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Provision of Humanitarian Energy Efficiency, Renewable Energy, and Micro-Grid Measures to the DPRK as Complementary to Engagement Focused CTR Activities

SEPTEMBER 2021

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ASIA-PACIFIC LEADERSHIP NETWORK (APLN)

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Provision of Humanitarian Energy Efficiency, Renewable Energy, and Micro-Grid Measures to the DPRK as Complementary to Engagement-Focused CTR Activities

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Abstract

A key reason for the Democratic Peoples' Republic of Korea's (DPRK's) development of nuclear weapons and missile systems has been the DPRK's *energy insecurity*, that is, its lack, since the breakup of the Soviet Union, of access to key fuels—particularly crude oil, oil products, and electricity—at affordable prices and in sufficient quantities to develop its economy. A consortium-led humanitarian/capacity-building/engagement project, focusing on the installation of energy-efficiency measures in the Democratic People's Republic of Korea (DPRK) buildings sector and mini-grid systems powered by renewable energy for electricity generation, could potentially be deployed rapidly and would meet the requirements of a substantial pilot engagement project that would contribute toward cooperative threat reduction on the Korean Peninsula. The project would offer positive attributes such as highly visible symbolic improvements for the DPRK energy sector, consistency with DPRK stated interests, limited potential for military diversion, affordability, scalability, humanitarian and economic development elements, and large

scope for face-to-face interactions between North Koreans and the international community. It would also provide a demonstrable model for both future direction in the DPRK energy sector and for productive and cooperative future engagement between the parties as they work toward threat reduction. In order for such a project to be deployed rapidly, it is likely that a consortium of third parties—that is, non-governmental organizations—in the international community will need to plan, organize, and deliver the project, albeit, of course, with the approval and support of the governments involved. The report that follows provides a summary of the authors' estimates of DPRK energy supply and demand, an appreciation for which is important in understanding what the goals of and challenges faced by a cooperative project would be, followed by an illustration of what the project might include, how it might be organized, what organizations and skills would be needed, and an example project budget and timeline, plus thoughts on the types of organizations might be involved in a project consortium, and overall conclusions.

1 Introduction

1.1 Current Setting of Discussions on DPRK Nuclear Weapons Issues

The apparent success of United States President Donald Trump's meeting with North Korean Chairman Kim Jong Un on June 30, 2019 in the Demilitarized Zone on the Korean Peninsula led to hopes of restarting talks between the Democratic People's Republic of Korea (DPRK), the U.S., and others to resolve issues related to the DPRK nuclear weapons and missile programs.[1] In the 20 months (as of this writing) since that meeting, despite sometimes inflammatory and sometimes appeasing rhetoric on both sides, little of a concrete nature has been accomplished in discussions on DPRK issues, although there have apparently been quiet talks behind the scenes between the United States, its allies in the region, and the DPRK that may lay the groundwork for future talks.[2] A late-2020 message from then-President Trump and remarks by the U.S. Secretary of Energy, delivered at an International Atomic Energy Agency meeting, read "[t]he United States remains ready to make progress toward the final, fully verified denuclearization of North Korea, and we urge North Korea to join us in negotiations toward this objective -- thereby ensuring a brighter future for the North Korean people."[3] Perhaps the best that can be said at this point is that further talks do not appear to be out of the question, although it seems likely that substantive discussions with the DPRK leadership may need to wait until the approach to

[1] See, for example, Yonette Joseph (2019), "4 Takeaways From the Trump-Kim Meeting at the DMZ", *The New York Times*, dated June 30, 2019, and available as https://www.nytimes.com/2019/06/30/world/asia/trump-kim-north-korea-meeting.html.
[2] Byun Duk-kun (2020), "Efforts under way with N. Koreans for new opportunity: Pompeo", *Yonhap News Agency*, dated September 15, 2020, and available as https://en.yna.co.kr/view/AEN20200915010100325.
[3] Thomas Maresca (2020), "Trump: North Korea denuclearization efforts should continue", *UPI*, dated Sept. 22, 2020, available as https://www.upi.com/Top_News/World-News/2020/09/22/Trump-North-Korea-denuclearization-efforts-should-continue/8431600762156/.

DPRK engagement that will be embraced by the administration of new United States President Joseph Biden is known.[4]

If talks between the DPRK and the United States, and/or talks between the DPRK and the Republic of Korea (ROK) are restarted, it is likely that leaders will wish to be able to point to an example of successful symbolic and substantive cooperation between the countries as a starting point for deeper engagement and agreement. As the DPRK's "energy insecurity"—including lack of stable, affordable, and clean energy supplies—is a key driver of its pursuit of a nuclear weapons (and weapons delivery) arsenal,[5] a cooperative project offering energy sector assistance is a natural starting point for engagement.

The authors of this paper have previously described a collaborative humanitarian/capacity-building/engagement project, focusing on the installation of energy-efficiency measures in the DPRK buildings sector and mini-grid systems powered by renewable energy for electricity generation.[6] Such a project could potentially be deployed rapidly—over a period of six month to a year, for example—and would "tick the boxes" required of a substantial pilot engagement project. That is, it would offer positive attributes such as highly visible symbolic improvements for the DPRK energy sector, consistency with DPRK stated interests, limited potential for military diversion, affordability, scalability, humanitarian and economic development elements, large scope for face-to-face interactions between North Koreans and the international community, and providing a demonstrable model for both future direction in the DPRK energy sector and for productive and cooperative future engagement between the parties. In order for such a project to be deployed rapidly, it is likely that a consortium of third parties—that is, non-governmental organizations—in the international community will need to plan, organize, and deliver the project, albeit, of course, with the approval and support of the governments involved.

Deploying such a DPRK/international engagement project will require a tightly managed consortium of different actors with diverse and specific skills and capabilities. Such a consortium would likely include:

- NGOs from different nations with expertise in working with North Koreans as well as topical expertise in energy efficiency and renewable energy;
- National institutes—as project advisors, with institute staff possibly involved as individual participants on planning and training tasks;

[4] See, for example, Julia Masterson (2020), "North Korea Douses Hope for New Talks", Arms Control Association, dated March, 2020, and available as https://www.armscontrol.org/act/2020-03/news/north-korea-douses-hope-new-talks.

[5] See, for example David von Hippel and Peter Hayes, "ENERGY INSECURITY IN THE DPRK: LINKAGES TO REGIONAL ENERGY SECURITY AND THE NUCLEAR WEAPONS ISSUE", NAPSNet Special Reports, January 03, 2018, available as https://nautilus.org/napsnet/napsnet-special-reports/energy-insecurity-in-the-dprk-linkages-to-regional-energy-security-and-the-nuclear-weapons-issue/.

[6] David von Hippel, Peter Hayes (2018), "ENERGY ENGAGEMENT OPTIONS TO SUPPORT A KOREAN PENINSULA DENUCLEARIZATION DEAL", NAPSNet Special Reports, May 28, 2018, available as https://nautilus.org/napsnet/napsnet-special-reports/energy-engagement-options-to-support-a-korean-peninsula-denuclearization-deal/.

- Private sector firms with expertise in rapid on-the-ground deployment of infrastructure projects;
- Academics and others for initial planning and parallel capacity-building with North Koreans.

1.2 Role of DPRK Energy Insecurity in DPRK Nuclear Weapons Development

Although the DPRK's efforts to develop nuclear weapons predates its difficulties with obtaining adequate energy supplies, it is clear that the lack of access to affordable and reliable energy supplies—meaning access to oil supplies and a reliable electricity system—has been a major driver of the DPRK's development of nuclear weapons, and, perhaps more accurately, its use of the nuclear weapons issue as a tool to bargain with the international community.

1.2.1 Historical context

The DPRK's first foray into nuclear technologies started in the 1960s or before with joint agreements with the Soviet Union (USSR) on prospecting for uranium and thorium in DPRK territory.[7] The DPRK obtained a small research reactor from the USSR in the 1960s, and developed a nuclear research and isotope production program through the 1970s, and began to acquire technology for reprocessing plutonium from the USSR. In the 1980s, the DPRK developed a graphite moderated reactor—nominally producing 5 electric megawatts (5 MWe), though it is unclear whether the reactor has actually generated electricity—that was ultimately used to produce plutonium for its nuclear weapons, along with uranium milling and fuel rod fabrication facilities. The DPRK signed the Non-Proliferation Treaty in December of 1985 as a non-nuclear weapons state in exchange for an agreement that the Soviet Union would help it to build four light water reactors to supply power for its electricity grid.

In 1991, the DPRK joined the ROK in signing the "…Joint Declaration on the Denuclearization of the Korean Peninsula, whereby both sides promised they would 'not test, manufacture, produce, receive, possess, store, deploy or use nuclear weapons.' The agreement additionally bound the two sides to forgo the possession of 'nuclear reprocessing and uranium enrichment facilities.'".[8]

In the meantime, however, the breakup of the Soviet Union, starting in 1989 with the separation of the satellite states of the Eastern Bloc from the USSR, and culminating in 1991 in the dissolution of the USSR,[9] had a profound effect on the DPRK economy in general, and particularly on its energy sector. 1989 and probably 1990 were arguably the

[7] See, for example, McLaughlin (2017). Other sources refer to a nuclear cooperation agreement signed by the DPRK and Russia in 1959, predated by nuclear prospecting by both the Japanese during World War II and by the Russians as early as 1946.

[8] Nuclear Threat Initiative (NTI, 2018), "North Korea: Nuclear", last updated October 2018, and available as https://www.nti.org/learn/countries/north-korea/nuclear/.

