Technological Level of the North Korean Steel Industry and Its Implications for Inter-Korean Cooperation

Jong-seon Kim*

ABSTRACT

North Korea is now under the pressure of international sanctions due to its nuclear tests, firing of long-range ballistic missiles, the sinking of the ROK naval frigate the Cheonan, and the artillery attack on Yeonpyeong Island that killed four people. To overcome the burden of sanctions North Korea has exerted various efforts to reconstruct its industries. However, it is very unlikely that these reconstruction efforts would produce significant results due to the structural problems of the antiquated infrastructure of North Korean industries.

In the future, it is expected that South Korea will have to cooperate with North Korea for the reconstruction of the North Korean economy after the North Korean nuclear issue will be peacefully resolved. South Korean government has to prepare for the reconstruction with careful planning based on analysis of North Korean industries. But, the number of previous studies that have analyzed the technological level of North Korean industries are quite limited.

In preparation for the future inter-Korean industrial cooperation, this study tries to analyze the technological level of North Korean industries. The steel industry has been selected as the focus for the main analysis of this study due to the importance of the steel industry as one of key infrastructure industries. Additionally, this study tests the sustainability of the North Korean steel industry by looking into the possibility of whether the North Korean steel industry can sustain or grow while maintaining global competitiveness in the future when the market opens to the world. Such analysis is expected to contribute to the joint prosperity of two Koreas in the short term and the reduction of unification costs in long term.

KEYWORDS: North Korea, industry, steel industry, Samhwa Iron, sustainability

* Associate Research Fellow, Science and Technology Policy Institute (STEPI)

1. INTRODUCTION

North Korea faces increasingly strict international sanctions that have been put in place due to its provocative acts like the 2nd round of nuclear tests, the launching of long-range missiles in 2009 the sinking of the ROK naval frigate the Cheonan, and the artillery attack on Yeonpyeong Island that killed four people. To overcome the economic constraints, North Korea is now trying to internally rebuild its industries through science and technology achievements while pursuing stronger economic cooperation with China externally.

North Korea has recently signed an agreement with China to develop "Hwangkumpyong Island" in the Amnokgang and is trying to construct highways and railroads that will connect to China near the Najin-Sunbong area to strengthen Chinese-North Korean economic cooperation. These cooperation efforts between North Korea and China are expected to significantly aid in the reconstruction of the North Korean economy over the next 2-3 years.

Internally, North Korea is making industrial reconstruction efforts through science and technology for rebuilding its economy. These efforts have created some changes in the focused areas of development over the past few years (for example, North Korea focused on rebuilding infrastructure industries in 2009). According to North Korea's self-evaluation, it had achieved significant success in steel and vinylon industries through the "150-day battle" and "100-day battle" movements in 2009. In 2011, the country became more interested in light industries related to daily necessities. However, the North Korean economy seems to have improved little despite these efforts. This situation can be inferred from that the New Year's Editorial run by state media reads, "this year, by further stepping up our efforts in light industries, let's make a breakthrough in the process of improving people's lives and building a powerful nation".

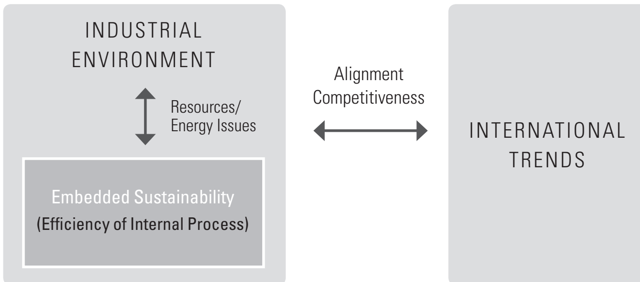
While inter-Korean cooperation is stagnant due to the estranged relations between two Koreas, economic cooperation between North Korea and China is increasing. If the current situation continues, South Korea's influence over North Korea through the means of aid from the South to the North is likely to dwindle. To resolve nuclear issues, various options will be explored including the Six-Party Talks. These positive efforts in these areas are quiet likely to facilitate inter-Korean cooperation in economic development. South Korea needs a strategic approach to overcome its disadvantages as a latecomer since China is already taking its advantages in many areas through bilateral cooperation with North Korea.

To be more effectively prepared for the coming era of inter-Korean cooperation, this study analyzes the technological level of the steel industry (a key industry) in North Korea. Since this analysis will allow South Korea to understand where the North Korean industries stand and it will help South Korea identify the direction and proper strategies for future industrial cooperation with North Korea.

