Energy and the Environment: Challenges to a Post-Unification Economic Recovery

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Abstract

After unification, Korea will need to address the challenges of failing energy infrastructure and years of environmental degradation in order for the post-North Korean segment of the economy to quickly transition to a market based system and become a source of job creation. The unification of Germany and Eastern European transitions to the free market can provide a glimpse of the challenges Korea may face during this process and the options that exist to address them.

Keywords: Energy, Environment, Unification, Germany, Pollution, Economic Growth

Introduction

After the Berlin Wall came down, people felt a sense of elation and hope that things would improve. Less than a year later the two Germanys were one nation and the process of rebuilding began. As with any endeavor on the scale of reforming and rebuilding a nation of 16 million, over time the inevitable sense of hope and elation gave way to the realization of the scale of the challenges ahead and the sense that the process will not be as quick or as inexpensive as many would have hoped.

While many hope that the process of Korean unification will be as smooth and as successful as the German case, a number of political, societal, and economic challenges must be addressed. The unification of the two Germanys saw a significant rise in unemployment in the East and a slowing of economic activity as the new Länder privatized their economy and moved to a market based economic system. If Korea tries to smooth the economic decline in the North and trigger economic recovery, then rebuilding the North Korean energy infrastructure is essential.

A unified Korea must also address the environmental legacy of North Korea. After the fall of communism in Eastern Europe, significant

efforts were needed to clean up environmental pollution that affected economic production and public health. Rehabilitating the environment in North Korea means more than shifting to cleaner sources of energy and limiting sources of pollution. Any new energy infrastructure in North Korea should play an important role reviving the economy as well as improving sustainability.

Due to the isolated nature of North Korea and a limited amount of available data, planning for unification presents unique challenges. However, while data is often lacking, some does exist in regards to energy and the environment. When combined with an understanding of the case of German unification and the transitions of Eastern Europe it is possible to gain a better understanding of the challenges a unified Korea may face rebuilding the energy infrastructure in the North and reversing a legacy of environmental degradation.

Rebuilding North Korea's Energy Infrastructure

Unification will present new opportunities and challenges for Korea in the area of energy that will likely shape the new energy infrastructure that emerges in the North and play an important role in how economic reconstruction takes place. North Korea's existing energy infrastructure will likely need to be completely rebuilt, but unification will also likely offer the possibility to transition to new, and potentially cheaper, sources of energy.

Today, South Korea is essentially an island, cut off from the Eurasian mainland and its energy resources by North Korea. As a result, it relies heavily on the Middle East for petroleum and natural gas. After unification, previously proposed projects such as a natural gas pipeline from Russia to South Korea via North Korea will become viable. These projects could potentially provide energy to the former South Korean economy at lower cost and serve as a source of energy for economic development in the North.

However, while unification presents new energy opportunities for Korea, any changes to energy infrastructure must meet four criteria. First, the system will need to scale up quickly in order to jumpstart economic growth. Second, the grid must connect electricity and heating to households in a reasonable timeframe. Third, the structure should minimize pollution and emphasize environmentally friendly technologies. Fourth, the grid's design must be flexible and able to match growth in demand. Meeting these demands will likely entail developing a

short-term plan that patches together these immediate needs with an eye towards the development of a long-term system.

The German Experience in Restructuring the Energy Sector

German unification provides a glimpse of the challenges involved in reconstructing North Korea's energy infrastructure. A unified Germany reformed the energy market in the east, quickly integrating the restructured energy infrastructure of the former East Germany with that of the west.

After unification, much of East Germany's infrastructure required significant repairs or upgrades. In the first two decades after unification, an estimated 67 percent of the funds allocated to transforming the East Germany economy were dedicated to infrastructure. At the time of unification, only 43 percent of roads were fit for unlimited usage, while 17 percent of the rail network was damaged. Investments were also needed in telecommunications, power, and the upgrading of buildings.[1]

In the power sector, efforts during the initial five years after unification created an energy infrastructure in East Germany more modern and technologically advanced than West Germany's. This required introducing market forces, privatizing industry, applying the technical skill of private sector companies and an initial investment of 50 billion DM ($30 billion)[2] in restructuring the East German energy infrastructure in those first five years[3].