[9] See, for example, BBC News (2013), "Soviet Union timeline", dated 31 October 2013, and available as https://www.bbc.com/news/world-europe-17858981.

last “normal” years for the DPRK economy. Thereafter, subsidized oil exports from the Soviet Union (and now Russia) to the DPRK’s refinery at Sonbong ceased, and had to be replaced with oil purchased at market prices. Moreover, many of the DPRK’s factories had been built with Soviet assistance and relied on spare parts and other supplies from the USSR, materials that were suddenly much less available, as the economies of Russia and the other Soviet Bloc countries retooled. Perhaps the most significant blow, however, was that the markets for many of the goods that the DPRK had previously exported to the USSR—goods made in the factories that the USSR helped to build—ceased to exist, leaving the DPRK without both cheap oil and the income needed to pay for oil at international prices. Many of the power plants in the DPRK—particularly the coal-fired plants—although they burned (and continue to burn) domestic coal, were equipped by the USSR, and also depended on USSR spare parts, as did the transmission and distribution system (T&D). All of these parts became much more difficult for the DPRK to acquire after 1990. Per capita energy use as of 1990, before the impacts of the collapse of the Soviet Union on the DPRK economy had been felt—was about 70 gigajoules (GJ). By 2010, by our estimates, per capita energy use had fallen to about 26 GJ, indicating a severe restriction in the energy services—such as heated homes, lighting, kilometers traveled, and industrial products manufactured—available to the DPRK populace.

As its energy problems mounted the DPRK looked to the development of nuclear technologies as a means to provide reliable electricity supplies and, perhaps more importantly, as a way to get the attention of the international community in order to obtain energy and economic assistance. Put a different way, one could argue that facing severe energy security problems, and with little to sell on international markets, the DPRK ramped up production of the one commodity on which it could reliably trade in the international community: threat, including the threat of instability and even collapse—an unnerving prospect for the DPRK’s neighbors--arising from energy deficits and related shortages of critical goods that could lead to massive humanitarian impacts inside the DPRK itself. This is, of course, necessarily a much-simplified explanation of the complex motivations behind the DPRK’s nuclear weapons program. An international crisis related to the DPRK’s production of fissile materials ultimately led to the signing of the Agreed Framework in late 1994, under which, in exchange for the DPRK freezing its nuclear weapons program, a group of international partners under the auspices of the Korean Peninsula Development Organization (KEDO) provided, for a number of years, shipments of heavy fuel oil (which is of limited utility to the DPRK, but also has limited potential for military diversion) to the DPRK, and began the process of constructing two commercial-scale nuclear power reactors at the Simpo site on the DPRK’s east coast. Disagreements between the Agreed Framework parties and the DPRK, including revelations of ongoing nuclear weapons-related research, and delays in completing the reactors at Simpo (no nuclear components were ever installed for those reactors, although significant site work was completed) ultimately led to the failure of the Agreed Framework, and to the suspension of KEDO in the mid-2000s. Since that time, negotiations between the DPRK and groups of international partners, including the “Six Party Talks” of the 2000s, have focused on working to bring the DPRK’s nuclear programs under international oversight, and ultimately to end the DPRK nuclear weapon program. These negotiations have all either explicitly or implicitly included, as an inducement to the DPRK (a “carrot”, in the “carrot and stick” model of rewards and punishments) elements of energy provision to address the DPRK's ongoing energy insecurity.

1.2.2 Description of Nautilus Estimates of Recent and Current Energy Supply and Demand in the DPRK

Although energy supply and, particularly, demand statistics are less complete than analysts might prefer in many countries, the DPRK is an outliner in terms of information provision, as it publishes essentially no direct information on its energy supply and demand. At the same time, its "energy insecurity"—that is, its lack of access to fuels, particularly petroleum fuels and electricity, and the energy services that those energy forms provide, has been and continues to be, a key driver of its decision to pursue nuclear weapons and related missile technology development over the past three decades. As such, understanding the DPRK's fuels supply and demand situation is critical to understanding potential solutions to the current political stalemate that international community actors might pursue, particularly including what form of energy aid might be most effective in securing the DPRK's cooperation.

Given the need to understand the DPRK energy sector, and the lack of direct data available, Nautilus Institute has built and periodically updated its analysis of North Korean energy supply and demand by collecting as much available public sector data relating to energy use and the DPRK economy as possible, including anecdotal information from visitors, customs statistics from the DPRK's trading partners, estimates on sectoral output by international and other organizations, and analyses of the DPRK economy by other researchers. This information was and is used to compile a "bottom-up" (demand-driven) analysis of changes to the DPRK economy, starting in 1990 (the last "normal" year for DPRK energy supply and demand), using as much sector detail as can be included. In order to ensure that these estimates are internally consistent, we use an "energy balance" approach widely used to report national energy supply and demand worldwide, for example, by the International Energy Agency (IEA).[10]

Our DPRK energy analysis works includes the preparation of energy balances—in which supplies (imports, exports, domestic production) of fuels are balanced by their use and conversion to other forms via energy transformation processes such as oil refining and electricity generation, and, ultimately, by end-use demand—for all of the fuel categories used in the DPRK economy.[11] Our most recent estimates of DPRK supply and demand are

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[10] See, for example, the IEA compendium available for sale at http://data.iea.org/payment/products/117-world-energy-balances-2019-edition-.aspx, or the energy balances published by the Korea Energy Economics Institute for the Republic of Korea (ROK) as a part of (for example) *Energy Info Korea 2017*, available as http://www.keei.re.kr/keei/download/EnergyInfo2017.pdf.

[11] Previous versions of our DPRK energy analysis work for all fuels are David von Hippel and Peter Hayes (2012), *Foundations of Energy Security for the DPRK: 1990 – 2009 Energy Balances, Engagement Options, and Future Paths for Energy and Economic Development*, dated September 13, 2012, and available as http://nautilus.org/wp-content/uploads/2012/12/1990-2009-DPRK-ENERGY-BALANCES-ENGAGEMENT-OPTIONS-UPDATED-2012_changes_accepted_dvh_typos_fixed.pdf; and David von Hippel and Peter Hayes (2014), *An Updated Summary of Energy Supply and Demand in the Democratic People's Republic of Korea (DPRK)*, NAPSNet Special Reports, April 15, 2014, available as http://nautilus.org/napsnet/napsnet-special-reports/an-updated-summary-of-energy-supply-and-demand-in-the-democratic-peoples-republic-of-korea-dprk/

provided in section 2 of this paper, and include an attempt to estimate DPRK supply and demand not only in 2019—for which very little of the usually sparse customs data on DPRK energy trade with other nations is yet available—but for 2020. 2020, the exceptional coronavirus-dominated (severe acute respiratory syndrome coronavirus 2—SARS-CoV-2, or COVID-19) year during which this paper is being written, is highly unusual in terms of energy use for most of the nations of the world, and the DPRK is no exception. Recovery from the situation in which the DPRK finds itself as a result of COVID-19 is part of the background that the international community will need to factor in as it develops proposals to induce the DPRK to return to and engage meaningfully at the bargaining table on nuclear weapons and related issues.

1.2.3 Importance of Engagement on Energy Sector Issues with the DPRK as a Part of Cooperative Threat Reduction Plus ("CTR+")

The availability of energy services at least sufficient to provide for basic needs, as well as for poverty reduction and economic growth, and of the energy supplies that provide energy services, is crucial in any nation. The DPRK has for much of the past 30 years suffered from levels of energy services inadequate to fully provide its population with basic needs such as a sufficient diet, transportation, heat in the winter, and cooking fuel, and other needs. The United Nations Security Council (UNSC) sanctions on DPRK oil imports, and of exports of coal, labor, and other commodities, have caused additional reductions in energy services through reduction in energy supplies and in the income needed to provide the funds to pay for fuels (imported or domestic), and have induced the DPRK to seek other, "unofficial", means of both obtaining fuel supplies and earning hard currency.[12] We would argue that the DPRK will never agree to measures to reduce its nuclear weapons program without seeing and receiving international assistance to progress on a path forward to economic development, and economic development will in turn require, along with non-energy material, policy, and other inputs, addressing the DPRK's "energy insecurity".

Cooperative nuclear threat reduction activities engaging the DPRK at virtually any level will therefore benefit from being integrated with energy sector assistance activities aiming to assist with development of peaceful economic opportunities for the DPRK, emphasizing employment growth, humanitarian benefits, and interaction with representatives of the international community. These interactions will necessarily involve official diplomacy, but should also include interactions at various technical levels, vastly outnumbering gatherings of negotiators, to provide North Koreans with increasing familiarity with working with foreigners, which we have found to be a key to promoting improved and improving cooperation.

1.3 Road Map of Remainder of Paper

In the remainder of this Report, we provide a summary of Nautilus's recently-updated estimates of the DPRK energy supply and demand situation, including a discussion of the

[12] See, for example, David von Hippel and Peter Hayes (2020), *UPDATED ESTIMATES OF REFINED PRODUCT SUPPLY AND DEMAND IN THE DPRK, 2010 – 2020*, NAPSNet Special Reports, September 02, 2020, https://nautilus.org/napsnet/napsnet-special-reports/updated-estimates-of-refined-product-supply-and-demand-in-the-dprk-2010-2020/.

implications of the results of our analysis for the prospects for efficiency and renewable energy in the DPRK. We then describe the key elements of a rapid-deployment energy-efficiency/renewable energy demonstration project (though many variant projects within this theme are possible), list the key tasks needed to develop and deliver such a project, offer ideas as to what types of organizations and individuals might be good candidates to participate in the different phases of the project, provide an illustrative budget and timeline for the project, and provide conclusions as to what type of support might be needed to enable such a project, key project risks and how they might be ameliorated, and describe how the project might be built upon as negotiations and engagement continues, as well as how the project might provide a driver for economic development in the DPRK.

