Abstract

This document examines Iran's steel research and industrial policy under unique constraints of comprehensive international sanctions while possessing significant natural resource advantages. With 31.4 million tonnes of annual crude steel production, ranking 10th globally, Iran demonstrates how a middle-income country can develop substantial steelmaking capacity despite isolation from Western technology and markets. The analysis explores Iran's distinctive reliance on natural gas-based direct reduced iron (DRI) production, representing the world's largest DRI capacity, the sanctions-driven imperative for technological self-sufficiency and domestic equipment manufacturing, state-directed industrial policy through entities like IMIDRO coordinating a mixed state-private sector, and the paradox of abundant natural gas enabling cleaner steelmaking pathways while carbon emissions remain peripheral concerns given geopolitical priorities. The document highlights how Iranian steel exemplifies autarkic industrialization driven by resource endowments and external constraints rather than climate policy, offering insights into technology development trajectories when conventional international cooperation channels are blocked.

Contents

1 Strategic Context: Sanctions and Self-Reliance

1.1 Production Capacity and Global Position

Iran ranks as the world's tenth-largest steel producer:

2024 Production: 31.4 million tonnes crude steel

- Global rank: 10th
- Middle East dominance: Largest producer in region
- Per capita production: 360 kg (relatively high)
- Export orientation: 25-30% of production

Technology distribution:

- DRI-EAF (natural gas-based): 55% of capacity
- Integrated BF-BOF: 35% of capacity
- Scrap EAF: 10% of capacity
- World's largest DRI production: 30 million tonnes annually

Growth trajectory:

- Rapid expansion 2000-2020: From 6 MT to >30 MT
- Government-promoted industrial development
- Import substitution and export development strategy
- Continued capacity expansion despite sanctions

1.2 The Sanctions Environment

Comprehensive sanctions regime:

- US: Secondary sanctions targeting third parties
- EU: Coordinated sanctions on financial, energy, technology sectors
- UN: Periodic sanctions (currently reduced but monitoring continues)
- Impact: Isolation from Western technology, financial systems, markets

Effects on steel industry:

- Technology access: Limited to Chinese, Russian, domestic suppliers
- Equipment procurement: Complex circumvention, higher costs, delays
- Export markets: Restricted to friendly countries, complicated logistics
- Financial transactions: Payment difficulties, currency restrictions
- Knowledge exchange: Academic and technical isolation

Sanctions circumvention and adaptation:

- Development of domestic equipment manufacturing capability
- Technology partnerships with China, Russia, occasionally India
- Barter arrangements and non-dollar trade
- Front companies and indirect procurement channels
- Reverse engineering and technology indigenization

1.3 Natural Resource Advantages

Natural gas abundance:

- World's second-largest proven reserves (after Russia)
- South Pars/North Dome field: Largest gas field globally (shared with Qatar)

- Domestic gas prices: Heavily subsidized, very low cost
- Stranded gas: Limited export infrastructure creates domestic surplus
- Strategic advantage: Natural gas-based DRI economics highly favorable

Iron ore resources:

- Significant domestic reserves (concentrated in central Iran)
- Quality: Variable, generally moderate grade (50-60% Fe)
- Beneficiation industry developed to upgrade domestic ores
- Some high-quality ore imports from neighbors when economically attractive

Coal resources:

- Limited high-quality coking coal
- Domestic coal generally unsuitable for steelmaking without blending
- Historically imported coking coal (Australia, others) when possible
- Sanctions complicating coal imports, favoring gas-based routes

2 Industry Structure and Major Producers

2.1 State-Owned Enterprises

2.1.1 Mobarakeh Steel Company (MSC)

Capacity and operations:

- Integrated capacity: 7.2 million tonnes (largest in Middle East)
- Location: Mobarakeh (Isfahan Province)
- Technology: Modern DRI-EAF and integrated BF-BOF
- Products: Flat and long products, diverse portfolio
- Vertical integration: Mining, power generation

Ownership and governance:

- Largest steel producer in MENA region
- Ownership: Partially state-owned, listed on Tehran Stock Exchange
- Management: Professional with state oversight
- Strategic importance: Flagship of Iranian steel industry

Modernization efforts:

- Investment: $2 billion (2020-2025) despite sanctions
- Focus: Energy efficiency, product quality, environmental controls
- Target: 10% energy intensity reduction
- Challenges: Technology access limitations, financing constraints

2.1.2 Khuzestan Steel Company (KSC)

Operations:

- Capacity: 5.5 million tonnes
- Location: Ahvaz (Khuzestan Province, southwest Iran)
- Technology: DRI-EAF using abundant local natural gas
- Products: Long products, billets, blooms
- Ownership: State-owned

Strategic significance:

- Proximity to gas fields enabling low-cost feedstock
- Regional economic development anchor
- Export-oriented given coastal proximity (Persian Gulf)
- Employment: Major local employer (10,000+ workers)

2.1.3 Esfahan Steel Company (ESCO)

Operations:

- Iran's first modern integrated steel plant (1970s vintage)
- Capacity: 2.5 million tonnes
- Technology: Older BF-BOF with partial modernization
- Products: Specialized steel grades including rail steel
- Challenges: Aging facilities requiring investment