Germany inherited an infrastructure from the former German Democratic Republic, whose energy policy focused on securing a domestic supply to become self-sufficient. It achieved this through burning indigenous lignite, which accounted for 70 percent of East Germany's power and through gasification of coal to meet the need for gas. East German energy policy also provided the public with energy subsidies and abundant energy, but showed little regard for the environmental impact of its energy policies.[4]

The restructuring in East Germany occurred in large part due to supply side decisions made by large and experienced firms who financed major infrastructure projects. Despite the fact that energy consumption in the East had declined by nearly fifty percent by 1994, these investments were made based on long-term projections of growth and demand[5].

While transitioning East Germany's energy policy occurred relatively quickly, it began prior to unification during the German

political transition and its direction was largely determined by concerns of the potential for an energy shortage in the first winter after unification The objectives of the new policy, which aimed to secure the energy supply during the transition winter of 1990-1991, were to improve the efficiency of a wasteful energy system and to shutter inefficient plants.[6]

Tied to the broad political and economic transition of unification, West German environmental regulations were extended to East Germany. The implementation of West German environmental standards triggered a mixture of closures, construction, and upgrades of plants in former East Germany. As a result, a transition period allowed power plants to meet the new standards. The government required small plants to comply with the new standards by January 1, 1995, large, new plants by July 1, 1996, and old plants deemed uneconomical to refurbish would shut down in 2001.[7]

To achieve these goals, the government privatized the energy market in the former East Germany, introducing competition. As a result, energy prices for industry and commerce moved according to the market. New fuel standards were introduced for motor vehicles, subsidies for gas and electricity for private consumers were ended, and subsidies for residential heating were ended except for those aiding the poor.[8]

Major restructuring also took place in the gas sector and household heating. Because of the limited availability of electricity and heating oil, Germans used brown coal to heat their homes. Household heating shifted to gas and away from coal gasification.[9] As a result, the gas market developed and energy supply diversified. Prior to unification, nine in ten households were heated by coal in one form or another. By 1994, 2.3 million households had modern heating equipment of which 65 percent were gas. By 1995, 13,000 kilometer (km) of high-pressure pipes, 30,000 km of medium- and low-pressure pipes, and 8,000 km of transport pipelines were laid. Five years after unification, 10 billion deutsche mark (DM) ($6 billion) had been invested by the gas industry in infrastructure.

The cost of building new generation and distribution capacity in the East German energy sector reached 50 billion DM ($30 billion) by 1995, with additional costs for installing new heating equipment in households.[10] While impressive, the relatively rapid restructuring of the East German energy infrastructure was shortly followed by a broader nationwide initiative to increase the use of renewable energy as part of a larger European effort to address climate change.

State of North Korean Energy Sector

While East Germany's energy infrastructure required significant investment to increase efficiency and reduce pollution, North Korea's energy infrastructure faces greater challenges and will likely need to be rebuilt rather than rehabilitated.

The North Korean energy infrastructure faces challenges from generation capacity, distribution, and degradation. These deficiencies impact both the livelihoods of North Koreans and the environment. Locations outside of Pyongyang have limited access to energy which is often only available seasonally. As a result, many households face a lack of power that prevents or disrupts pumping water, cooking, and sewage disposal. To compensate they use car batteries to store energy for outages and rely on biomass to heat their homes.[11]

While the energy infrastructure needs extensive renovation, the lack of exact statistics means that only estimates of the needs can be developed. One estimate for the cost of replacing the infrastructure is $10 billion, excluding the cost of replacing control systems, power lines and generation facilities.[12] Given the costs of renovations in East Germany, this may be a low estimate.

Some of North Korea's power is hydroelectric, but thermal plants exist in Pyongyang and the Northeast. North Korea's total energy generating capacity is estimated to range from 6,500 megawatt (MW) to 9,500 MW, with one study estimating that North Korea has 7,242 MW of generating capacity of which 3,200 MW is from thermal power plants and 4,042 MW is from hydroelectric power. However, the amount generated may be significantly lower. North Korea shares hydroelectric power plants with China in Supung, Unbong, Whiwon, and Taepyungman. While these plants are believed to have a generating capacity of 1,780 MW, this is shared between China and North Korea and the actual output is thought to have fluctuated between 27 percent and 47 percent.[13]