2 Summary of Nautilus Estimates of Recent and Current Energy Supply and Demand in the DPRK

Direct information on DPRK energy supply and demand is scarce. The DPRK has not published comprehensive energy statistics for decades, and what data are available, for example, official news reports, are typically incomplete, fragmentary, or not entirely clear. Nonetheless, as the DPRK's energy situation is a key (though not the only) reason for the DPRK's pursuit of nuclear weapons and missile technologies, it behooves the international community to understand the DPRK energy situation to the maximum extent possible, as the energy sector has and will continue to provide a constructive area of engagement with the DPRK.

To that end, Nautilus Institute has been working since 1994 to develop and update an internally-consistent assessment of DPRK energy supply and demand, assembling and evaluating all of the information we could access, and using the international standard "energy balance" framework to make sure that assumptions as to DPRK energy supply and demand match for each fuel and in each year. This framework, and the accrued databased of information, allows us to track DPRK energy supply and demand over the years, albeit in an approximate way that is necessarily limited by the available data. Our understanding of energy supply and demand in the DPRK informs a projection of what types of energy efficiency and renewable energy (EE/RE) measures might be attractive for application in the DPRK. We have also been fortunate to have the input, in the context of both EE and RE-focused missions to the DPRK (1998, 2000, and 2009) and in international workshops involving DPRK delegations (1997 through 2019), of DPRK experts themselves, which have allowed us to gauge the interest in and potential for update of different energy sector measures in the DPRK.

We have recently undertaken an update of our DPRK Energy Sector Analysis through the year 2020. Although a full report on that update is still forthcoming, below we provide some of the highlights of our analysis, followed by some thoughts on the implications of our analysis for the design of an EE/RE/CTR+ engagement project.

2.1 Introduction to Nautilus DPRK Energy Analysis Update (2020)

The last full published update of Nautilus Institute's DPRK Energy Analysis was published in 2012.[13] Since that time, we have continued to collect information from all publicly available sources to estimate DPRK energy supply and demand, most recently in the years 2014 through 2020. For this work, we use analysis published by other experts, international customs data (for trades with the DPRK as recorded by its trading partners, news reports (including Korean Central News Agency—KCNA—and other press releases by the DPRK itself), satellite imagery (Google Maps and Google Earth), the anecdotal accounts of recent visitors to the DPRK, and any other germane information sources we could access. The collected information was organized into a set of calculations covering each demand sector and the various energy transformation processes (such as coal mining, oil refining, and electricity generation) in use in the DPRK. The calculations generally estimate economic and energy sector data based on conditions in 1990, which we use as a reference year. We emphasize that the results shown below are estimates. To our knowledge, no one outside the DPRK, and possibly not even anyone **inside** the DPRK,[14] has both complete and accurate knowledge of current and/or historical energy supply and demand in the DPRK.

As noted above, our current update of our DPRK Energy Sector Analysis runs through 2020, a year not yet concluded as of this writing. We have therefore prepared rough estimates of 2020 DPRK energy demand based on a set of informed assumptions about the DPRK's response to the COVID-19 pandemic. Officially, the DPRK has as yet reported no internal cases of coronavirus during the current global pandemic,[15] although it reported that an individual who crossed the border from the ROK to the DPRK in the Kaesong area may have been infected. The report of no COVID-19 infections, however, appears at odds with DPRK requests for corona-virus related supplies from Medecins Sans Frontieres, UNICEF, the WHO, and others, as well as reported quarantines of foreigners and DPRK citizens, and the use of facemasks in the DPRK by most residents pictured in recent photos (with the exception of Chairman Kim Jong Un). Reports by observers outside the DPRK, including those receiving intelligence briefings, include descriptions of hundreds of covid-19 deaths among soldiers, a one-month military "lockdown", quarantines of thousands within and outside of the military, and other evidence of significant changes in life in the DPRK in recent months.

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[13] David von Hippel and Peter Hayes (2012), *Foundations of Energy Security for the DPRK: 1990 – 2009 Energy Balances, Engagement Options, and Future Paths For Energy and Economic Development*, dated September 13, 2012, and available as http://nautilus.org/wp-content/uploads/2012/12/1990-2009-DPRK-ENERGY-BALANCES-ENGAGEMENT-OPTIONS-UPDATED-2012_changes_accepted_dvh_typos_fixed.pdf

[14] Based on our observations, information in the DPRK is highly compartmentalized, with few or no individuals, possibly with the exception of Chairman Kim Jong Un, having comprehensive access to full energy sector data. Even for the DPRK's top leaders, it is unclear that their picture of DPRK energy statistics will be fully accurate, as there is a tendency to adjust performance data as it is passed up the chain of command to conform with expected results.

[15] South China Morning Post (Agence France-Presse), 2020, "North Korea insists it has no coronavirus cases, thanks to shutting borders, containment", dated 3 April, 2020, available as https://www.scmp.com/news/asia/east-asia/article/3078226/north-korea-insists-it-has-no-coronavirus-cases-thanks-shutting.

Whatever the actual covid-19 situation is in the DPRK, it is clear that the DPRK's response to the pandemic has changed the way that the country operates its economy, including its energy sector. Worldwide, national and local "lock-downs" and "stay-at-home" orders have resulted in vast reductions in energy demand, particularly for transportation, in part causing, among other impacts, a vast drop in oil prices, and rapidly filling oil and gas storage depots. The DPRK's energy supply situation is unlike that of other countries, particularly for oil products, due to UNSC sanctions and resulting restrictions on its oil imports. This requires the DPRK to use "unofficial" means to obtain much of its oil supplies and export much of its coal, strategies that are likely more difficult to carry out during the pandemic, due to the need for cooperation by outside trading partners.

The coronavirus pandemic has thus undoubtedly affected DPRK energy supply and demand. Because of the lack of information from the DPRK itself, and because most of the year 2020 lies ahead, this estimate has been guided by a set of assumptions how the COVID-19 situation is changing the DPRK economy. Below we present our assumptions, based on various news reports, about how the DPRK is responding to the coronavirus pandemic. These assumptions drive the estimates of 2020 energy supply and demand in the DPRK reported in the remainder of this section of this paper.

Some of the reported changes in the DPRK that would affect 2020 (and perhaps 2021) energy supply and demand in the DPRK include:

- Quarantines of thousands of individuals, with an April 28 report stating that the DPRK has extended its "COVID-19 National Emergency" through the end of the year, including a strengthening of quarantine procedures.[16]
- A one-month military "lockdown" in February and March, with at least a subsequent (though directly COVID-19-related) reduction in military drills due to summer flooding in the DPRK.[17]
- Curtailing of border crossing and travel between the DPRK and China, apparently since January 26.[18] More recent news reports suggest that these restrictions will continue for some months.[19]
- "[W]idespread stories of inflation and the hoarding of critical goods. Many schools have been closed [apparently, from at least February 20 through April 15, based on

[16] Hyemin Son, Leejin Jun, and Eugene Whong (2020), "North Korea Extends COVID-19 National Emergency to End of Year", *Radio Free Asia*, dated 2020-04-28, and available as https://www.rfa.org/english/news/korea/national-emergency-04282020184222.html?utm_source=AM+Nukes+Roundup&utm_campaign=ba43f31c3a-EMAIL_CAMPAIGN_2018_07_25_12_19_COPY_01&utm_medium=email&utm_term=0_547ee518ec-ba43f31c3a-391728633.

[17] Jeong Tae Joo (2020), "Summer military drills stalled as soldiers sent to flood-ravaged areas", *Daily NK*, dated 9-3-2020, and available as https://www.dailynk.com/english/north-korea-summer-drills-stalled-soldiers-sent-flood-ravaged-areas/.

[18] Gabriela Bernal (2020), "North Korea's silent struggle against Covid-19: Sources inside report via smuggled cellphones that official and unofficial measures have been surprisingly effective", *Asia Times*, dated March 31, 2020, available as https://asiatimes.com/2020/03/north-koreas-silent-struggle-against-covid-19/.

[19] *Radio Free Asia* (2020), ibid.

Asia Times reporting], social gatherings have been limited, and much tourism is suspended."[20] More recent reports suggest that DPRK schools closed again in July after reopening.[21]

- Announcement of construction of a new, modern hospital in Pyongyang.
- Shutdown of most air, rail, road, and ship travel into and out of the country.
- A "huge economic loss" reported by DPRK state media.[22]
- An increase in the "price of gas", presumably gasoline.
- Issues with industrial output due to lack of inputs and spare parts from China, affecting the mining sector as well.[23]
- A crackdown on cross-border smuggling.
- A demonstrable idling of the DPRK's maritime fleet, including many of the ships that have been implicated in unofficial trade in coal and oil products, starting with a recall of ships on January 22.[24] The *New York Times* summary of the situation as of late March concluded "The long-term disruptions to North Korea's revenue stream remain unclear, partly because the duration of the pandemic and its impact on maritime commerce are not yet known. But analysts said it was reasonable to assume damage has been done to North Korean agriculture, industry and the overall economy."

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[20] Mitchell Lerner (2020), "History Shows North Korea Will Respond to the Coronavirus by Lashing Out: Will the pattern repeat?", *National Interest*, April 1, 2020, available as https://nationalinterest.org/blog/korea-watch/history-shows-north-korea-will-respond-coronavirus-lashing-out-139732.

[21] Colin Zwirko (2020), "North Korean schools close one month into new term, sources say: Earlier reports indicated COVID-19 is to blame for ending an already-delayed school year", *NK News*, dated July 7, 2020, and available as https://www.nknews.org/2020/07/north-korean-schools-close-one-month-into-new-term-sources-say/.

