South Korea Steel Research and Industrial Policy: Strategic Autonomy and the HyREX Revolution

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Abstract

This document examines South Korea's steel research and industrial policy as a distinctive model combining export-driven industrial strategy with aggressive decarbonization commitments. With 63.6 million tonnes of annual crude steel production concentrated in two major integrated producers (POSCO and Hyundai Steel), South Korea demonstrates how a technology-focused developmental state can pursue simultaneous goals of industrial competitiveness, energy security, and climate leadership. This analysis explores the K-Steel Act as legislative framework elevating steel to national security priority, POSCO's proprietary HyREX (Hydrogen Reduction) technology as alternative to conventional hydrogen-DRI approaches, government support through the Green Innovation Fund and industrial policy coordination, and South Korea's unique challenge of scrap supply constraints in a densely populated, highly industrialized context. The document highlights how South Korean steel policy reflects broader national strategies of technology sovereignty, export competitiveness, and navigating geopolitical tensions between the United States and China.

Contents

1 Strategic Context: Steel as National Security Priority

1.1 Production Capacity and Global Position

South Korea ranks as the world's sixth-largest steel producer:

2024 Production: 63.6 million tonnes crude steel

- Global rank: 6th (declining from 5th in 2023)
- Share of global production: 3.4%
- Per capita production: 1.2 tonnes (among world's highest)
- Export orientation: 50% of production exported

Technology distribution:

- Integrated BF-BOF: 70% of capacity
- Electric arc furnace: 30% of capacity
- World-class operational efficiency
- Advanced automation and digitalization

1.2 Economic and Strategic Significance

Downstream industrial integration:

- Shipbuilding: World's largest shipbuilder (requires specialized steel grades)
- Automotive: Hyundai/Kia production demanding high-quality steel
- Construction: Domestic infrastructure and export markets
- Electronics and appliances: Samsung, LG requiring specialized materials

Employment and economic contribution:

- Direct employment: 100,000 workers in steel production
- Indirect employment: 300,000-400,000 in value chains
- Contribution to GDP: 2% directly, 5% including downstream
- Regional concentration: Pohang, Gwangyang creating company towns

National security framing:

- Steel viewed as foundation of industrial sovereignty
- Defense applications requiring domestic steel supply
- Geopolitical vulnerability: Heavy import dependence for iron ore, coal
- Strategic autonomy imperative in US-China competition context

1.3 The Geopolitical Squeeze

South Korea faces unique pressures:

US-China technological decoupling:

- Alliance with US while China is largest export market
- Technology transfer restrictions affecting equipment and processes
- Pressure to align with US on critical technologies
- Risk of Chinese market access restrictions as retaliation

Trade vulnerabilities:

- 2024: Targeted by US 50% steel tariffs under Section 232
- Chinese overcapacity threatening third-country export markets
- Southeast Asian competition in regional markets

- Need to diversify export destinations

Energy insecurity:

- Nearly 100% import dependence for fossil fuels
- Limited renewable energy potential (high population density, geography)
- Nuclear power political controversy
- Green hydrogen import dependency inevitable

2 The K-Steel Act: Legislative Framework

2.1 Origins and Political Context

Legislative history:

- Introduced 2024 with bipartisan support (106 lawmakers)
- Response to US tariff threats and Chinese import surge
- Elevates steel to strategic sector with special government support
- Framework for comprehensive industrial policy

Political coalition:

- Conservative and progressive parties aligned on steel importance
- Labor unions supporting as employment protection
- Industry backing for government assistance
- Rare consensus in polarized political environment

2.2 Key Provisions

2.2.1 Governance Structure

Presidential Committee on Steel Industry:

- High-level oversight body chaired by senior Blue House official
- Representation: Government ministries, industry, labor, academia
- Authority to coordinate policy across government
- Quarterly reporting to President on sector status

Five-Year Master Plans:

- Comprehensive sectoral strategies updated every five years
- Technology roadmaps with specific milestones
- Investment targets and government support commitments
- Alignment with national innovation and climate strategies

Annual Implementation Roadmaps:

- Detailed action plans for each year
- Budget allocations and program specifications
- Performance indicators and accountability mechanisms
- Flexibility to adjust to changing circumstances