North Korea's capacity and actual generation are significantly below those of South Korea. For example, in 2009 South Korea had 73,470 MW of capacity and generated 433.3 kilowatt hours (TWh), while North Korea had 6,930 MW of capacity and actually generated 23.5 TWh.[14] These figures indicate that although North Korea has 9.4 percent of the generating capacity of South Korea, it produced only 5.4 percent of what South Korea did. While a rough estimate, if after unification Korea tried to bring the North up to half of the capacity of the South on a per capita

basis, North Korea would need roughly 11,500 MW of capacity, if North Korea's current 6,930 MW were viable.[15]

Prior to 1945, all of North Korea's power was supplied from hydroelectric plants. However, in the 1950s and 1960s it developed thermal power plants of Eastern European design with funds from China and the Soviet Union. The factories to produce parts for the power plants were built in the 1950s and 1960s as well. Since then, most of the factories have degraded and are either outdated or likely producing products of inferior quality. As a result even repaired power facilities in North Korea are likely well below international standards.[16]

North Korea has built new, small-scale hydroelectric plants to limited effect, but due to the poor transmission network these often only have an impact in the area where the plant was built. The isolated nature of much of North Korea's energy generation has also had an environmental impact with the usage of biomass having doubled since 1990 due to shortages in coal and electricity. This has contributed to deforestation which has increased vulnerabilities to landslides and other natural disasters. In addition, reduced energy supplies and floods have damaged mines[17] leading to a reduction in coal production, further reducing electricity generation.

As of 2009, North Korea's energy mix consisted of more than 50 percent domestic coal, 27 percent was biomass, with refined petroleum products and hydropower each consisting of about seven percent each and the remainder being crude oil.[18] Since the end of the Soviet Union, North Korea has struggled to find supplies of petroleum and survives on a small amount of refined petroleum. The composition of demand has also changed. In 1990, the industrial sector was the largest consumer of energy, whereas now residential users consume the most. The military consumes ten percent, and commercial and agriculture sectors consume five percent each.[19]

Power transmission is also an issue. North Korea loses between 20-30 percent of its electricity between the point of generation and consumption[20] and its electrical grid is separated into two grids operating at different voltages. Transmission and distribution substations and transformers rely on technology that is no longer produced. Before the 1970s, many power lines dated back to the Japanese colonial period. Most of those have since disappeared, while the lines that do exist use different voltages. This increases the difficulty and risk of connecting South Korea's grid to resolve North Korean energy needs. The instability

of the North Korean grid could affect the South Korean grid without preliminary efforts to stabilize and standardize the North's system.[21]

Additionally, the current power distribution system is estimated to suffer from a 5-20 percent loss in voltage, while the power quality and frequency variation are also substandard. The experience of the Agreed Framework demonstrates the challenges a physically degraded and fragmented electrical grid present for the operating requirements of large-scale power sources, such as a light water reactor or power transmission from the South.

Beyond problems relating to generation and transmission, North Korea often lacks adequate and safe storage facilities for fuel. During the Agreed Framework, North Korea was known to use holes in the ground covered with tarps to store the heavy fuel being supplied.[22]

What New Capacity Options Would Korea Have?

When developing new generating capacity, there are a series of factors to consider. These include the current and future costs of the new generating capacity, performance characteristics, construction and operating costs, and how the new capacity will compete against existing capacities. Factors that can influence how a new capacity competes against an existing capacity include government policies such as subsidies and environmental regulations.

In the case of unification, time looms as a more significant consideration than others. Time affects the reconstruction of North Korea's energy infrastructure in two distinct ways: one relates to the balance between quickly scaling up power to revive the economy and create jobs and the second relates to the lack of a target date for unification. Since there is no set date for unification, technologies and costs could change significantly between now and when unification occurs. Thus, rather than developing a plan for reconstructing North Korea's energy infrastructure based on today's technology and prices, a more flexible process should be adopted. In recent years, we have seen the shale gas revolution in the United States change energy markets by driving down the price of natural gas and turning the United States into the world's largest producer of petrochemicals.[23] Similar changes could occur between now and unification.

With that in mind, the following is an effort to lay out some of the possibilities that may exist for reconstructing North Korea's energy infrastructure largely based off of a study of power generating costs done

by the International Energy Agency for plants commissioned in 2020.[24] The International Energy Agency analyzed 181 power plants across 22 countries using different technologies and fuel sources on an adjusted lifetime cost basis and accounting for the cost of carbon emissions. Per Table 1, wind- and gas-powered plants can be constructed faster than other technologies, and gas-fired plants are the least expensive to build.[25] Of note is the increasing price competitiveness of renewable resources since the 2010 version of the study.