[22] Chad O'Carroll (2020), "COVID-19 in North Korea: an overview of the current situation: Pyongyang officially claims no infections within its territory, and has taken strict steps to stave off an outbreak", dated March 26, 2020, available as https://www.nknews.org/pro/covid-19-in-north-korea-an-overview-of-the-current-situation/?t=1585236870435.

[23] Benjamin Katzeff Silberstein (2020), "The North Korean Economy: Coronavirus Measures Causing Economic Anxiety", *38 North*, dated March 27, 2020, available as https://www.38north.org/2020/03/bkatzeffsilberstein032720/.

[24] See Christoph Koettl (2020), "Coronavirus Is Idling North Korean Ships, Achieving what Sanctions Did Not", *New York Times*, dated March 26, 2020, available as https://www.nytimes.com/2020/03/26/video/coronavirus-north-korea.html, which also quotes Royal United Service Institute (RUSI) Project Sandstone (2020), "Rickety Anchor: North Korea Calls its Illicit Shipping Fleet Home amid Coronavirus Fears", dated 26 March 2020, and available as https://rusi.org/commentary/rickety-anchor-north-korea-calls-its-illicit-shipping-fleet-home-amid-coronavirus-fears.

2.2 Summary of Energy Supply Situation

The main fuels used in the DPRK are coal, biomass, petroleum products, and electricity. Of these, coal and biomass are sourced primarily from domestic supplies, while virtually all oil products are either imported or are refined in the DPRK from crude oil imported from China. Electricity production is mostly in thermal power plants fueled with coal, and in hydroelectric plants. Figure 2-1 shows estimated DPRK supplies of fuels in 2019, and Figure 2-2 shows our estimates of how DPRK fuel supplies might look in COVID-19-afflicted 2020.

Figure 2-1:

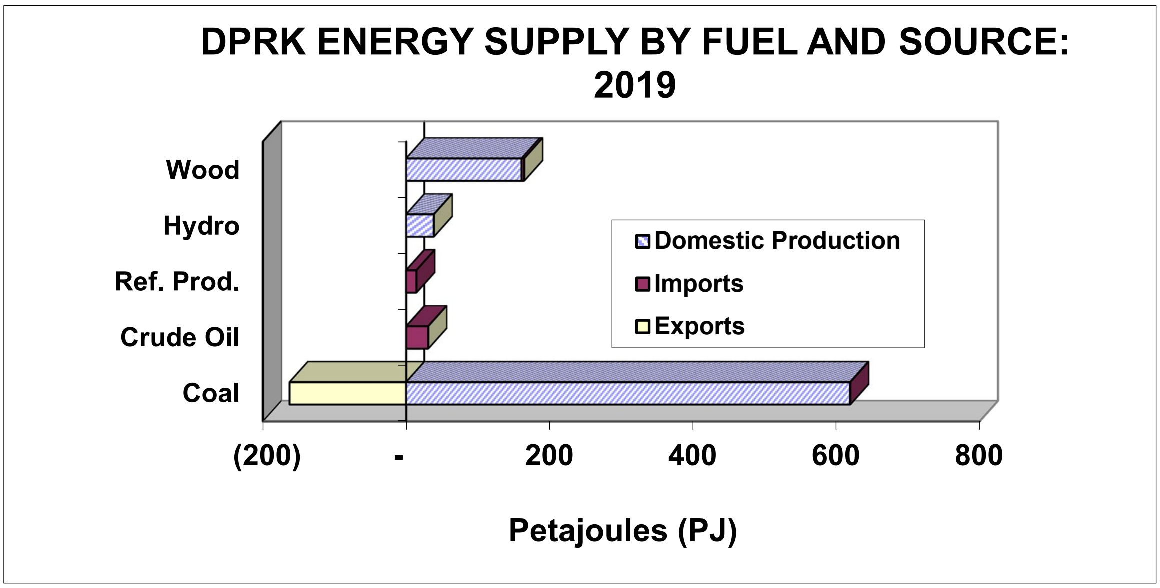
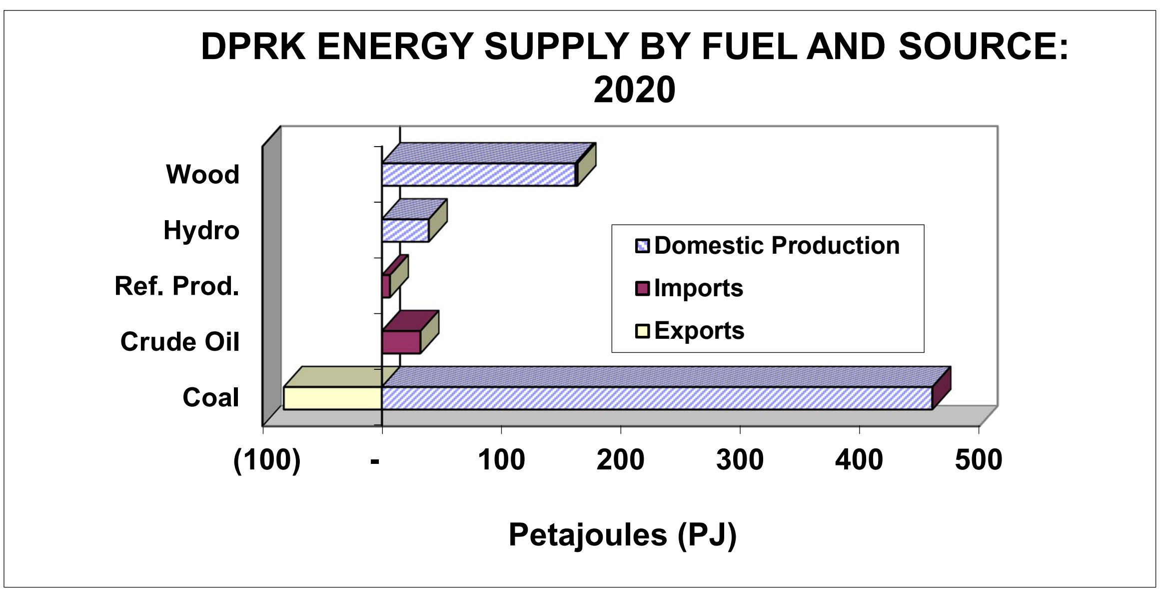


Figure 2-2:

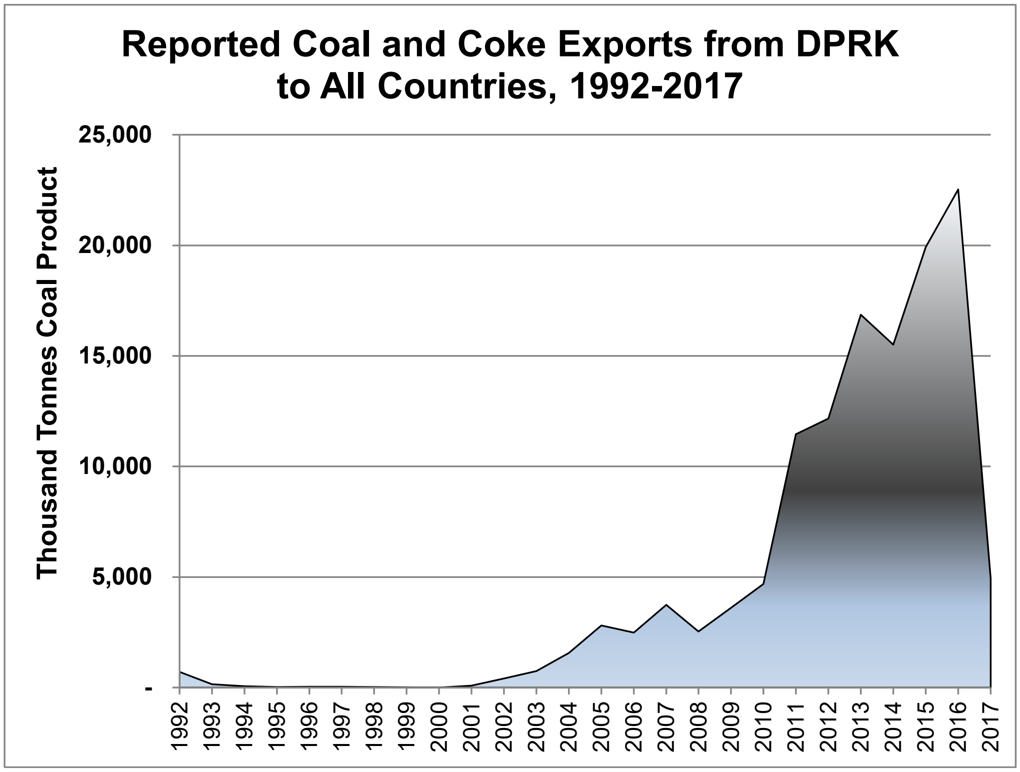


2.2.1 Coal

The DPRK has abundant coal resources, including deposits of anthracite coal and lignite, or "brown" coal. It substantially lacks, however, bituminous coal, which is the most common coal used worldwide as an input to coke production for steelmaking, and as a power plant fuel. Coal quality in the DPRK seems to be quite variable, with reported energy contents for different DPRK coals ranging from a very low 1000 and 2300 kilocalories (kcals) per kilogram for "low grade coal" (lignite and anthracite, respectively) to a relatively high 6150 kcal/kg for high-grade anthracite coal,[25] The DPRK's total coal resource or reserves have been variously estimated at levels ranging from 600 million tonnes ("proven coal reserves", and "recoverable coal reserves", as noted in international compendia of energy statistics[26]) to resources ("coal deposits") of nearly 15 billion tonnes. DPRK coal production has by our estimate varied over the year, falling to a low of about 340 PJ (petajoules, or about 11.5 million tonnes of coal equivalent (TCE) in 2000 before rebounding in the 2010s due to rapidly expanding exports of coal to China. Coal exports to China rose dramatically starting in about 2010, to over 22 million tonnes by 2016, almost all of which went to China (see Figure 2-3). Coal exports, or at least reported exports, have fallen dramatically since then as a result of UNSC sanctions, although we estimate, based on information compiled by the UN Panel of Experts, that the DPRK may have managed to export on the order of 5.5 million tonnes of coal in 2019.[27]

[25] Choi Su Young (1993), *Study of the Present State of Energy Supply in North Korea*, RINU, 1993. P. 14.
[26] For example, U.S. Department of Energy's Energy Information Administration (2018), "North Korea", updated June 2018, and available as https://www.eia.gov/international/analysis/country/PRK.
[27] The UNSC "Panel of Experts" in UNSC (2020), *Note by the President of the Security Council, number S/2020/151*, dated 2 March 2020, and including "Annex: Letter dated 26 February 2020 from the Panel of Experts established pursuant to resolution 1874 (2009) addressed to the President of the Security Council", available as https://undocs.org/S/2020/151.