2. RESEARCH METHOD

This study has selected the steel industry, one of the most important industries in North Korea, as the subject for the analysis and analyzes its sustainability. Here, sustainability refers to the level of technological competitiveness in an industry that will determine whether the industry will be maintained or grow when North Korean industries are finally opened to the outer world. Sustainability will be analyzed in three areas. First, the efficiency or the sustainability of the internal process of the steel industry will be analyzed. Next, the sustainability of the steel industry will be analyzed in the context of its relations with the industrial environment. For example, we will examine whether the industry can be sustained under the current industrial infrastructure such as resources or energy. Lastly, sustainability will be analyzed at the macro-level by trying to understand how well the technology development direction of North Korea is aligned with the international technological trends and how competitive North Korean technologies are.

FIGURE 1 Perspectives of Analyzing the Sustainability of the North Korean Industries



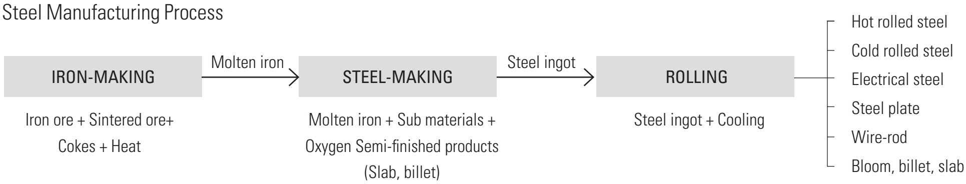
3. LEVEL OF THE NORTH KOREAN STEEL INDUSTRY

There are various industries in North Korea; however, the steel industry forms the basis of all other industries because it supplies steel products consumed by other industries. The steel industry is regarded as the backbone of North Korean industry and has a critical role in the North Korean economy. Based on this understanding, through the analysis of the level of the North Korean steel industry this study try to identify the short-term challenges that North Korean industries face as well as barriers that need to be resolved in inter-Korean cooperation from the long-term perspective of the reunification of the two Koreas.

3.1 Steel Industry in North Korea

Before analyzing the North Korean steel industry, it would be helpful to first review the general steel manufacturing processes. In general, steel manufacturing process can be divided into three sub-processes: iron-making, steel-making, and rolling. First, the iron-making is the process of melting iron ore along with coke. The outcome of this iron-making process is molten iron that contains a relatively high portion of carbon; however, the molten iron is brittle due to the high carbon content. The elimination of some of the carbon from the molten iron is the very essence of the steel-making process; it adds flexibility and hardness to the metal. The steel-making process supplies oxygen and burns carbon contained in the molten iron. The product of the steel-making process is again processed into different shapes through the rolling process.

FIGURE 2 Steel Manufacturing Process



Source: Korea Development Bank (2005)

Among the key representative steel works of North Korea are Kimchaek Iron Works in the east, Hwanghae Works in the west, Chollima Steel Complex, and Seongjin Steel Plant. Kimchaek Iron Works (the No. 1 steel works in North Korea) mainly produces pig iron, steel ingots, and rolled steel products. Kimchaek Iron Works annually produces about 2,167,000 tons of pig iron, accounting for almost 40% of the total pig iron produced in North Korea. It also annually produces 2,400,000 tons of steel ingot (40% of total steel ingot produced in North Korea) and 1,470,000 tons of rolled steel products (36.4% of total rolled steel products in North Korea). Hwanghae Works (North Korea's second largest steel works) produces pig iron and steel ingot as well as processed metals. Hwanghae Works accounts for about 20% of the total steel production in North Korea and annually produces 1,134,000 tons of pig iron (21.0%), 1,145,000 tons of steel ingot (24.1%), and 750,000 tons of rolled steel products (18.6%). Seongjin Steel Plant accounts for about 10% of the annual total steel production in North Korea while Chollima Steel Complex is responsible for more than 10% of steel ingot and rolled steel annually products produced in North Korea.