Table 1: Projected Costs of Generating Power By Type

Type of Power Generation	Construc-tion Time[26]	Overnight Costs (USD/ kWe)	3% Discount Rate (USD/ MWh)	7% Discount Rate (U.S./ MWh)	10% Discount Rate (USD/ MWh)
Coal Fired w/o Carbon Capture Technology	4 years	1,218-3,067	66-95	76-107	83-119
Gas Fired Plants	2-3 years	845-1,289	61-133	66-138	71-143
Nuclear Power	5-10 years	2,021-6,215	29-64	40-101	51-136
Onshore Wind Power	2-6 months[27]	1,571-2,999	33-135	43-182	52-223
Offshore Wind Power	N/A[28]	3,703-5,933	98-214	136-275	167-327
Residential Solar	N/A	1,867-3,366	96-218	132-293	162-374
Commercia l Solar	16 weeks[29]	1,029-1,977	69-142	98-190	121-230
Large, Ground-mounted Solar	16 weeks	1,200-2,563	54-181	80-239	103-290

Source: International Energy Agency, *Projected Costs of Generating Electricity 2015 Edition*

Possibilities for Restructuring the Energy Infrastructure in North Korea

The challenges of restructuring the energy infrastructure in North Korea will be on a different scale than that of East Germany. Just as East Germany saw a drop in demand for power after unification, there will likely be a similar drop in economic activity in North Korea. However, while that drop in demand did not preclude a smooth transition in Germany, many in North Korea still lack access to power. As was previously discussed, the system will most likely need to be completely overhauled.

Since the system will need to be rebuilt, two urges will need to be avoided. The first would be to rebuild the energy infrastructure as though it was being rebuilt from scratch. While this should be a consideration, especially in terms of thinking through how power can quickly be deployed to remote areas to help spur economic growth, trying to jump to a next-generation (whichever generation that may be) may lead to delays and cost overruns.

The second instinct to avoid is to rebuild North Korea's energy infrastructure in the image of South Korea. For example, a significant portion of South Korea's electricity generation comes from nuclear power. Acknowledging current costs and construction times, greater emphasis on gas-fired plants may better meet the needs for power generation to support economic revival.

A hybrid system that uses existing generation capacity in urban areas until more efficient and environmentally friendly plants are built and creates small-scale solar and wind capabilities in rural areas will best achieve these goals. The creation of mini-grids[30] that could be built into a larger national grid with new storage options, such as used lithium ion batteries, can quickly meet electricity needs in rural areas. At the same time, these solutions must be able to power heating, cooking, and other electronic items. For example, solar-powered cell phones and a cellular network powered by renewable energy could help quickly connect rural North Koreans to the formal banking system and expand business opportunities fairly quickly.

Should relations between North and South Korea improve in the future to the point where energy cooperation is viable, Seoul should engage North Korea on the subject of renewable energy even before unification. North Korea has expressed interest in expanding renewable energies to resolve its energy problems. According to a report, Kim

Jong-un said, "[t]his will resolve our heating problems, and the people will be able to use hot water year-round" when discussing renewable energy and he noted that North Korea "must aggressively develop and utilize renewable energy sources, such as solar heat."[31] North Korea changed its environmental protection laws to promote renewable energy and there are reports it has installed new windmills in the western part of the country.[32]

Some of this is already taking place. The UN Development Program oversees a series of renewable energy projects in North Korea. In rural Hanchon, for example, the UNDP installed small wind turbines on two farms. The turbines generate 300 watts of energy and charge 12 volt batteries. The turbines allow farmers to operate lighting, a television, and other small household appliances. It takes about four to six hours to charge a battery that lasts about a week. Others in the village can bring batteries to be charged. In Pyongsong city, a 5kW wind turbine and a solar panel provide backup power to an emergency room and two operating rooms. These units cost about $30,000.[33] In 2010, a mini 600 kW hydro turbine was installed on a farm in Jangyon county that provides power to 700 households, businesses and community facilities.[34]

South Korean officials should acquire the skills needed to deploy new generating capacity quickly, cheaply, and efficiently across a less than ideal environment. One way to acquire these skills would be to focus a portion of its international development assistance on power generation in remote areas. This would help South Korea to become more familiar with small scale technologies and how to deploy them quickly when unification does occur.