Figure 2-3:



2.2.2 Wood and Biomass

After 1990, as the availability of commercial energy (electricity, oil, and coal) to households and other DPRK energy users fell, biomass (including wood) energy use rose to fill the gap, particular for end-uses such as cooking and heating. Biomass energy was and is an imperfect substitute for the fuels it replaced, probably in most cases providing only some of the energy services than were supplied by other fuels (for example, less heat), and providing those services at lower energy efficiency. Heavy biomass use in the DPRK has led to deforestation and soil degradation, as deforested slopes have been subject to erosion and landslides. We estimate total DPRK wood production for all uses (but mostly for energy) of about 6.5 million tonnes in 2019, and perhaps slightly higher in 2020, with COVID-19 quarantine measures meaning more time spent at home by household members and less access to commercial fuels. We estimate that the DPRK used another 4 million tonnes of crop wastes and other biomass for fuel in each of 2019 and 2020.

2.2.3 Crude Oil and Oil Products

The DPRK obtains the petroleum products that are used in factories, engine-generators, boats and ships, households, and particularly vehicles from two sources: imports of refined products, and domestic refining from crude oil that in turn is almost entirely imported.[28]

[28] There have been reports of some domestic DPRK oil production in the past, including old images of onshore drill rigs, and reports of joint ventures for mostly offshore oil exploration that included DPRK and foreign

By our estimates, overall supplies of refined products increased by on the order of 25 percent between 2010 and 2016, with some of that increase being used to expand activity in the transport and other end-use sectors, but much of it going to fuel gasoline- and, particularly, diesel-engine generators, which had been imported in increasing number in previous years, largely from China. Increased use of generators is an indicator of DPRK citizens and organizations taking more of the initiative in providing for their needs for energy services—in this case electricity—in response to limited supplies of electricity available from national and regional grids.[29]

The supplies and thus use of oil products decreased between 2016 and 2017, by our estimates, as the impacts of UNSC sanctions on oil products imports, although it is our estimate that "off-books" imports of oil products must have continued at a significant level in 2017. Supplies decreased only somewhat from 2017 to 2018, despite ongoing UNSC sanctions, again, we estimate, because off-books imports were significant, and also because we assume that crude oil supplies increased somewhat in 2018 (see below).[30]

Another key set of difference between the amount of refined product supplies estimated for 2017 and subsequent years versus those of 2016 and previous years is the implication of the impacts of the installation of a catalytic cracking unit at the DPRK's refinery in its far Northwest at Sinuiju, the Ponghwa Chemical Factory. The Ponghwa Chemical Factory is at present the DPRK's only large (by DPRK, if not global standards) operating refinery, and is fueled with crude oil arriving by pipeline from across the Yalu River, where it is loaded into the pipeline in the Chinese city of Dandong. The estimated impacts of the addition of the catalytic cracking unit to the Sinuiju refinery include a reduction in the amount of heavy fuel oil available to and used by the DPRK (as heavy fuel oil is a key input to the cracking unit) and a nearly corresponding increase in gasoline and diesel oil, with an emphasis on gasoline and similar light oil products.

Crude oil supplies from China have been relatively stable since the early 2000s, as recorded in customs statistics through 2014 (see Figure 2-4). China's oil exports to the DPRK have not been supplied in customs statistics since that time, and although China has reported in recent years sending the DPRK exactly the 525,000 tonnes allowed annually under UNSC sanctions, we estimate that somewhat more oil has been supplied, in part because of the physical properties of the China/DPRK pipeline and the waxy crude oil that flows through it, and in part because China may wish to send the DPRK additional oil in order to help

firms (European, Chinese, and others). Most of these ventures have thus far, for various reasons, not resulted in producing wells (most of the ventures are in fact defunct). We have found nothing definitive about DPRK oil production, however, and assume that if such production is still operating, it is likely to be minimal—perhaps a few thousand tonnes per year.

[29] See David von Hippel and Peter Hayes (2018), *DPRK Imports of Generators in Recent Years: An Indication of Growing Consumer Choice and Influence on Energy Supply Decisions?*, NAPSNet Special Reports, November 02, 2018, https://nautilus.org/napsnet/napsnet-special-reports/dprk-imports-of-generators-in-recent-years-an-indication-of-growing-consumer-choice-and-influence-on-energy-supply-decisions/.

[30] For additional detail on our estimates of recent refined product supplies in the DPRK, see David von Hippel and Peter Hayes (2020), *Updated Estimates of Refined Product Supply and Demand in the DPRK, 2010 – 2020*, NAPSNet Special Reports, September 02, 2020, https://nautilus.org/napsnet/napsnet-special-reports/updated-estimates-of-refined-product-supply-and-demand-in-the-dprk-2010-2020/.

stabilize its economy. Our overall estimates of DPRK oil product supplies from 1990 through 2020 are provided in Figure 2-5.

Figure 2-4: Reported Crude Oil and Refined Products Imports to the DPRK

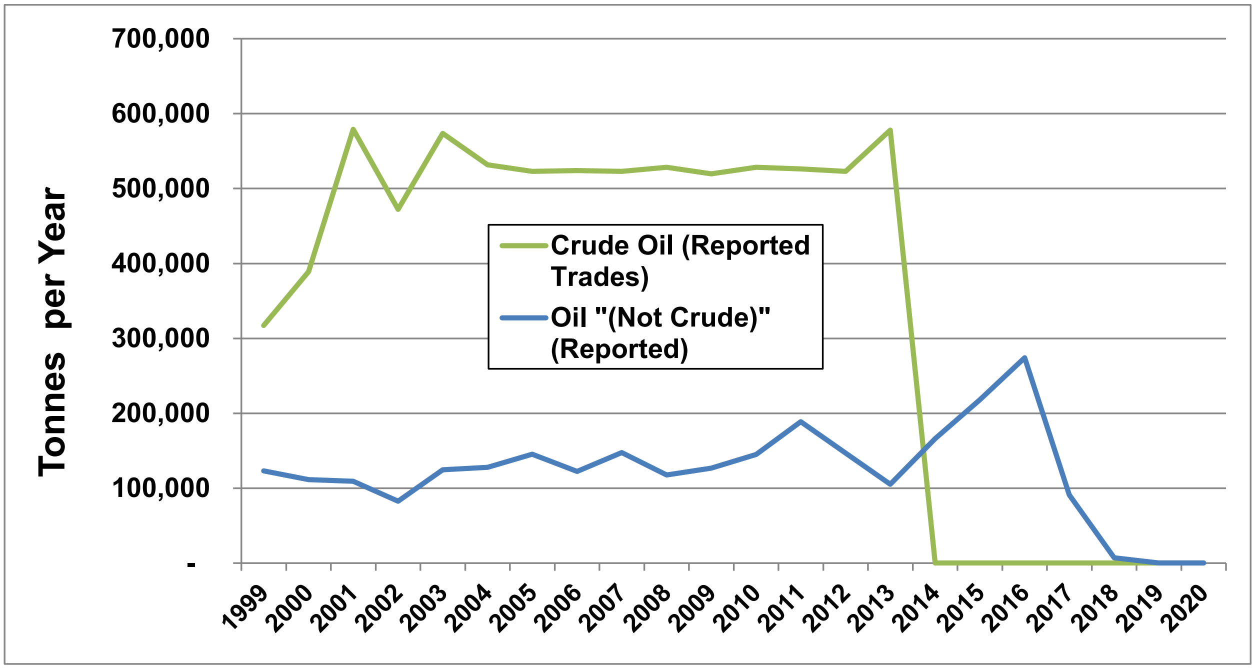
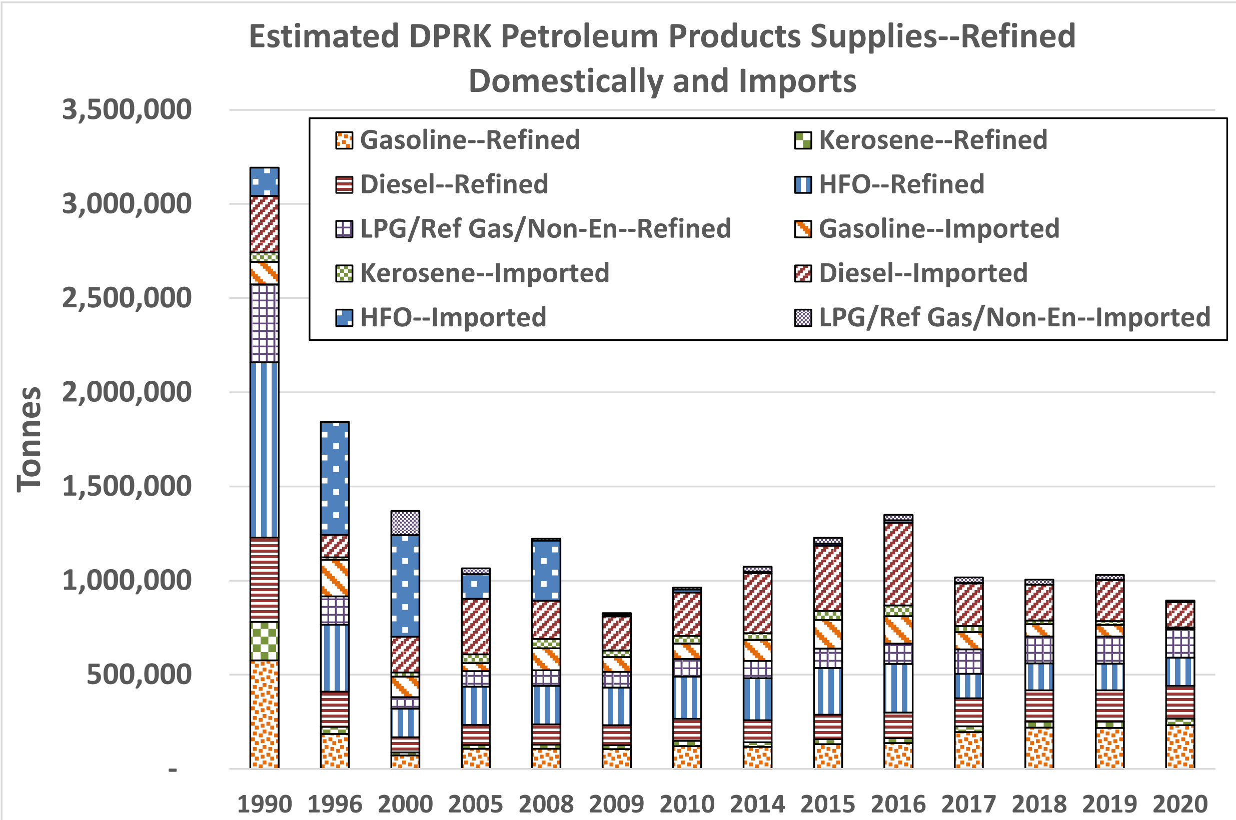