2.2 IMIDRO Coordination Role

Iranian Mines and Mining Industries Development and Renovation (IMIDRO):
Structure and mandate:

- State holding company under Ministry of Industry, Mine and Trade
- Oversight of major state-owned steel and mining companies
- Strategic planning and coordination function
- Investment allocation and capital provision
- Technology acquisition and transfer coordination

20-Year Vision Plan steel provisions:

- Target: 55 million tonnes capacity by 2025 (behind schedule due to sanctions)
- Emphasis on value chain integration (mining to finished products)
- Export development to reduce domestic market dependence
- Quality upgrading for higher value-added products
- Regional hub ambitions for steel and metallurgy

2.3 Private Sector Producers

Growing private participation:

- Numerous small to medium EAF producers
- Scrap-based operations serving domestic construction
- Family-owned businesses and regional entrepreneurs
- Less visibility than state sector but economically significant
- Flexibility and entrepreneurial adaptation to sanctions environment

3 Technology Development and DRI Dominance

3.1 Natural Gas-Based DRI Leadership

Global DRI context:

- Iran: World's largest DRI producer (30 million tonnes annually)
- Technology: Primarily Midrex process (historical partnerships)
- Domestic licensing and adaptation following sanctions
- Low-cost natural gas creating economic competitiveness

DRI technology advantages:

- Lower capital cost than integrated BF-BOF
- Modular and scalable facilities
- Natural gas feedstock abundant and cheap in Iran
- Flexibility in product mix
- Inherently lower emissions than coal-based routes

Technical challenges:

- Product quality: DRI suitable for many but not all applications
- Metallization rate optimization
- Carburization control for different product requirements
- Energy efficiency improvements
- Integration with EAF operations

3.2 Domestic Equipment Manufacturing

Sanctions-driven indigenization:

- Development of domestic engineering and equipment capabilities
- Reverse engineering of imported technologies
- Local suppliers for refractories, electrodes, spare parts
- Quality gap vs. international best but functional
- Pride in self-reliance despite higher costs and lower efficiency

Key domestic suppliers:

- IDRO (Industrial Development and Renovation Organization): Equipment manufacturing
- Multiple smaller engineering firms providing design and equipment
- Adaptability: Modifying designs to use available materials and components
- Innovation constraint: Limited access to frontier technologies

3.3 Research Institutions

3.3.1 Institute of Materials and Energy Research Center

Focus areas:

- Materials science and metallurgy
- Energy-efficient process development
- Corrosion and materials degradation
- Applied research for industry needs

3.3.2 University Centers

Sharif University of Technology:

- Premier technical university
- Materials Science Department with metallurgy focus
- Industry collaboration on specific challenges
- Graduate education for steel sector engineers

University of Tehran:

- Metallurgical Engineering Department
- Research on Iranian ore utilization
- Process optimization studies

- Training of industry professionals

Other technical universities:

- Isfahan University of Technology: Regional collaboration with Isfahan steel cluster
- Iran University of Science and Technology: Industrial engineering focus
- Amirkabir University: Materials and metallurgy programs

3.4 R&D Priorities and Constraints

Industry research focus:

- DRI process optimization for Iranian gas compositions
- Domestic ore beneficiation and utilization
- Product quality improvement to substitute imports
- Energy efficiency despite cheap gas (recognition that efficiency still valuable)
- Environmental management and emissions control

Resource constraints:

- Limited R&D budgets relative to production scale
- Sanctions limiting access to advanced equipment and materials for research
- Brain drain: Talented researchers emigrating for opportunities abroad
- Currency devaluation affecting purchasing power for imported research equipment
- Information isolation: Limited access to international journals, conferences

Workarounds and adaptations:

- Open-source and publicly available information leveraging
- Academic exchanges with friendly countries (China, Russia, occasionally Turkey)
- Iranian diaspora: Some continued informal connections despite sanctions
- Focus on practical, applied research with immediate industry relevance

4 Decarbonization Context

4.1 Climate Policy Framework

Paris Agreement status:

- Signatory but limited formal commitment specificity
- NDC submission: General emissions reduction intentions
- Implementation: Climate policy not priority given economic and geopolitical challenges
- Domestic air quality: Greater concern than global climate in urban areas

National circumstances:

- Development priority: Economic growth and self-sufficiency paramount
- Energy subsidy policy: Cheap gas for industry and consumers
- Carbon pricing: No meaningful carbon tax or trading system
- Environmental standards: Gradual tightening but lax enforcement

4.2 Emissions Profile

Steel sector emissions:

- Total: 65-70 million tonnes CO_2 annually
- Per tonne intensity: 2.0-2.3 tonnes CO_2/tonne steel (higher than global average)
- Despite DRI dominance: Natural gas-based DRI still carbon-intensive vs. hydrogen alternative
- BF-BOF component: Higher intensity dragging up average

Comparison context:

- Higher than EAF-dominant countries (Turkey, Italy)
- Lower than coal-heavy countries (China, India baseline)
- Natural gas advantage vs. coal but still fossil-based
- Potential for improvement with technology but limited policy driver