The State of the Environment after Unification

While repairing, revamping, and reconstructing North Korea's energy system will be key to enabling economic recovery in the North, addressing environmental degradation will compete with other priorities such as economic recovery, maintaining stability, providing social welfare and emergency aid to North Koreans, among other pressing needs when unification occurs. However, rather than being viewed as a secondary concern after unification, addressing the environmental damage in North Korea is part of the larger picture of economic and social recovery.

With much of North Korea's infrastructure and industry outdated and

obsolete, and the reality that heavy industry is unlikely to be the key to North Korea's immediate economic revival, putting in place systems that protect the environment would demonstrate the benefits of unification to the North Korean populace, restore lands for agricultural production, and safeguard the health of the population.

Economic recovery, the environment, energy, and health issues are all interrelated challenges that a unified Korea will face. North Korea faces a broken healthcare system and a malnourished population, but health issues are compounded by environmental damage. Improving the environment can play a role in aligning the health of the population with economic revival.

Developing a plan that integrates a revived energy infrastructure and addresses environmental concerns in a sustainable manner requires an understanding of the situation in North Korea. However, a complete picture of the environmental state in North Korea does not exist. While information is available on the level of forest cover, soil damage, and some additional issues, the opaque nature of the regime makes it difficult to know the full extent of any environmental damage in North Korea. However, an understanding of the types of environmental challenges that a unified Korea may face can be developed by considering the types of issues that the transition states in Eastern Europe faced after the end of Communism. These challenges included air pollution, water pollution, deforestation, soil degradation, radiological pollution, and subsequent health consequences to the public.

Environmental Issues in East Germany and Eastern Europe after the Fall of Communism

After the Berlin Wall fell, governments struggled with not only outdated and broken infrastructure, but also a legacy of environmental degradation in East Germany and the rest of the former Eastern bloc countries. While the region as a whole faced environmental challenges, differences in energy production and manufacturing industries resulted in extensive environmental damage to East Germany, Poland, and Czechoslovakia.[35]

East Germany faced a series of environmental problems related to air quality, water quality, deforestation, and contaminated sites. The air quality in East Germany suffered from the burning of brown coal, a highly toxic fuel, in power plants. The level of carbon dioxide per capita reached double that of the West, and sulfur dioxide emissions were five

times those of the West. A lack of wastewater treatment facilities resulted in lakes and rivers polluted by factory sewage.[36] Agriculture and the chemical industry polluted groundwater, and only 17 percent of East Germany's rivers had potable water.[37] A quarter of the East's forests were damaged, and more than 65,000 agricultural, mining, and industrial sites were contaminated.[38] Radiation was also an issue near East Germany's uranium mines and nuclear power plants.[39]

A region known as the "black triangle" near the German-Czech-Polish border suffered some of the worst air pollution. Power plants in the area burned lignite, an especially dirty form of coal. Although the power plants in this region were outfitted with scrubbers to remove particulate matter, they did not remove sulfur dioxide and other gases. As a result of the high concentration of coal burning plants and the lack of effective scrubbers, approximately 20 percent of all of Europe's sulfur dioxide emissions originated in this region.[40]

For many countries, water pollution was a more pressing issue. Heavy industrialization resulted in factories dumping wastewater into rivers with little or no treatment, releasing heavy metals and toxins into the water. Hungary, Poland, Romania, and Bulgaria faced water pollution challenges that exceeded those of air pollution.[41]

Eastern Europe also suffered soil degradation from the overuse of fertilizers and pesticides, over farming, and poor conservation practices.[42]

The Costs of Environmental Damage

The toll of environmental damage on the populations of Eastern Europe can be difficult to trace. However, no doubt the cost of rehabilitating contaminated environments can be regained in the benefit to public health. In the case of Eastern Europe, life expectancy stagnated and fell behind Western countries in the mid-1960s, weighed down by environmental pollution, alongside deficient healthcare and diets.[43]

The case of Katowice, Poland illuminates this distressing trend. At the end of the Cold War, its population of four million suffered contamination from extremely high levels of lead, sulfur dioxide, nitrogen oxide, and airborne dust. Airborne dust exceeded safe limits by 35 times, while lead levels exceeded government limits by 196 times. The soil in and around Katowice exceeded the World Health Organization's recommended limits for lead by 5 to 80 times. Sulfur dioxide levels were double safe limits.[44]