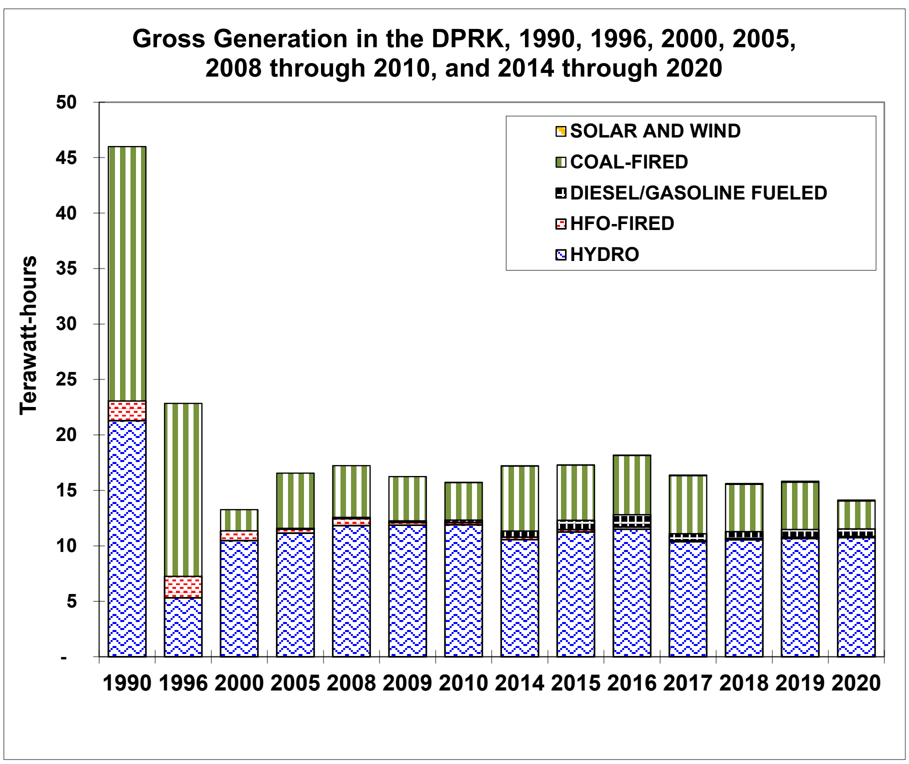
Figure 2-5:



Although the DPRK grid nominally has a capacity of 8,000 to 10,000 MW (megawatts), roughly split between thermal (mostly coal-fired) and hydroelectric plants, the total generation capacity is limited by the poor state of repair of generation, transmission, and distribution equipment, as well as by seasonal water flows for hydroelectricity production. Almost all of the coal-fired generation is 30 years old or more, and, having mostly been built with help from the Soviet Union, suffers from a lack of spare parts, as noted above. Most of the larger hydroelectric plants are even older, some dating to the Japanese colonial period in Korea, and though the DPRK has made an effort to add hydroelectric capacity in the last two decades or so, most of the capacity added has tended to be relatively small plants—on the order of tens of megawatts or less—and some have had problems due to the use of substandard materials and rushed construction. As a result, our estimate is that total available generation in the DPRK is on the order of 2000 to 3000 MW, with output on the order of 15.7 terawatt hours (TWh, or billion kilowatt hours) in 2019, and 14.0 TWh in 2020. Factoring in losses and electricity consumed by generation stations, in coal mining, and in oil refining, annual electricity actually consumed by 2019 by the nation of 25 million people was about 9.6 TWh, comparable to (in fact, somewhat less than) that used in

Washington DC.[31] In recent years, the lack of electricity supplies from the central grid (and the lack of reliability of same), plus rising disposable incomes in some areas of the DPRK, have fueled investments by homes and businesses in on-site electricity generation devices. At the low end, these generators include small solar panels of a few or tens of watts used to charge cell phones and other devices, and to provide lighting in the evenings via LED bulbs, with both the bulbs and panels imported from China, or possibly, for some devices, assembled in the DPRK from imported parts. At the higher-capacity end, businesses such as coal mines, factories, and markets have purchased diesel generators and in some cases, reportedly, generators driven by small coal-fired gasifiers, of tens or hundreds of megawatts. Our estimate of the total capacity of solar PV systems adopted by DPRK residents is not particularly significant relative to overall electricity generation capacity in the DPRK, but is highly significant in terms of providing households and others with energy services that they would not have access to otherwise. Our estimate of the capacity of diesel and smaller gasoline-fueled generators, on the other hand, is significant relative to total operable DPRK generation capacity, totaling over 1000 MW by the late 2010s, although we estimate that the use of these generators was limited by the availability and possibly costs of fuels. Figure 2-6 summarizes our estimates of DPRK electricity output (gross generation) over the years.

Figure 2-6:



[31] Based on US Department of Energy statistics, Washington D.C. used about 11.4 TWh of electricity in 2017, See USDOE Energy Information Administration (2020), "District of Columbia Electricity Profile 2018", available as https://www.eia.gov/electricity/state/districtofcolumbia/index.php.

2.3 Summary of Energy Demand Situation

The DPRK's economy include the industrial, residential, transport, public/commercial, agricultural, fisheries, and military sectors. Of these, the industrial sector, with heavy industries such as iron and steel, cement, fertilizers, other metals, and non-metallic minerals dominating the economy, consumed the major share of energy supplies in the DPRK, particularly coal, as of 1990. As markets for the DPRK's industrial goods dried up with the dissolution of the USSR, output and energy use in the sector fell. Similarly, energy use in the transport sector fell, with passenger transport declining mostly for lack of fuel, and freight transport declining because of the reduction in industrial output. These declines coincided with relatively stable overall energy use in the residential sector—stability that conceals two offsetting factors, namely (1) the reduction in the use (or availability of) energy services due to a lack of access to coal, oil products, and electricity, and (2) the increase in the use of wood and other biomass fuels, which are more inefficient sources of heat than, for example, coal, and therefore require more fuel to produce the same output. Figure 2-7 shows the increasing dominance of the residential sector in the overall energy demand picture in the DPRK over time, and Figure 2-8 shows the increase in the proportion of DPRK fuel demand provided by biomass fuels between 1990 and 2020.