TABLE 1 Production Capacity of Major Steel Works in North Korea and their Ratio (as of 2004)

(Unit: 10,000 tons, %)

Steel works	Iron-making		Steel-making		Rolling	
	Production Capacity	Ratio	Production Capacity	Ratio	Production Capacity	Ratio
Kimchaek	216.7	40.0	240.0	40.0	147.0	36.4
Hwanghae	113.4	21.0	114.5	24.1	75.0	18.6
Seongjin	48.0	8.9	72.6	12.1	41.5	10.3
Chongjin	96.0	17.7	-	-	-	-
Chollima	-	-	76.4	12.7	55.0	13.6

Source: Korea Development Bank (2005)

The steel industry is viewed as a critical industry by North Korea and much efforts have been to improve the industrial competitiveness; however, North Korea is been very dependent on imported bituminous coal (the source material of coke) as the country lacks domestic mines that produce bituminous coal. Because of the scarcity of bituminous coal, North Korea could supply only 60% of its demand for bituminous coal in 1970. Later in the mid-1970s and the 1980s, North Korea was able to produce a surplus of bituminous coal. However, only about 10% of the bituminous coal demand was supplied when the "Hardship Period" started in the late 1990s. From the 2000s, the situation improved somewhat when about 20% of the total demand for bituminous coal was supplied domestically.

North Korea is also lacks a supply of iron ore in addition to the shortage of bituminous coal. About 90% of the demand for iron ore was supplied during the early 1990s; however, this rate dropped to slightly over 30% in 1998 during the "Hardship Period". The supply rate recovered to more than 50% due to constant efforts to increase the supply of iron ore in the 2000s; however, the supply of iron ore remains in shortage.

TABLE 2 Supply and Demand of Coke in North Korea

(Unit: 10,000 tons, %)

Year	Pig iron production	Demand for coke	Demand for bituminous coal	Supply of bituminous coal	Supply rate
1970	153	92	122	73	59.8
1975	224	135	179	282	157.5
1980	253	152	202	334	165.3
1985	323	194	258	261	101.2
1990	330	198	263	251	95.4
1997	330	198	263	32	12.2
1998	330	198	263	30.3	11.5
1999	330	198	263	68.9	26.2
2000	330	198	263	35	13.3
2001	330	198	263	57.4	21.8
2002	330	198	263	58.3	22.2
2003	330	198	263	71.7	27.3
2004	330	198	263	60.4	23.0

Source: Korea Development Bank (2005)

TABLE 3 Supply and Demand of Iron ore in North Korea

(Unit: 10,000 tons, %)

Year	Total demand for iron ore	Supply volume	Volume in shortage	Supply rate
1970	364			
1980	657			
1990	908	843	65	92.8
1991	908	817	91	90.0
1992	908	575	333	63.3
1993	908	476	432	52.4
1994	908	569	449	62.7
1995	908	422	486	46.5
1996	908	344	567	37.9
1997	908	291	617	32.0
1998	908	289	619	31.8
1999	908	378.6	529.4	41.7
2000	908	379.3	528.7	41.8
2001	908	420.8	487.2	46.3
2002	908	407.8	500.2	44.9
2003	908	443.3	464.7	48.8
2004	908	457.9	450.1	50.4

Source: Korea Development Bank (2005)

The collapse of socialist regimes in other countries and the economic crisis in North Korea during the "Hardship Period" made it more difficult to operate companies in North Korean industries. Steel works that had operated well before were no exception and the production of steel products has become a challenge. North Korea's isolation from the international community and continued economic hardship has made the situation worse. To overcome these difficulties, North Korea is exerting its utmost efforts. For example, during the hardship period, at Kimchaek Steel Works, #2 Electric Arc Furnace was the only furnace in operation from among the five installed electric arc furnaces. In 2009, North Korea restarted the operation of #3 Electric Arc Furnace at Kimchaek Steel Works. The North also touts that it has reduced the production time by improving the container refinery method at Hwanghae Steel Works. Despite various efforts to rebuild industries in North Korea, however, it is still difficult to reconstruct the North Korean steel industry due to the lack of coke and scrap iron and continued economic crisis.

