DRI's Central Role in Steel Decarbonization

Direct reduced iron has emerged as the critical enabler of steel sector decarbonization globally. The innovative EAF pathway, recognized internationally as the most technically and economically viable route to near-zero emission steel production

Mass balance framework improvements implemented

DRI supply strategies disclosed and validated

Hirohata innovative EAF construction completed

Government procurement policies strengthened

Renewable electricity procurement mechanisms enhanced

2027-2030: Initial Transformation

- Hirohata innovative EAF commences operation
- Yawata/Shunan and Kurashiki innovative EAF construction progresses
- Malaysia and other DRI projects commence production
- First substantial volumes of innovative EAF steel enter markets
- Mass balance schemes subject to first comprehensive review and tightening

2030-2035: Acceleration Phase

- Yawata/Shunan and Kurashiki innovative EAFs achieve full operation
- Additional EAF projects announced and implemented
- H_2-DRI supplies begin to supplement natural gas-based DRI
- Mass balance schemes progressively phased out
- Genuine near-zero emission steel production achieves commercial scale

2035-2040: Maturation Phase

- Mass balance schemes sunset completely
- Majority of Japanese steel production through innovative EAF or equivalent near-zero emission routes
- H_2-DRI becomes predominant feedstock
- Renewable electricity dominates steel sector energy supply
- Japan competitive in global markets differentiated by authentic carbon footprint

10.2 Final Assessment

Japan's steel decarbonization policy reflects pragmatic recognition of both the necessity of transformation and the complexity of executing it. The mass balance approach, while raising legitimate concerns, serves a defensible transitional function if properly bounded and regulated. The innovative EAF projects represent genuine commitment to breakthrough technologies and infrastructure transformation. However, the critical gap remains DRI supply security, particularly for Nippon Steel's ambitious projects. Without resolution of this fundamental challenge, Japan risks:

- Substantial public investment in infrastructure lacking adequate feedstock
- Delay in achieving actual emission reductions despite impressive plans
- Loss of competitive position to nations executing more integrated strategies
- Credibility damage to mass balance approaches if breakthrough projects fail to deliver

Conversely, successful execution of the innovative EAF program, supported by adequate DRI supplies and renewable electricity, would position Japan as a leader in steel decarbonization among major industrialized nations. This would demonstrate that even resource-constrained island nations can achieve industrial transformation through strategic planning, government support, and international partnerships. The coming five years (2025-2030) represent the critical window in which Japan's steel decarbonization trajectory will be determined. The decisions made, investments committed, and strategies executed during this period will establish whether Japan emerges as a decarbonization leader or struggles with expensive stranded assets and loss of competitive position in global steel markets increasingly differentiated by authentic carbon footprint. The path forward requires:

- Clear-eyed recognition of challenges, particularly DRI supply
- Enhanced transparency and accountability in mass balance schemes
- Unwavering commitment to genuine breakthrough technologies over incremental optimization
- Comprehensive policy support spanning the entire value chain
- International cooperation recognizing that steel decarbonization is inherently global

Japan's steel industry has demonstrated technological excellence and operational efficiency throughout its history. Applying these strengths to the decarbonization challenge, while learning from international experiences and maintaining policy focus, can deliver successful transformation of this critical industrial sector.

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