4.3 Pragmatic Decarbonization Opportunities

Energy efficiency:

- Despite cheap gas, efficiency improvements economically attractive
- Waste heat recovery for power generation
- Process optimization and control improvements
- Benefit: Reduced gas consumption valuable even at low prices (opportunity cost)

Natural gas to hydrogen transition potential:

- Existing DRI infrastructure adaptable to hydrogen
- Natural gas reforming with CCUS as transitional pathway
- Long-term: Green hydrogen using solar energy (Iran has excellent solar resource)
- Timeline: Not priority now but technical foundation exists
- Barrier: Capital investment requirements and lack of policy incentive

Air quality co-benefits:

- Urban air pollution: Major public health concern (Tehran, other cities)
- Steel plant emissions contribute to air quality issues
- Local environmental improvements: More immediate driver than climate
- Technology upgrades for pollution control also reduce CO_2

5 Trade and Market Dynamics

5.1 Export Markets Under Sanctions

Primary destinations:

- Iraq: Major market for construction steel
- Afghanistan: Long-standing trade relationship
- UAE: Trans-shipment hub (some controversy over sanctions circumvention)
- Pakistan: Episodic trade dependent on bilateral relations
- Turkey: Opportunistic trade when economically attractive

Trade challenges:

- Payment mechanisms: Dollar transactions impossible, barter or local currency
- Logistics: Sanctions on shipping and insurance complicating transport

- Quality perception: Iranian steel seen as lower-tier in some markets
- Competition: Chinese, Turkish, Indian steel in same markets
- Volatility: Political tensions affecting trade flows

Export strategy:

- Competitive pricing leveraging gas cost advantage
- Geographic proximity to regional markets
- Relationship-based trade with friendly countries
- Product mix toward construction and industrial grades (less demanding)

5.2 Domestic Market Protection

Import substitution policy:

- Government priority: Reduce imports, develop domestic industry
- Import restrictions and tariffs protecting steel sector
- Procurement preferences for domestic steel in government projects
- Result: Captive domestic market supporting industry

Downstream industries:

- Construction: Major consumer (60-70% of demand)
- Automotive: Domestic manufacturing using Iranian steel
- Appliances and consumer goods: Protected market
- Machinery and equipment manufacturing
- Trade-off: Downstream competitiveness constrained by input costs/quality

6 Future Outlook and Scenarios

6.1 Sanctions Persistence Scenario

Assumptions:

- Comprehensive sanctions continue through 2030+
- Minimal sanctions relief despite periodic negotiations
- Iran continues current trajectory of autarkic development

Outcomes for steel:

- Capacity growth slows but continues (target 40-45 MT by 2035)
- Technology gap widens vs. international best practice
- Domestic equipment industry matures further
- Regional export markets maintained at modest levels
- Quality and efficiency improvements incremental
- Environmental standards lag international norms
- Decarbonization not priority

6.2 Sanctions Relief and Normalization Scenario

Assumptions:

- Nuclear deal breakthrough and comprehensive sanctions lifting
- Normalization of economic relations with West
- Foreign investment and technology access restored

Outcomes for steel:

- Technology modernization surge with access to global best practices
- Foreign partnerships and joint ventures (European, Asian companies)
- Export market expansion to Europe and broader Asia
- Product quality upgrading to compete in premium markets
- Environmental standards tightening to meet international expectations
- Potential decarbonization investments if carbon pricing emerges
- Capacity expansion to 50+ MT by 2035 with better technology
- Integration into global steel value chains

6.3 Realistic Hybrid Scenario

Assumptions:

- Partial sanctions relief in some areas, persistence in others
- Selective engagement with international partners
- Continued emphasis on self-sufficiency while seeking technology access

Outcomes:

- Technology partnerships with China, Russia, possibly some Europeans
- Gradual quality and efficiency improvements
- Export market diversification with some success
- Environmental standards improve slowly under urban air quality pressure
- Capacity growth to 40-45 MT with mixed technology levels
- Decarbonization rhetoric but limited concrete action

7 Conclusions

Iran's steel industry demonstrates how a middle-income country can develop substantial industrial capacity despite comprehensive international sanctions, leveraging natural resource advantages and state-directed development policy. The overwhelming reliance on natural gas-based DRI reflects both resource endowments and constraints imposed by isolation from global coal markets and technology suppliers.

Key characteristics:

- Autarkic development driven by sanctions, not choice
- Natural gas abundance enabling large-scale DRI production
- State-coordinated industrial policy through IMIDRO
- Technological self-reliance through necessity
- Climate policy peripheral to economic and geopolitical imperatives

Future trajectory:

Iran's steel sector future depends overwhelmingly on geopolitical factors beyond industry control. Sanctions relief would enable technology leapfrogging and market expansion. Sanctions persistence means continued gradual development with widening technology gaps versus global leaders. In either scenario, decarbonization remains unlikely priority given development needs and absence of carbon pricing or international pressure mechanisms effective under sanctions.

The Iranian case offers lessons on industrial development under extreme constraints but is not a model other countries would choose to replicate. It exemplifies how resource endowments and political circumstances shape technological pathways more than optimal policy design.

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