Figure 2-7:

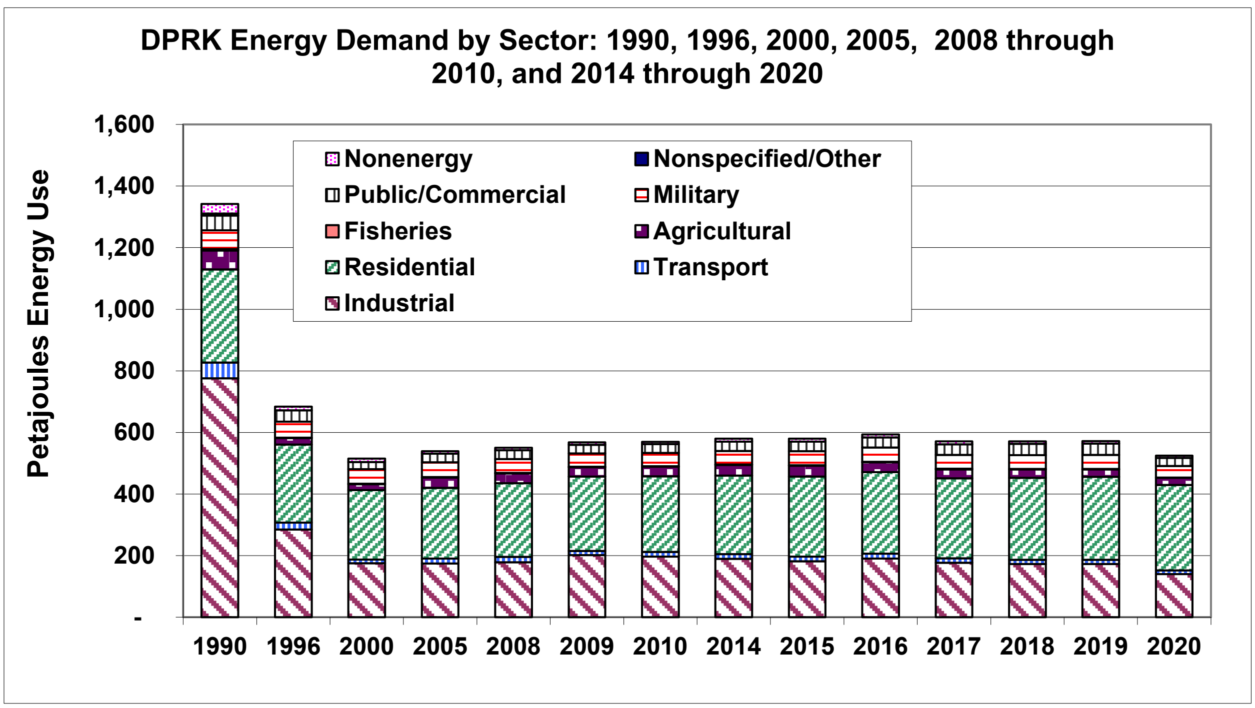
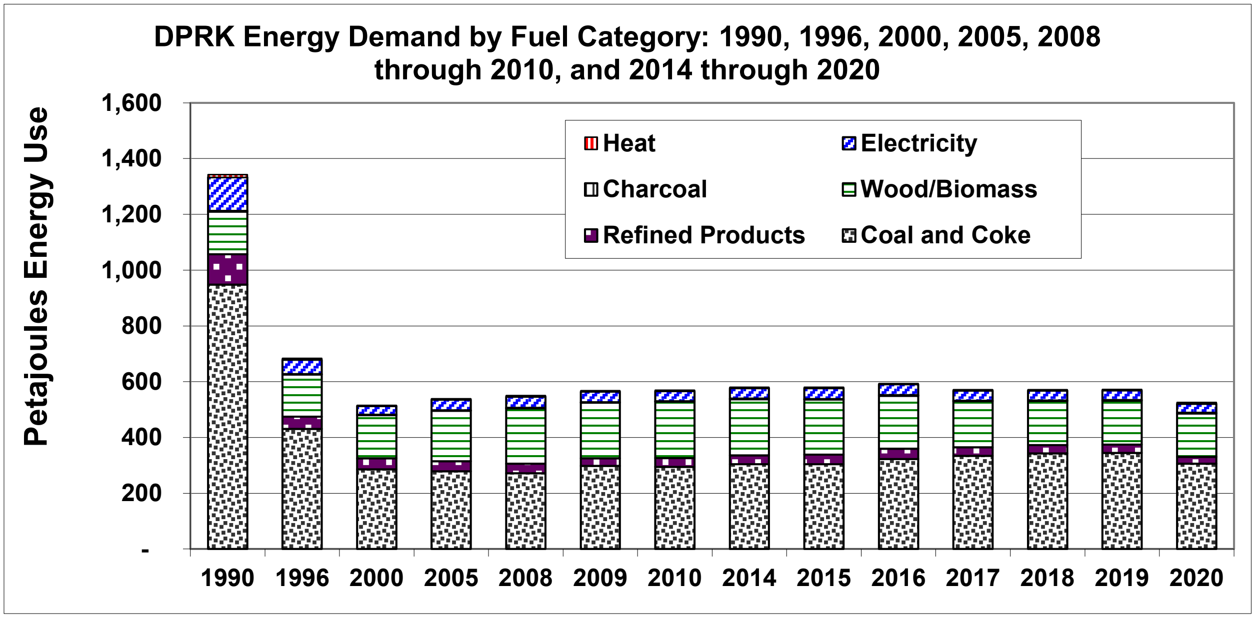


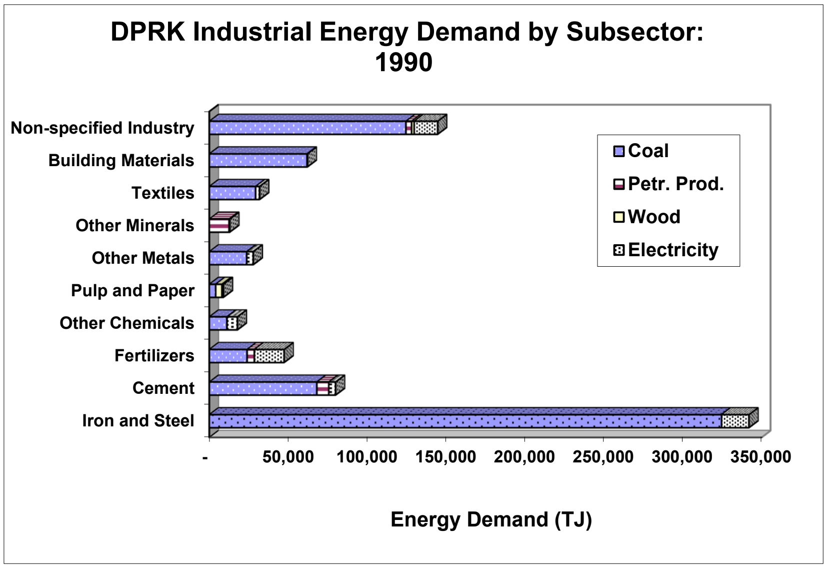
Figure 2-8:

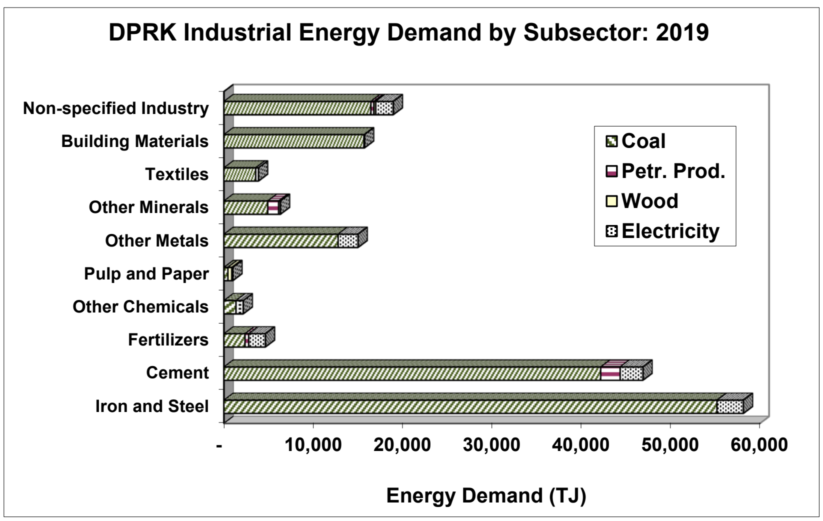


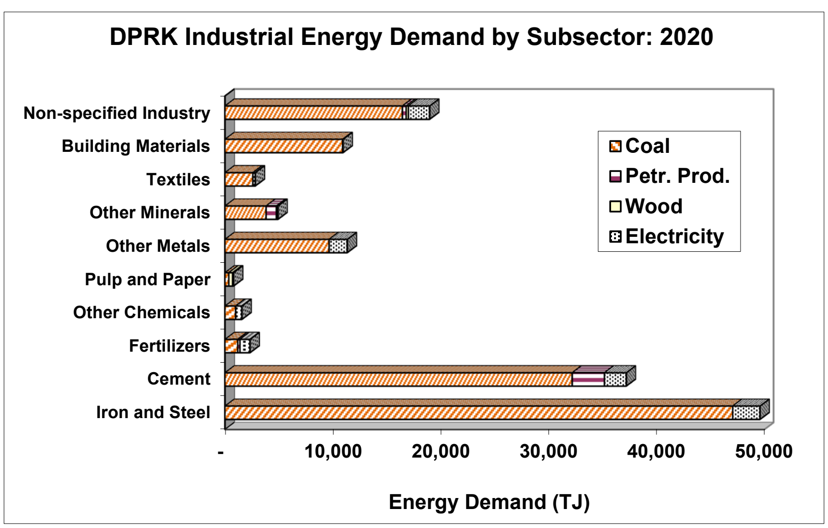
Within the industrial sector, by our estimate, heavy industries continue to use much of the fuels and electricity consumed in the sector, but lighter industries, including, for example, finishing of textile goods under contract to Chinese firms, have played a larger role in the economy. Based on UN Comtrade customs statistics,[32] these textile/clothing trades accounted for over $800 million in exports to China from the DPRK in 2015, nearly balanced by about $650 million in textile imports to the DPRK from China, most of which, we assume were factor imports, such as cut cloth to be sewed into garments in DPRK factories. Figure 2-9 shows DPRK industrial demand in 2019 and 2020 (reduced due to COVID-19 responses), along with, by comparison, our estimates for 2020. Note that the three panels in this Figure have different scales.