2.2.2 Financial Support Mechanisms

Green transition subsidies:

- Direct subsidies for low-emission technology adoption
- CAPEX support: 20-40% of investment costs
- OPEX support: Production cost gap compensation
- Technology-specific programs (hydrogen, EAF, CCUS)

Low-interest financing:

- Korea Development Bank (KDB) preferential loans
- Interest rate subsidies: 1-3% below market rates
- Long-term maturities: 15-20 years for major transformation projects
- Grace periods during construction and ramp-up

Tax incentives:

- Corporate tax credits for R&D investments
- Accelerated depreciation for green equipment
- Tax exemptions for hydrogen production facilities
- Carbon tax deferrals for companies with credible transition plans

Production cost support:

- Direct payments compensating cost differential for green steel
- Particularly for hydrogen-based steelmaking
- Time-limited with phase-out as technologies mature
- Performance-based with emissions reduction requirements

2.2.3 Trade Protection and Market Development

Import monitoring and safeguards:

- Real-time tracking of steel imports by origin and product
- Rapid response mechanisms for import surges
- Coordination with Fair Trade Commission on dumping investigations
- Strategic use of WTO-compatible trade defense measures

Green public procurement:

- Mandatory low-carbon steel for government infrastructure projects
- Premium pricing: 5-10% above market for certified green steel
- Gradual tightening of emissions intensity requirements
- Certification and verification system development

2.3 Implementation Status

First Master Plan (2025-2029):

- Carbon neutrality by 2050 as binding target for steel sector
- Phase 1 hydrogen steelmaking pilot by 2026
- EAF capacity expansion to 40% by 2030
- Investment target: ₩50 trillion ($38 billion$)
- Government support: ₩15 trillion ($11 billion$)

Budget allocations (2025):

- Total steel industry support: ₩1.8 trillion ($1.4 billion$)
- Technology development: ₩800 billion
- Production cost support: ₩600 billion
- Infrastructure and skills: ₩400 billion

3 Research and Innovation Framework

3.1 National Innovation System

3.1.1 Government Research Institutes

Korea Institute of Industrial Technology (KITECH):

- Focus: Applied industrial technology development
- Steel programs: Process optimization, energy efficiency, quality improvement
- Pilot facilities for technology demonstration
- Industry collaboration and technology transfer

Korea Institute of Energy Research (KIER):

- Hydrogen production and storage technologies
- Renewable energy integration for industrial applications
- Energy system modeling and optimization
- Support for steel sector energy transition

Korea Institute of Science and Technology (KIST):

- Materials science and advanced metallurgy
- Carbon capture and utilization technologies
- Computational materials design
- Fundamental research for breakthrough innovations

3.1.2 University Research Centers

POSTECH (Pohang University of Science and Technology):

- Established by POSCO, located adjacent to Pohang steelworks
- Graduate School of Iron and Steel Technology
- Joint research programs with POSCO
- Pipeline of engineers for steel industry

Seoul National University:

- Department of Materials Science and Engineering
- Advanced steel characterization and modeling
- Collaboration with major steel producers
- Graduate education for industry leaders

KAIST (Korea Advanced Institute of Science and Technology):

- Process systems engineering for steel production
- AI and machine learning applications
- Energy systems integration
- Startup incubation for steel technology innovations

3.1.3 Industry R&D Centers

POSCO Technology Research Laboratories:

- One of world's largest steel R&D facilities
- 1,000 researchers across multiple institutes
- Annual R&D budget: $300 - 400 million$
- Focus areas: HyREX, hydrogen, advanced materials, digitalization

- Pilot facilities for technology validation

Hyundai Steel R&D Center:

- Integrated with Hyundai Motor Group requirements
- Specialization: Automotive steel grades
- Collaboration with Primetals on hydrogen technologies
- Focus on customer-driven innovation

3.2 Funding Mechanisms

3.2.1 Green Innovation Fund

Structure and scale:

- Total fund: ₩20 trillion ($15 billion) for industrial decarbonization
- Steel sector allocation: 25% (₩5 trillion / $3.8 billion)
- Timeline: 2021-2030
- Administered by Korea Energy Agency

POSCO HyREX project:

- Government contribution: ₩500 billion ($380 million)
- Total project cost: ₩3 trillion ($2.3 billion) through 2030
- Pilot plant (300,000 tonnes) operational target: 2026
- Commercial scale (2.5 million tonnes): 2030-2035

Hyundai Steel hydrogen project:

- Government support: ₩200 billion ($150 million)
- Partnership with Primetals for hydrogen BF injection
- DRI-EAF pilot development
- Target: 10

3.2.2 National R&D Programs

Industrial Technology Innovation Program:

- Ministry of Trade, Industry and Energy (MOTIE) managed
- Competitive grants for pre-commercial technology development
- Cost-sharing: 50-75% government, remainder industry
- Focus on technologies 3-7 years from commercialization

Carbon Neutrality Technology Innovation Program:

- Cross-sectoral program targeting decarbonization
- Steel sector priority area
- Support for breakthrough technologies with high risk/reward
- International collaboration encouraged

3.2.3 Private Sector Investment

POSCO commitments:

- Total decarbonization investment: ₩40 trillion ($30 billion) through 2050
- Near-term (2025-2030): ₩10 trillion ($7.5 billion)
- Breakdown: HyREX development, renewable energy, infrastructure
- Funded through: Operating cash flow, green bonds, project financing

Hyundai Steel commitments:

- Carbon neutrality investment: ₩10 trillion ($7.5 billion) through 2050
- Phased approach aligned with technology maturity
- Integration with Hyundai Motor Group strategy
- Focus on automotive-grade green steel

4 Technology Strategies: The HyREX Innovation

4.1 POSCO HyREX Technology

4.1.1 Technical Concept

Distinctive features vs. conventional H2-DRI:

Conventional approach:

- Direct Reduced Iron (DRI) produced in shaft furnace
- DRI cooled, transported, stored
- DRI reheated in EAF for melting
- Energy losses and oxidation risks in intermediate steps

HyREX innovation:

- Hydrogen reduction and melting integrated in single reactor
- Hot DRI directly melted without cooling/reheating
- Continuous process eliminating intermediate handling
- "Ore Thermal Furnace" combining reduction and melting functions
- Produces liquid pig iron suitable for secondary refining

Technical advantages:

- Energy efficiency: 10-15% improvement vs. separate DRI-EAF
- Operational flexibility: Can adjust hydrogen/natural gas ratio
- Product quality: Better control of carbon content and impurities
- Capital efficiency: Fewer process steps and equipment
- Scalability: Modular design enabling phased implementation

4.1.2 Development Timeline

Phase 1: Laboratory and bench scale (2018-2022):

- Fundamental research on hydrogen reduction kinetics
- Small-scale reactor testing (kilograms per hour)
- Process modeling and simulation
- Patent portfolio development

Phase 2: Pilot demonstration (2023-2026):

- 300,000 tonnes/year pilot plant at Pohang
- Construction: 2024-2025
- Commissioning and testing: 2026
- Product qualification with downstream customers
- Operational learning and process optimization

Phase 3: Commercial deployment (2026-2035):

- Scale-up to 2.5 million tonnes/year commercial units
- Multiple reactors at Pohang and Gwangyang sites
- Progressive blast furnace retirement as HyREX capacity grows
- Technology export and licensing to other producers

Phase 4: Full transformation (2035-2050):

- Complete transition from BF-BOF to HyREX-based production
- Achievement of carbon-neutral steelmaking
- Establishment of HyREX as global standard (aspirational)
- Technology revenue supplementing steel production margins

4.1.3 Technical Challenges and Risks

Hydrogen supply:

- Phase 2 pilot: Natural gas reformed hydrogen acceptable
- Phase 3-4: Green hydrogen essential for carbon neutrality
- Required volume: 6-7 million tonnes hydrogen annually for full sector
- Cost target: $2 - 3 perkgcompetitivethreshold$
- Infrastructure: Pipelines, storage, import facilities required

Scale-up challenges:

- Transition from 300k to 2.5M tonnes/year unprecedented
- Refractory materials performance at commercial scale
- Process control and automation complexity
- Integration with existing infrastructure during transition
- Reliability and availability targets for continuous operation

Product quality validation:

- Demonstration of steel quality meeting customer specifications
- Particularly critical for automotive, shipbuilding applications
- Traceability and certification for green steel claims
- Customer acceptance and willingness to pay premium