3.2 Sustainability Analysis of Samwha Iron Process (or "Juche Iron")

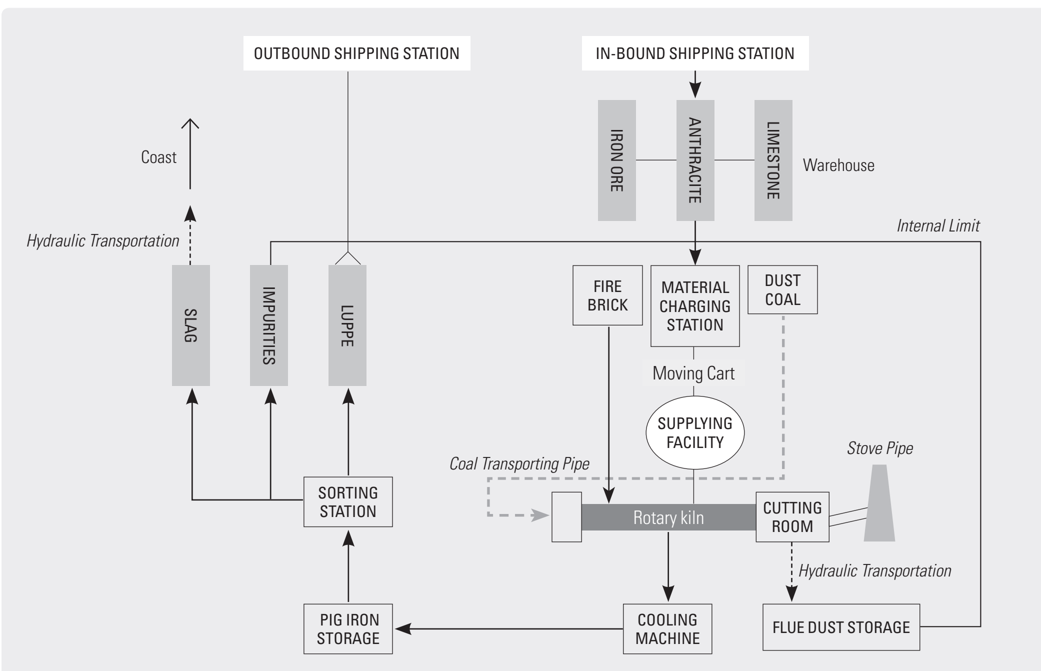
North Korea has developed the Samwha Iron Proces to overcome the shortage of coke and to utilize abundant North Korean iron powder. However, this method has limitations as it requires another round of melting pig iron produced through the Samwha Iron Process so that the carbon contained in pig iron can be removed in the electric arc furnace. For this purpose, electricity should be passed through pig iron produced from Samwha Iron Process. Pig iron with a high carbon content is a poor electrical conduit and it does not melt well in a general electric arc furnace. The electric conductivity of pig iron for the electric arc furnace needs to be increased to solve this problem; for this purpose, North Korea mixes scrap iron with pig iron produced from the Sanwha Iron Process. However, since the start of the "Hardship Period" (due to the economic crisis of North Korea), the volume of scrap iron in North Korea has plummeted (due to selling scrap iron to other countries for their survival) and it has become difficult to import scrap iron from other countries. As result, steel-making using the Samwha Iron Process (about 30% of North Korea's domestic steel production) faces major challenges.

The New Year's Editorial released by North Korea's state media touted that North Korea had invented an innovative method of manufacturing steel from pig iron without using scrap iron by overcoming the limitations of Juche Iron(Samwha Iron). Therefore, this study attempts to analyze the sustainability of Juche iron-making process that the North proudly boasts of.

a. Juche Iron (Samwha Iron) –based Steel-Making Process: A super electric North Korean arc furnace is used in the steel-making process for Samwha Iron. Before analyzing the sustainability of this new manufacturing process, it is necessary to explain the entire process of making Samwha Iron from iron-making to steel-making.

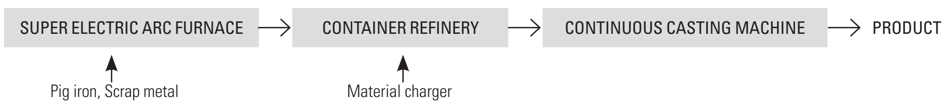
First, the Samwha Iron process starts with the mixing of iron powder, anthracite, and limestone to form a ball. Then these ball-shaped raw materials are charged into the rotary kiln and melted into pig iron; in addition, dust coal is intermediately added to control the temperature of the rotary kiln. It is then sorted using magnets since the pig iron produced from the Samwha iron-making process contains a large portion of slag and impurities (of sorted pig iron, steel content is more than 90% and the carbon content is only about 1.2%).