Heavy metal contamination from industry was widespread. Children from Riga had elevated levels of manganese, lead, chromium, and nickel. Children in Poland, Hungary, and Czechoslovakia all had elevated levels of lead in their blood. Due to leaded gasoline in Hungary, children from the Upper Silesia region of Poland ingested contaminates by consuming vegetables grown in local, contaminated soil.[45]

If unmanaged, heavy metal contamination from mining and industrial processes reaches toxic conditions in the soil, and enters humans through the food supply. Among heavy metals, cadmium, arsenic, lead, and mercury are the main threats to human health. Cadmium exposure is linked to kidney damage and cancer in humans. Arsenic exposure is linked to cancer of the bladder, skin, kidney, and lungs. Mercury exposure damages the nervous system. Lead exposure affects the nervous system through learning and concentration difficulties in children, sleeplessness and restlessness. After prolonged exposure, victims suffer memory deterioration, reduced comprehension, and prolonged reaction time.[46]

However, the cost of environmental damage in Eastern Europe is also reflected in shortened life spans and disabilities. In parts of Czechoslovakia, air pollution shortened life spans by an estimated three to four years, while in Hungary the government linked six percent of deaths and four percent of disabilities to air pollution.[47]

Environmental Conditions in North Korea

In 2003, the UN Environment Program, along with the UN Development Program and North Korea's Ministry of Land and Environment Protection produced a report on the state of the environment in North Korea that addressed deforestation, air pollution, water quality, soil degradation, and biodiversity. This report, with recent visits to North Korea, and satellite imagery provide insight into the environmental situation a unified Korea would inherit in the North.

Forest Depletion

Despite reforestation efforts by the DPRK, forest cover in the northern half of the peninsula continues to shrink. Over the last few decades, North Korea has seen its forest cover decrease significantly, especially in the western portion of the country. During the famine in the mid-1990s, significant deforestation occurred as the population sought firewood and cleared land for agriculture.

Between 1980 and 1990, the area of forest in North Korea fell from 74.6 percent of land coverage to 70.5 percent, while the land available for agriculture expanded from 16.9 percent to 19 percent. This trend accelerated in the decade from 1990 to 2000, with forest only accounting for 57.7 percent of land coverage in 2000, while agricultural land grew to 23 percent of land coverage. Grasslands expanded from 4.8 percent in 1990 to 11.6 percent in 2000.[48]

There has also been a decrease in the connectivity of forests. The branches, islets, and edges of the forests that maintain the forest's broader ecosystem have been decreasing. Much as the decrease of connectivity in any ecosystem makes it more difficult to maintain, the loss of connectivity potentially increases the difficulty in reforesting North Korea.[49] At the same time, forests in North Korea face further stress from acid rain and nitrogen from air pollution originating in China and on the peninsula.[50]

The problems from deforestation extend beyond the forest areas themselves, as deforestation contributes to soil erosion and water loss. For example, much of the soil in the Tumen River Basin is susceptible to erosion and the process is facilitated by continued deforestation.[51] Exacerbating the issue, efforts to restore forests face challenges from the poor soil, water issues, and the poor survival rates of seedlings.[52]

Air Pollution

The level of air pollution is largely determined by energy consumption of industry and emissions from power plants, motor vehicles and other sources. Meteorological conditions and technologies, such as scrubbers which clean emissions, also play a role.

In Pyongyang, industry and larger scale electrical production for heating and electricity has a more significant impact on air pollution. As the economy decelerated in the 1990s, the level of particulates in the air fell. At the same time, however, air pollution even with economic deceleration exceeded North Korean environmental standards. Additionally, because coal is an important energy source, sulfur dioxide and nitrogen dioxide emissions are an issue.[53]

Some studies have indicated that the level of sulfur dioxide in urban areas is no greater than in Seoul, while nitrous oxide levels may be lower. However, despite the relatively small size of its economic output, the Global Carbon Project estimates that North Korea is the world's 45th largest emitter of pollution.[54] There is a possible explanation for this.

What industry North Korea does have may emit a high level of pollution, but the lack of vehicles within North Korea's urban centers could leave the air in North Korean cities just as polluted as that in the South when it would otherwise have been worse.