4.2 Hyundai Steel Hydrogen Integration

Blast furnace hydrogen injection:

- Partnership with Primetals Technologies (October 2023)
- Research on hydrogen use in existing blast furnaces
- Incremental emissions reduction: 10-20% near-term potential
- Bridge technology while long-term solutions develop

DRI-EAF pathway:

- Target: 0.2 tonnes CO_2 per tonne steel via H2-DRI-EAF
- Timeline: Pilot by 2028, commercial by 2035
- CCUS for residual emissions
- Learning from POSCO HyREX while pursuing parallel approach

4.3 EAF Expansion and Scrap Strategy

4.3.1 Capacity Targets

Current status (2024):

- EAF share: 30% of Korean steel production
- Capacity: 19 million tonnes
- Major producers: Dongkuk Steel, Daehan Steel, others
- Product focus: Long products (rebar, sections, wire rod)

Expansion plans (2025-2030):

- POSCO: 2.5 million tonnes new EAF at Gwangyang ($450M investment$)
- Hyundai Steel: EAF capacity additions under evaluation
- Secondary producers: Modernization and efficiency improvements
- Target: 40% EAF share by 2030, 50%+ by 2040

4.3.2 The Scrap Challenge

Current supply-demand balance:

- Domestic scrap generation: 12 million tonnes annually
- Current EAF consumption: 19 million tonnes
- Import dependency: 7 million tonnes (mostly from US, Russia)
- Scrap exports: 1 million tonnes (to Southeast Asia)

Structural constraints:

- Limited domestic scrap availability: Young steel stock, long product lifetimes
- High population density limiting expansion of collection infrastructure
- Quality challenges: Tramp elements from mixed scrap streams
- Export restrictions anticipated post-2030 globally

Government strategy:

- Scrap collection infrastructure investment: $140M (2023 - 2025)$
- Expansion from 4 to 8 regional collection centers
- End-of-life vehicle processing regulation and support
- Overseas scrap collection center establishment
- Technology for scrap quality upgrading and contamination removal

4.3.3 Alternative Iron Units

DRI and HBI imports:

- Supplement scrap for quality-sensitive EAF production
- Sourcing: Middle East, India, potential future Korean production
- Cost considerations: Currently expensive vs. scrap
- Strategic reserves for supply security

Domestic DRI production:

- HyREX technology potentially producing DRI for sale to EAF producers
- Internal POSCO use and external market opportunities
- Green DRI premium pricing potential
- Coordination of integrated and EAF sectors

5 Policy Coordination and Industrial Strategy

5.1 Ministry Responsibilities and Coordination

5.1.1 Ministry of Trade, Industry and Energy (MOTIE)

Primary industrial policy leadership:

- K-Steel Act implementation and oversight
- R&D program management and funding
- Industrial competitiveness and export support
- Energy policy including hydrogen strategy

Steel-specific initiatives:

- Five-year master plan development
- Technology roadmap coordination with industry
- Trade negotiation and protection measures
- Investment attraction and business environment improvement

5.1.2 Ministry of Environment

Environmental regulation:

- Emissions standards and monitoring
- Environmental permits and compliance enforcement
- Integration with climate change strategy
- Coordination with MOTIE on balancing growth and environment

Carbon pricing and trading:

- Korea ETS (Emissions Trading System) administration
- Steel sector currently with free allocation
- Gradual transition to auctioning planned
- Debate on inclusion of steel in carbon trading vs. exclusion

5.1.3 Ministry of Science and ICT

National research strategy:

- 5th Basic Plan for Science and Technology (2023-2027)
- R&D investment: 4.96% of GDP (2nd highest globally after Israel)
- Steel technology as part of "577 Initiative" (semiconductors, shipbuilding, automotive, steel, textiles, materials, bio)
- Government education budget: ₩98.5 trillion for 2025

5.2 Industrial Policy Context

5.2.1 Developmental State Legacy

Historical model:

- Government-coordinated industrialization (1960s-1990s)
- POSCO established as state-owned enterprise (privatized 2000)
- Heavy and chemical industry drive creating steel-using sectors
- Export-led growth with government support
- Chaebol system: Family-controlled conglomerates with government partnership