FIGURE 3 Rotary kiln-based Steel Manufacturing Process using Samwha Iron



Pig iron melted in the rotary kiln is re-melted with a super electric arc furnace. Scrap iron (if it is available) is mixed in the melting process at this stage. Melted iron is poured into containers, which are carried to a refinery station. At the refinery station, additives are inserted and the steel ingot is transported to a continuous casting machine to be molded in different shapes. A roller and cutting machine is then used to create products in different shapes and sizes.

FIGURE 4 Iron-Making, Steel-Making and Casting Processes



b. Sustainability Analysis: The sustainability of the Samwha Iron Process (or Juche Iron Process) will be analyzed in this section; subsequently, data on raw materials and energy consumption needs to be used for this purpose. This study applied resources consumption per unit production of pig iron at the Chollima Steel Complex as the basis for the sustainability analysis.

First, pig iron is produced using a rotary kiln (a key feature of the Samwha Iron Process) at the Chollima Steel Complex. The daily production capacity of the Chollima Steel Complex is about 200 tons and its annual production capacity is around 70,000 tons; however, the Chollima Steel Complex is trying to increase the annual production capacity from 70,000 tons to 400,000 tons as well as diversify the size and specifications of its steel products.

To produce 1 ton of pig iron, the Chollima Steel Complex consumes 22.3 tons of iron ore, 114 kgs of limestone, 1.5 tons of anthracite, and 220 kWhs of electricity. Based on this, the annual consumption of resources is estimated at 156,100 tons of iron ore, 7,980 tons of limestone, 105,000 tons of anthracite, and 15,400,000 kWhs of electricity. The Chollima Steel Complex is trying to reduce the consumption of anthracite and limestone while it strives to increase production volume. As part of this effort, the Chollima Steel Complex has set a future target of reducing the consumption of anthracite from 1.5 tons to 1.1 tons and electricity from 220 kWhs to 110 kWhs when producing 1 ton of pig iron.

TABLE 4 Juche Iron Production Capacity and Resources Consumption per 1 ton of Juche Iron

Index			Current	Future
Production Capacity	Classification		70,000 tons	400,000 tons
	Annual	3.6 X 60m	70,000 tons	150,000 tons
		4.2 X 75m	-	250,000 tons
	Daily	3.6 X 60m	130 tons	200,000 tons
		4.2 X 75m	-	400,000 tons
Consumption per ton	Iron ore		2.230kg/ton	2,200kg/ton
	Limestone		114kg/ton	114kg/ton
	Anthracite		1,500kg/ton	1,100kg/ton
	Electricity		220kwh/ton	110kwh/ton

This study analyzes the embedded efficiency of the Samwha Iron Process that North Korea boasts about from the energy efficiency perspective. For this purpose, we first calculated the energy requirements of the entire Samwha Iron Process. The input energy is assumed as the sum of anthracite and electricity consumption.

It is necessary to understand the heating value of North Korean anthracite to calculate the input energy and the heating value of coal consumed in the steel-making process using Luppe is reference. In manufacturing Luppe, various kinds of coal is used, of which lignite (brown coal) and anthracite are the two main ones. In the case of lignite: it should contain more than 30% of ash, less than 0.4% sulfur, the grain size should be larger than 25 mms, the content of volatile matters should exceed 30%, and the minimum heating value should exceed 18,900kJs per 1 kg. In case of anthracite: it should contain less than 10% of ash, contain 83-85% of fixed carbon, the reaction rate should be between 28-30%, the grain size should be larger than 13mms, and the content of volatile matters should be more than 5%. There are two kinds of anthracite (depending on the sulfur content): one with a sulfur content of less than 0.5% (minimum heating value 27,300 kJs per 1 kg) and the other with a sulfur content of less than 1.0% (minimum heating value 25,200kJs per 1 kg). The Chollima Steel Complex uses anthracite (not brown coal) and its heating value is estimated at 25,000kJ-27-,000kJs per 1 kg.