Water Quality

Water management is a serious issue in North Korea. Deforestation in North Korea makes the country more prone to drought and simultaneously more susceptible to flood damage. According to UNEP's report, North Korea faces severe pollution of rivers and streams, with contaminants accumulating at wastewater discharge points on tributaries to the Taedong River. Wastewater carrying fertilizers and pesticides from agriculture, household sewage, and industrial discharge all degrade North Korea's water supply. Wastewater treatment facilities in factories are either outdated or run intermittently.[55]

In the north, the Tumen River basin collects North Korean and Chinese pollution from sources such as the Awudi Chemical Works and the Musan Iron Mine.[56] The recent commodities boom[57] saw increased North Korean mining with no practical increase in wastewater management at new mines. For instance, at the Sangnong mine, some 200,000 people have developed health problems.[58]

Soil Degradation

Flooding, drought, deforestation, overuse of fertilizers,[59] and even poor quality irrigation water[60] have damaged soil in the North. Participants at a 2012 conference in North Korea examined some farmland, observing soil devoid of organic matter and destroyed by over-fertilization. Efforts to restore the soil could take 10 to 15 years.[61]

While soil degradation affects North Korea's ability to grow food, it can also affect the North's ability to produce power. As noted earlier, one of North Korea's primary sources of energy is hydroelectric power. Soil erosion can cause the silting of rivers which, if untended, can negatively affect the functioning of hydroelectric power plants.

Addressing the Environmental Challenges of North Korea

If the history of Eastern Europe is any guide, North Korean efforts to address climate change are unlikely to make much progress. In East Germany, as in much of Eastern Europe, environmental laws on paper gave way to the necessities of economic growth. Often, efforts to address

environmental degradation only materialized after a situation had become so dire that news spread to the wider world.[62]

The collapse of industry in East Germany after unification was a major factor in reducing pollution. As less competitive plants lost demand for their products, their demand for power also fell. When the North Korean economy is opened to international competition after unification, it will likely face a similar pattern.

In the immediate aftermath of unification, policy makers must consider sending water and other vital supplies north to substitute for contaminated supplies. In the short run, policymakers should evaluate which power plants must shut down and which upgraded to reduce air and water pollution. Nuclear facilities, such as the reactor at Yongbyon, should be shut down until a safety evaluation is completed. Policymakers must also determine ways to reconstruct North Korea's power infrastructure in an environmentally friendly manner. Plans must include water treatment facilities and reforestation. With North Korea's increasing expansion of extractive industries, areas with mines will likely face more severe pollution. All of this must be built into a broader plan for restructuring and rebuilding the North Korean economy.

A balance should exist when determining which polluting industries and power stations to maintain in the interest of avoiding layoffs. Local political interests may have a vested interest in existing structures. In Germany, some coal plants were maintained after receiving upgrades and coal continued to be mined so as to avoid job losses at the plants and in the coal mines. This precluded a full upgrade of the East German power system. Korea will face similar challenges.

A unified Korea will also need to address environmental standards in the north. After unification, West German environmental standards were enacted and policy towards the East consisted of three strategies for dealing with environmental issues: avoidance, rehabilitation, and acceptance of responsibility. A series of restoration projects in the decade after unification cost upwards of 200 billion DM ($120 billion).[63] Should South Korea extend its own environmental standards to the north, it must balance how quickly regulations are phased in with environmental needs and economic concerns.

From an economic perspective, the key issue in any environmental cleanup of the north is who should be held liable to pay for it. As sites were privatized in Germany, the new owner became responsible for 10

percent of the cleanup costs, while Treuhandanstalt and the local Länder paid the remainder.[64]

If factories and mines are privatized after unification as in the German case, some form of cost sharing may be appropriate. However, if a unified Korea honored the contracts of foreign firms that had invested in mining and other operations, the principal of 'polluter pays' indicates a greater share ought to be paid out by private firms.

Lastly, beyond the liability of foreign firms operating in the DPRK, there is one international issue to consider. At the recent Paris Climate Conference, South Korea pledged to reduce emissions 37 percent below the 2030 business-as-usual level.[65] The question becomes how to handle emissions after unification. As mentioned previously, North Korea is a large producer of emissions despite its small economy. Closing or restructuring inefficient power plants and industries will reduce emissions, but the North will see a spike in emissions as the economy revives, new power and industry comes online, and motor vehicles proliferate.

With this emissions spike in mind, how a unified Korea minimizes new emissions from economic growth in the north should be handled in a future climate agreement. Such an agreement could include a waiver for emissions in the north after unification, or merely a grace period to cut emissions. Another option might label the territory of the former North Korea as a separate and developing entity for the purposes of any successor agreement requiring a subsequent agreement after the Kyoto Protocol successor to change its status.