Contemporary adaptation:

- Less directive, more facilitative government role
- Private sector innovation with public sector support
- Targeted interventions in strategic sectors
- Balance between market mechanisms and industrial policy

5.2.2 Regulatory Environment Challenges

"Positive regulation" critique:
K-Steel Act debate highlighted regulatory modernization needs:

- Current system: Activities require explicit permission ("positive list")
- Innovation constraint: New technologies await regulatory approval
- Shadow regulations: Agency guidelines creating de facto requirements
- International comparison: "Negative list" systems (permitted unless prohibited) more innovation-friendly

Reform proposals:

- Regulatory sandboxes for innovative technologies
- Fast-track approval for green technologies
- Consolidation and simplification of overlapping requirements
- Risk-based approach rather than prescriptive rules
- Challenge: Bureaucratic culture and political resistance

6 International Dimensions

6.1 Trade Policy and Export Markets

6.1.1 Geographic Diversification

Traditional markets under pressure:

- US: Tariff threats and Section 232 restrictions
- China: Overcapacity reducing import needs, political tensions
- Southeast Asia: Growing domestic capacity competing with Korean exports
- Europe: CBAM creating new barriers for carbon-intensive steel

Diversification strategies:

- Middle East: Infrastructure development creating demand
- India: Growing market but also developing domestic capacity
- Africa and Latin America: Long-term growth potential
- Premium positioning: Green steel for European, Japanese markets

6.1.2 Free Trade Agreements

Strategic use of FTAs:

- US-Korea FTA (KORUS): Preferential access amid tariff threats
- EU-Korea FTA: European market access
- ASEAN agreements: Regional market integration
- RCEP (Regional Comprehensive Economic Partnership): Asia-Pacific framework

6.2 Technology Transfer and Partnerships

6.2.1 International Collaboration

Technology import:

- Partnership with Primetals Technologies (Austria) on hydrogen
- Equipment and engineering services from global suppliers
- Licensing agreements for specific technologies
- Academic collaboration with US, European institutions

Technology export potential:

- HyREX technology licensing to other producers
- Steel plant engineering and construction services
- Operational consulting and management
- Digital technologies and Industry 4.0 solutions

6.2.2 Geopolitical Navigation

US alliance implications:

- Technology sharing and joint R&D opportunities
- Pressure to align on China policy
- Trade tensions despite alliance relationship
- Balancing security ties with economic interests

China economic interdependence:

- China largest export market for Korean steel
- Automotive and electronics sectors dependent on Chinese demand
- Risk of retaliation for perceived anti-China positions
- Need to maintain economic relationship amid political tensions

7 Challenges and Critical Assessment

7.1 Hydrogen Supply and Cost

Domestic production limitations:

- Limited renewable energy potential: High population density, geography
- Offshore wind potential but high development costs
- Nuclear power expansion politically controversial
- Green hydrogen production costs: $6 - 8/kgcurrently, target$2-3/kg by 2030

Import dependency strategy:

- Anticipated 60-70% of hydrogen needs imported by 2050

- Source diversification: Australia, Middle East, potentially Russia (geopolitically sensitive)
- Ammonia as hydrogen carrier for shipping
- Infrastructure: Import terminals, pipelines, storage facilities
- Cost and security concerns with heavy import dependence

7.2 Competitiveness and Cost Pressures

High production costs:

- Energy costs among highest in Asia
- Labor costs higher than China, Southeast Asia
- Stringent environmental regulations vs. regional competitors
- Currency exchange rate volatility

Green steel premium uncertainty:

- Customer willingness to pay unproven at scale
- Shipbuilding, construction sectors cost-sensitive
- Automotive sector more receptive but price limits exist
- Export markets may not value green premium

7.3 Scrap Supply Constraints

Fundamental limitation:

- Domestic scrap generation insufficient for ambitious EAF expansion
- Import dependence creates supply security risks
- Global scrap markets tightening as other countries pursue EAF expansion
- Potential future export restrictions by scrap-generating countries

Strategic responses:

- Maximize domestic collection and processing
- Overseas scrap procurement and processing facilities
- DRI production for EAF quality dilution
- Material efficiency in steel-using sectors to extend product lifetimes