TABLE 5 Characteristics of Coal Materials used for Manufacturing Luppe

Index	Lignite	Anthracite	
		1	2
Ash (less than x %)	30	10	10
Sulfur (less than x %)	0.4	0.5	1.0
Fixed carbon (more than x %)	-	85	83
Reaction point (950 degrees) (more than x %)	-	30	28
Grain size (bigger than xmm)	25	13	13
Volatile matters (more than x %)	30	5	5
Heating value (more than x kJ/kg)	18,900	27,300	25,200

TABLE 6 Calculation of Energy Consumption in Samwha Steel Process

Classification	Input Volume/ton (kJ/kg or kJ/kw)	Unit energy	Total energy (kJ)	Total energy(kcal)
Anthracite	1,500kg -	25,200 - 27,300	37,800,000 - 40,950,000	9,0720,000 9,828,000
Electricity	220kwh	3,600 (1h = 3,600sec)	792,000	188,000
Total	-	-	38,592,000 - 41,742,000	9,261,000 - 10,017,000

A total of 1.5 tons of anthracite and 220 kWhs of electricity are consumed at the Chollima Steel Complex to produce 1 ton of pig iron. To calculate energy in calories, the heating value should be multiplied by the anthracite tonnage in kilograms, which is 1,500. Depending on the grade of anthracite, the energy value of 1.5 tons of anthracite ranges from 37,800,000 kJs-40,950,000 kJs and the energy value of 220 kWhs of electricity is equal to 792,000 kJs. The total energy input to produce 1 ton of pig iron is the sum of these two numbers that ranges from 38,590,000 kJs-41,742,000 kJs. By converting the unit of these figures into kilo calories, we can estimate the final figures of 9,261,000 kcals-10,020,000 kcals as total energy consumption.

Table 6 shows that to manufacture the Samwha Iron Process (or Juche Iron) that North Korea boasts about, a total 9,261,000 kcals-10,017,000 kcals of energy is required per 1 ton of pig iron.

In the case of using a blast furnace, pig iron moves from a blast furnace to a LD converter and the manufacturing process consumes 2,550,000 kcals; however, in the case of using electric arc furnace, the manufacturing process consumes 3,830,000 kcals. Considering these figures, the manufacturing process of Juche Iron consumes more than three times of energy than a conventional manufacturing processes. This highly energy-consuming structure of the Samwha Iron Process (or Juche Iron) significantly lowers the efficiency of the manufacturing process and weakens its competitiveness.

Juche Iron produced at Samwha Iron Plant is re-melted in a super electric arc furnace. In this process, the capacity of one batch is 30 tons of steel and takes about 90 minutes. Since this is also a type of an electric arc furnace, it requires electrodes and refractory. The super electric arc furnace used in the Samwha Iron Process consumes about 5 kgs of electrode, 30 kgs of refractory, and 500 kWhs of electricity and requires an electric transformer with a capacity of 26,000 kVAs to produce 1 ton of steel.

TABLE 7 Consumption of Energy and Resources by the Super Electric Arc Furnace

Steel-Making Capacity	30 tons/charge
Steel-Making Lead Time	90 minutes/charge
Electricity Consumption	500kwh/ton
Electrode Consumption	5kg/ton
Refractory Consumption	30kg/ton
Capacity of Electric Transformer	26,000kVA

To understand the actual energy consumption of the super electric arc furnace, it is necessary to convert 500 kWhs/ton into joule (J) by multiplying it by 3,600 (or 1,800,000 Js). If we convert this again into calories, we can come up with 432,000 kcals.

Iron melted with scrap in the super electric arc furnace is transformed into steel after going through the container refinery machine. The capacity of the container refinery machine at the Chollima Steel Complex is 30 tons per batch and the refining process takes about 40 minutes. The refining process requires relatively low electricity of about 70 kWhs per ton and requires an electric transformer with a capacity of only 5,000 kVAs. The energy input per ton is about 252,000 kJs (70kWh x 3,6000) or about 60,000 kcals. The refined steel coming from the refinery machine is molded in the continuous casting machine in the various forms needed.

TABLE 8 Consumption of Energy and Resources in Case of Converter Refinery

Refinery Capacity	30 tons/charge
Refining Lead Time	40 minutes/charge
Electricity Consumption	70 kWh/ton
Electrode Consumption	2 kg/ton
Argon Consumption	0.3Nm3/ton
Capacity of Electric Transformer	5,000kVA

TABLE 9 Specifications of Continuous Casting Machine

Production Capacity	300,000 tons
Yield Rate	97%
Length of 1 cut	2.8 - 6m
Radius	R6m
No. of lines	3 lines
Speed of Casting	1.5-3.0m/min.