Conclusion

Any path to unification, even a long-term consensual one, requires North Korea's energy infrastructure be rebuilt to revive the economy and rehabilitate the environment for public health. The current energy system is beyond repair and likely could not meet the needs of an expanding economy. Without soil restoration and reforestation efforts, North Korea would struggle to grow enough food and face risks from natural disasters.

These two goals are not mutually exclusive. An energy mix of gas-fired plants and smart grid technology, coupled with improved manufacturing technology, should improve the air quality and safeguard the environment from the negative effects of economic revival. Renewable energy infrastructure for North Koreans in rural areas or

areas beyond North Korea's current energy infrastructure could provide access to hot water, heat, and power that could improve health and living standards, reducing reliance on biomass and slowing deforestation and soil degradation trends. A quick build of power in rural areas would also lessen the need for North Koreans in rural areas to migrate after unification.

There are paths forward to grow North Korea's economy while protecting the environment, and some of the groundwork could be laid prior to unification. However, solutions must be flexible to adjust to changing circumstances in the North and to technological and cost shifts in the energy and environmental sectors.

Notes:

[1] Zawilska-Florczuk, Marta and Artur Ciechanowicz. *One Country, Two Societies? Germany twenty years after reunification*. Report. Warsaw: Center for Eastern Studies, 2011. Electronic Document.

[2] As a founding member of the Eurozone the German deutsche mark (DM) no longer exists. The dollar amount listed here is based on the value of the DM in U.S. dollars when accounting records switched from DMs to euros at the end of 1998. This and other U.S. values for DM's in this paper are not in current U.S. dollars, but rather the prior exchange rate. The value used is from the U.S. Federal Reserve's historical currency data accessible here: http://www.federalreserve.gov/releases/h10/hist/dat96_ge.htm.

[3] Hansen, Ulf. "Restructuring the East German energy system." *Energy Policy* (1996): 553-562. Electronic Document.

[4] Hansen, ibid.

[5] Hansen, ibid.

[6] Hansen, ibid.

[7] Hansen, ibid.

[8] Hansen, ibid.

[9] Coal gasification is the process of converting coal into a synthetic gas that was traditional used for the heating of homes and municipal lights.

[10] Hansen, ibid.

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[14] Yoon, Jae-Young, ibid.
[15] Author's calculation.
[16] Yoon, Jae-Young, ibid.
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[18] Hayes, Peter, David von Hippel and Scott Bruce, ibid.
[19] Hayes, Peter, David von Hippel and Scott Bruce, ibid
[20] Hayes, Peter, David von Hippel and Scott Bruce, ibid.
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[22] KEDO, Former Senior Level U.S. Government Officials Involved in. Interview. Troy Stangarone. 10 June 2015. In Person Interview.
[23] Katakey, Rakteem. "U.S. Ousts Russia as Top World Oil, Gas Producer in BP Data." *Bloomberg*. 10 June 2015. Electronic Document.
[24] International Energy Agency. *The Costs of Generating Electricity, 2015 Edition*. 2015.
[25] The discount rate is the balance over an annual period.
[26] Construction times from the International Energy Agency's *The Costs of Generating Electricity, 2010* study.
[27] From the European Wind Energy Association's fact sheet located at: http://www.ewea.org/wind-energy-basics/faq/.
[28] According to Sieman's Fact Sheet on "Industrialization of Offshore Logistics SEA INSTALLER – New Installation Vessel," once an offshore wind turbine is constructed it can be installed in about 24 hours. Additional time would be needed to connect the turbine to a power grid. The fact sheet can be found here: http://www.siemens.com/press/pool/de/feature/2013/energy/2013-01-rotorblade/factsheet-seainstaller-e.pdf.
[29] These estimates are from Vogt Solar's fact sheet on how long it takes to build a solar farm. The fact sheet can be found here: http://www.vogtsolar.co.uk/en/home/why-solar/faqs-solar-farms/.
[30] Mini-grids are decentralized power and distribution networks separate from a main grid.
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[32] Nakano, ibid.
[33] UNDP. "Wind Energy Project Improves Livelihoods in Rural Areas." n.d. *United Nations Development Project.* Website. 13 May 2015.
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[60] Wang and Wang, ibid.
[61] Stone, ibid.
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