7.4 Technology and Execution Risks

HyREX commercialization uncertainty:

- Unproven at commercial scale
- Complex scale-up challenges from 300k to 2.5M tonnes
- Potential for technical failures or performance shortfalls
- Backup plans if HyREX doesn't succeed as hoped

Timeline pressures:

- 2050 carbon neutrality target constrains transformation timeline
- Blast furnace asset lifetimes (30-40 years) creating lock-in risk
- Need for rapid hydrogen infrastructure development
- Coordination of multiple simultaneous transformations
- Risk of stranded assets if timing misaligned

8 Social Dimensions and Just Transition

8.1 Employment and Workforce Transformation

Current workforce profile:

- Direct steel employment: 100,000 workers
- Aging workforce: Average age 45+ years
- Highly skilled: Decades of operational experience
- Geographic concentration: Company towns (Pohang, Gwangyang)
- Strong labor union representation

Transformation impacts:

- Technology shift requiring new skills (hydrogen, digitalization)
- Potential job reductions through automation and efficiency
- Need for retraining programs at scale
- Early retirement packages for older workers
- Concerns about regional economic impacts

8.2 Labor Union Role

Korean Metal Workers Union (KMWU):

- Powerful union representing steel workers
- Traditionally militant, frequent strikes in past
- Recent moderation and partnership approach on green transition
- Demands: Job security guarantees, worker participation in planning
- Support for K-Steel Act as protecting employment

Social partnership agreements:

- POSCO-union agreements on transformation
- Job security commitments through transition period
- Investment in training and skills development
- Worker representation in technology deployment decisions
- Profit-sharing arrangements to align interests

8.3 Regional Economic Development

Pohang and Gwangyang dependencies:

- Single-industry cities heavily reliant on steel
- Supplier networks entirely focused on steel sector
- Local services dependent on steel worker spending
- Limited economic diversification opportunities

Diversification strategies:

- Technology parks and research centers
- Attraction of steel-related but diversified industries
- Tourism development (limited potential)
- Regional government support programs
- Recognition: Diversification difficult in company town contexts

9 Future Outlook and Strategic Scenarios

9.1 Optimistic Scenario: HyREX Success and Global Leadership

Pathway (2025-2050):

- 2026: HyREX pilot successful, product quality validated
- 2030: First commercial HyREX units operational, EAF share 40%
- 2040: Majority of capacity converted to HyREX and EAF
- 2050: Carbon neutrality achieved, 60+ MT capacity maintained
- Technology export revenue significant

Enabling conditions:

- HyREX technology commercialization without major setbacks
- Hydrogen supply and cost targets achieved
- Customer acceptance and premium pricing for green steel
- Government support sustained across political cycles
- Successful navigation of geopolitical tensions

Outcomes:

- Korea positioned as global green steel technology leader
- Employment maintained through productivity and exports
- Strengthened industrial sovereignty and competitiveness
- Model for other countries to emulate

9.2 Realistic Scenario: Gradual Transformation with Challenges

Pathway (2025-2050):

- 2026-2030: HyREX pilot experiences delays, technical issues
- 2030-2040: Commercial deployment slower than planned
- 2040-2050: Partial transformation, some capacity reduction
- 2050: 70-80% emissions reduction, capacity declining to 50-55 MT

Challenges encountered:

- HyREX scale-up more difficult than anticipated
- Hydrogen costs decline slower than projected
- Customer willingness to pay limited
- Competitiveness pressures force capacity reductions
- Geopolitical turbulence disrupting markets

Outcomes:

- Transformation achieved but with economic pain
- Some job losses and regional economic challenges
- Technology leadership ambitions partially realized
- Continued heavy reliance on government support

9.3 Pessimistic Scenario: Competitiveness Crisis

Pathway (2025-2050):

- 2026-2030: HyREX pilot fails or severely delayed
- 2030-2040: Conventional BF-BOF increasingly uncompetitive

- 2040-2050: Major capacity closures, production declining to 30-40 MT
- Heavy import dependence for steel

Risk factors:

- Fundamental HyREX technology obstacles
- Hydrogen costs remain prohibitively high
- Trade conflicts severely restricting export markets
- Chinese and other competitors maintaining cost advantages
- Political instability undermining long-term planning

Consequences:

- Massive job losses and regional economic crises
- Downstream industries impacted by supply disruptions
- Loss of industrial sovereignty and strategic capability
- National competitiveness concerns

10 Policy Recommendations

10.1 For Government

Maintain long-term commitment:

- Ensure K-Steel Act implementation across political cycles
- Protect funding allocations from budget pressures
- Resist protectionist pressures that undermine exports
- Build bipartisan consensus on strategic importance

Accelerate hydrogen infrastructure:

- Prioritize import terminal and pipeline development
- Coordinate with Japan, China on regional hydrogen markets
- Diversify supply sources for security
- Support domestic renewable energy and nuclear power

Regulatory modernization:

- Shift from positive to negative regulation where appropriate
- Fast-track approval for green technologies
- Simplify overlapping requirements
- Enable rapid innovation and deployment

Just transition planning:

- Proactive workforce retraining programs
- Regional economic diversification support
- Social safety nets for displaced workers
- Community engagement and participation

10.2 For Industry

Technology development focus:

- Continue aggressive HyREX development with risk management
- Pursue parallel pathways as backups
- Collaborate internationally on pre-competitive research

- Protect but also license IP for technology revenue

Customer engagement:

- Early dialogue with downstream sectors on green steel
- Joint development of certification and tracking
- Transparent communication on costs and timing
- Build value proposition beyond compliance

Supply chain development:

- Invest in scrap collection and processing
- Secure long-term hydrogen supply agreements
- Diversify raw material sources
- Build resilience against disruptions

10.3 For International Cooperation

Technology partnerships:

- Share HyREX learning with potential adopters
- Collaborate on hydrogen infrastructure with regional partners
- Participate in global green steel standards development
- Balance IP protection with knowledge diffusion

Trade coordination:

- Negotiate green steel provisions in trade agreements
- Coordinate with like-minded countries on Chinese overcapacity
- Support multilateral frameworks for carbon border adjustments
- Maintain export competitiveness while decarbonizing

11 Conclusions

South Korea's steel transformation exemplifies the developmental state model adapted for the 21st century climate imperative. The K-Steel Act framework demonstrates how government can coordinate industrial policy, research support, and competitiveness protection within a single legislative framework.

11.1 Key Strengths

Policy coherence and commitment:

- Clear legislative framework with bipartisan support
- Substantial and sustained funding commitments
- Coordination across government ministries
- Long-term planning with accountability mechanisms

Technological innovation capacity:

- HyREX as proprietary, differentiated technology
- Strong R&D infrastructure and investment
- History of successful technology development and deployment
- Integration of industry, government, and academia

Industrial capabilities:

- World-class operational efficiency as baseline
- Financial strength to fund transformation
- Skilled workforce and engineering excellence
- Integration with globally competitive downstream sectors

11.2 Critical Challenges

Resource constraints:

- Hydrogen import dependency creating cost and security risks
- Scrap supply limitations constraining EAF expansion
- Limited domestic renewable energy potential
- Geography and population density constraints

Technological and execution risks:

- HyREX unproven at commercial scale
- Aggressive timelines with limited slack
- Coordination complexity across simultaneous transformations
- Backup plans if primary pathways fail

Geopolitical vulnerabilities:

- US-China tensions complicating trade and technology
- Export market access uncertain
- Regional competition intensifying
- Energy import dependencies

11.3 Broader Implications

South Korea's experience offers important lessons for other countries:

Government coordination value:

- Clear policy frameworks enable industry planning
- Sustained funding commitments reduce investment risk
- Coordination mechanisms overcome fragmentation
- Long-term perspective essential for transformation

Technology sovereignty imperative:

- Proprietary technologies create competitive advantages
- Technology export potential offsets transformation costs
- Reduces dependency on foreign suppliers
- Strategic autonomy in era of geopolitical competition

Limits of industrial policy:

- Cannot overcome fundamental resource constraints
- Market forces constrain policy effectiveness
- International context shapes national options
- Success depends on execution not just planning

Korea's steel transformation journey is being closely watched globally. Success would validate the developmental state approach to industrial decarbonization. Failure would raise questions about ambitious climate targets for trade-exposed industries. The outcome will significantly influence global steel decarbonization pathways and industrial policy debates for years to come.

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