So far, the entire steel manufacturing process has been reviewed by looking into the process of manufacturing Samwha Iron at the Chollima Steel Complex. The entire process from iron-making to steel-making requires 9,753,000 kcals-10,509,000 kcals of energy per ton. This means the energy consumption level of the Samwha Iron Process is about 3.75 times higher than that of a blast furnace process that consumes 2,600,000 kcals per ton. The Samwha Iron Process consumes about 1.9 times more energy than a general electric arc furnace (about 4,960,000 kcals) when compared to the energy consumption level of a general electric arc furnace. A review of the whole Samwha Iron Process has revealed that the process that North Korea boasts about is inherently less competitive than conventional methods in terms of energy efficiency.

This analysis casts doubt on whether or not North Korea will truly be able to secure world-class competitiveness in its steel-making process even after the country achieves its targets through technological innovation in steel manufacturing. To answer this question, this study analyzes energy consumption based on the operational conditions that Samwha Iron Process considers as ideal. This means the analysis will be based on the following assumptions; anthracite consumption is reduced from 1,500 kgs to 1,100 kgs per 1 ton of pig iron and electricity consumption is lowered to 110kWhs. In this case, total energy consumption of the Samwha Iron Process can be significantly reduced from the current level of 7,396,000 kcals to 6,841,000 kcals. Samwha Iron Process will still be consuming 2-3 times more energy than a blast furnace-based conventional method even if North Korea achieves this ideal situation in the near future. This implies that the Samwha Iron Process (North Korea's breakthrough technology) will face difficulties in securing competitiveness in energy efficiency.

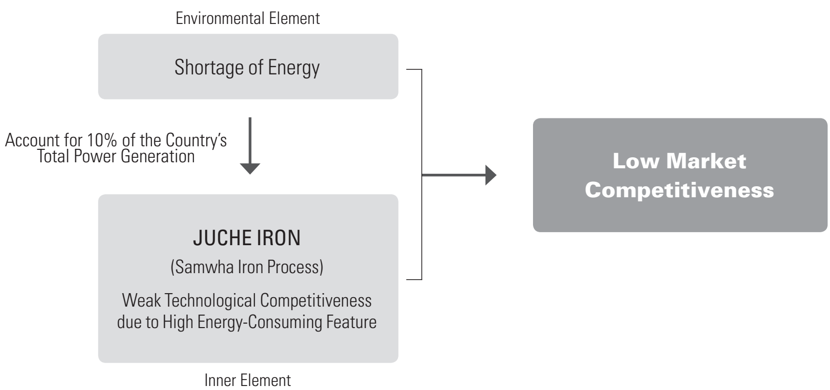
This study will next analyze the feasibility of utilizing Samwha Iron Process nationally (steel production from the Samwha Iron Process accounts for about 30% of the total steel production in North Korea) from the viewpoint of power generation capacity based on the assumption that all input and output conditions of Samwha Iron Process are the same as those of Chollima Steel Complex.

The total volume of power generation in North Korea will be reviewed for this purpose. In 2005, the hydroelectric power generation capacity in North Korea reached 1,240,000kWs and the country's thermal power generation capacity stood at around 600,000-700,000 kWs. The total power generation capacity combined is estimated at around 1,800,000 kWs- 1,900,000 kWs. Here, the power generation capacity means the maximum value of power to be generated by power plants in full capacity utilization. It is very likely that the actual volume of power generation does not reach the maximum level. When assuming a power generation capacity of 1,800,000 kWs and this capacity is fully utilized at 100%, the maximum power North Korea can generate will be around 15,770,000,000 kWhs.

The Samwha Iron Process consumes 790 kWhs of electricity to produce 1 ton of steel in the steel-making process. According to the Korea Development Bank (KDB), the total production volume of the Samwha Iron Process was estimated at 1,776,000 tons in 2004. This means it requires about 1,403,000,000 kWhs of electricity to produce 1,776,000 tons of steel using the Samwha Iron Process (1,776,000 tons x 790 kWhs). This is equal to 8.9% of the total power generated in North Korea when assuming North Korea utilizes 100% of its power generation capacity. When it is assumed North Korea utilizes only 70% of its power generation capacity, the ratio of power consumed by the Samwha Iron Process increases to 12.7% of the total power generation. The Samwha Iron Process accounts for about 30% of total steel production, this ratio of power consumption of the Samwha Iron Process seems quite high. If we take power consumption by other types of steel industries into consideration, this figure implies that the steel industry alone may consume more than 20% of the total power generation of North Korea and there is the possibility of serious power shortages in other industries.

The sustainability of the Samwha Iron Process that North Korea proudly advertises as a historic achievement that is as successful as the third round of nuclear testing, has been analyzed in terms of energy efficiency. The results of the analysis show that, because of the highly energy-consuming structure of the Samwha Iron Process, it is doomed to be less competitive than conventional steel-making processes using a blast furnace. The improved process will remain uncompetitive to conventional manufacturing processes even after technological innovation allows North Korea to achieve a significant improvement in the current Samwha Iron Process. In addition, the Samwha Iron Process places a significant strain on the North Korean power supply as the process consumes far more power than conventional methods. In conclusion, despite pride in Samwha Iron (or Juche Iron), the North Korean steel industry is unlikely to be competitive after the market opens to the outside.

FIGURE 5 Elements of Low Market Competitiveness in Case of North Korea's Juche Iron



4. IMPLICATIONS FOR INTER-KOREAN COOPERATION

The sustainability analysis of the Samwha Iron Process has revealed that the North Korean steel industry has a high energy-consuming structure and is likely to suffer from energy shortages in consideration of the industrial environment that surrounds the steel industry. Compared with international standards, the efficiency of the Samwha Iron Process cannot justify the investment and it is difficult for the Samwha Iron Process to become globally competitive.

Important implications can be drawn from the analysis of technological level of the North Korean steel industry and its future development directions. First, in order for inter-Korean cooperation to successfully support North Korean industrial reconstruction to achieve joint prosperity on the Korean peninsula, it is necessary to define development directions of North Korean industries that possess technological characteristics unique to North Korea including steel (often represented by the Samwha Iron Process) and chemical (represented by vinylon technology) industries. It is also necessary to join the global technology trends while utilizing the proprietary technologies that the North Korean industries possess.

The analysis of this study also helps understand challenges caused by the shortage of energy in infrastructure industries like the steel industry. To overcome these challenges, it would be necessary to promote inter-Korean cooperation to secure energy supply and reduce energy-intensity in industries.

It may take quite a long time to increase the steel supply through the normalization of the steel industry because of the low productivity and outdated facilities of the North Korean steel industry. To normalize the operation of the outdated facilities, significant maintenance and repair efforts are needed. At the same time, to normalize other industries in North Korea, South Korea should support the North by providing extra supplies of steel.

Given the strengths and weaknesses of the industries of the two Koreas, it would be worth to establish and strengthen linkages in an industrial value chain between the two Koreas. A good example of this type of linkage is the allocation of preliminary processing to the North, which would help utilize the cheap but skilled human resources of North Korea. The impact on their economy is expected to be quite significant since this kind of cooperative linkage will offer immediate benefits to both parties.

References

Choonkeun Lee, Jong-seon Kim, Yongho Bae, Myungjin Lee, Taeyoung Shin & Woosung Lee. "Promoting inter-Korean S&T cooperation for joint prosperity", 2009, Science Technology Policy Institute (STEPI).

Jong-seon Kim. "Recent reconstruction of infrastructure industries in North Korea and their sustainability", *STEPI Insight*(2010), Vol. 15, Science and Technology Policy Institute (STEPI).

Jong-seon Kim, Choonkeun Lee, Jieun Seong, Soojung Son & Yongseok Chang. "North Korea's industrial technology development path, its level and plans to strengthen inter-Korean industrial linkage", 2010, Science and Technology Policy Institute (STEPI).

Korea Development Bank. "Industries in North Korea", 2005, Vol. I & II.

Seogki Lee, Seokjin Kim & Kyehwan Kim. "Promoting North Korea's export industries and inter-Korean economic cooperation", 2009, Korea Institute for Industrial Economics and Trade (KIET).

Seogki Lee, Youngseok Oh, Yoonae Cho, Hoon Park, Jinki Hong, Jungsoo Park, Seokjin Kim, Wonbin Lee, & Wookyung Song. "Basic strategy and implementation plan of inter-Korean industrial cooperation", 2007, Korea Institute for Industrial Economics and Trade (KIET).

Seokjin Kim. "Industrial reconstruction in North Korea based on the trade statistics", 2007, Korea Institute for Industrial Economics and Trade (KIET).

Seokjin Kim, Seogki Lee, Kyehwan Kim & Doohee Lee. "North Korea's industrial development strategy based on the case analysis of countries whose political system has been transformed", 2008, Korea Institute for Industrial Economics and Trade (KIET).