[32] United Nations (2020), "UN Comtrade Database", accessed at https://comtrade.un.org/.

Figure 2-9:

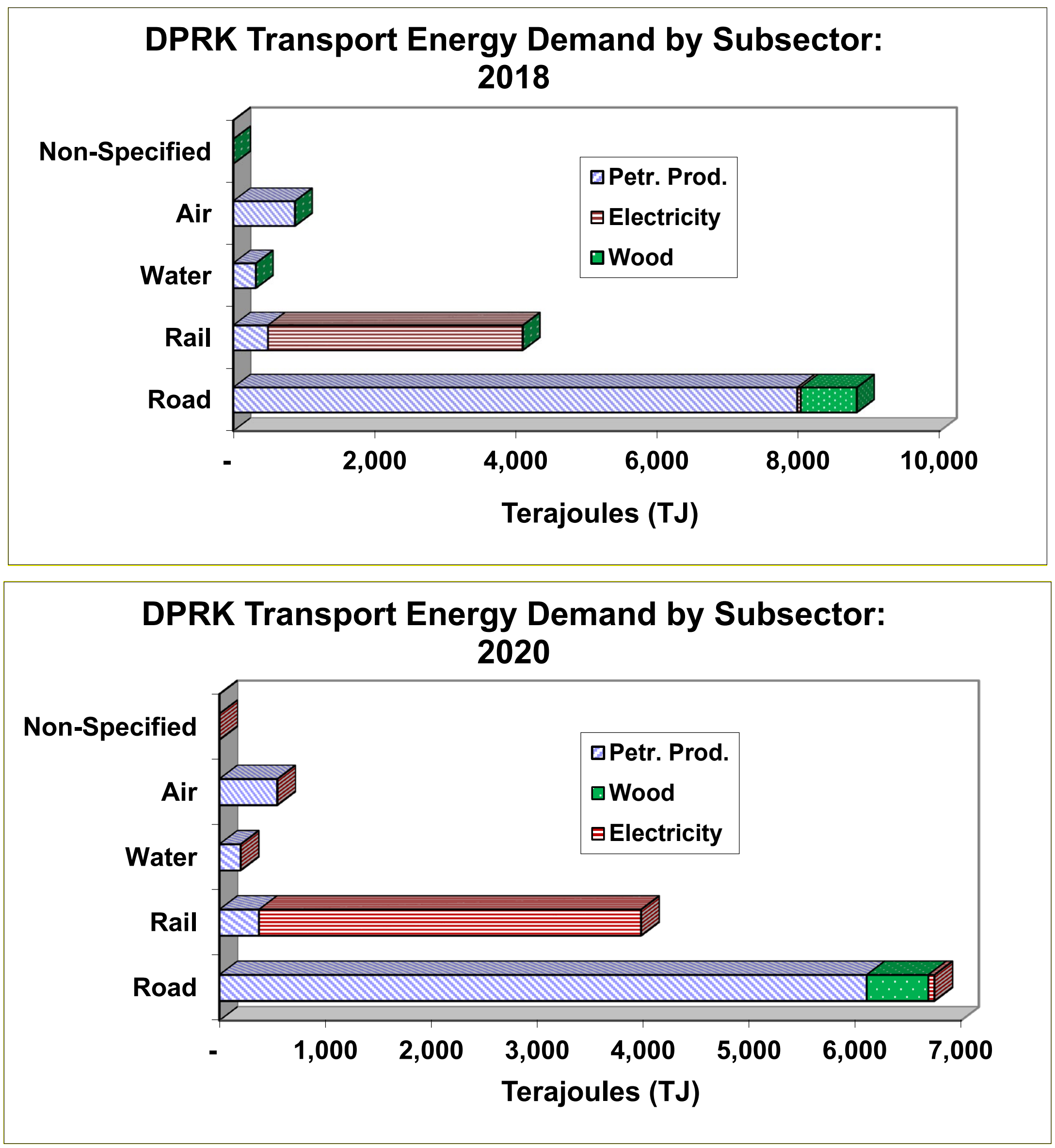

DPRK Industrial Energy Demand by Subsector: 1990
Non-specified Industry
Building Materials
Textiles
Other Minerals
Other Metals
Pulp and Paper
Other Chemicals
Fertilizers
Cement
Iron and Steel
Coal
Petr. Prod.
Wood
Electricity
-
50,000
100,000
150,000
200,000
250,000
300,000
350,000
Energy Demand (TJ)


DPRK Industrial Energy Demand by Subsector: 2019
Non-specified Industry
Building Materials
Textiles
Other Minerals
Other Metals
Pulp and Paper
Other Chemicals
Fertilizers
Cement
Iron and Steel
Coal
Petr. Prod.
Wood
Electricity
-
10,000
20,000
30,000
40,000
50,000
60,000
Energy Demand (TJ)


DPRK Industrial Energy Demand by Subsector: 2020
Non-specified Industry
Building Materials
Textiles
Other Minerals
Other Metals
Pulp and Paper
Other Chemicals
Fertilizers
Cement
Iron and Steel
Coal
Petr. Prod.
Wood
Electricity
-
10,000
20,000
30,000
40,000
50,000
Energy Demand (TJ)

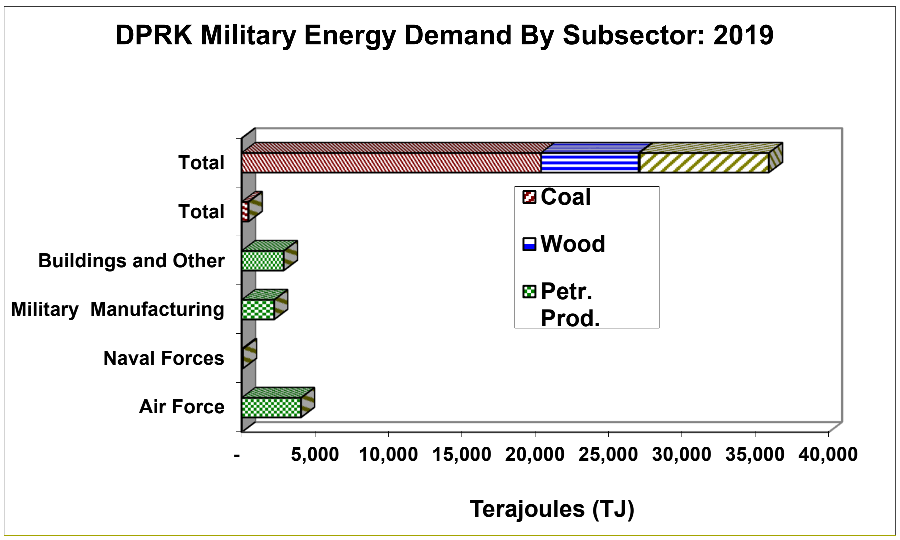
Transport sector energy demand in the DPRK is dominated by the road subsector and by the use of petroleum products, although, by our estimate, a significant amount of electricity is used for rail transport (and electric trolleys and subways), and some biomass/wood is used in trucks run from using producer gas from onboard gasifiers. These trucks, which typically are based on DPRK-made versions of Soviet and Chinese designs (albeit with standard engines), are local adaptations to scarce fuel supplies, and are reportedly used mainly in more remote areas of the DPRK. Transport energy use in 2018 and in 2020, the latter reduced by COVID-19 measures, are shown in Figure 2-10. Once again, the two panels of this Figure use different scales.

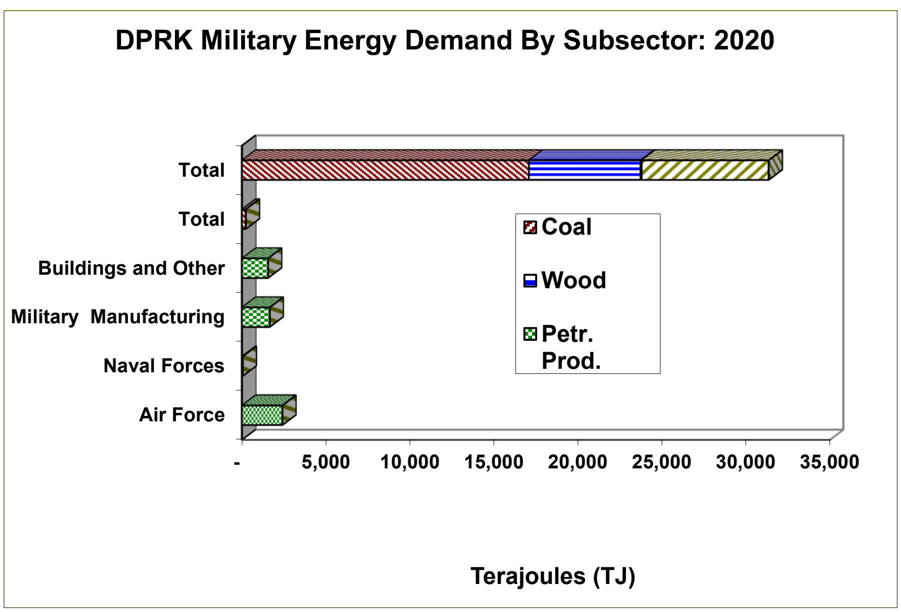
Figure 2-10:



The military sector uses a substantial fraction of the oil products used in the DPRK—29 percent in 2019, by our estimate—and as a priority sector, we estimate that its energy use has not fallen as much as that in other sectors since 1990. Oil products are consumed in the military in aircraft, naval vessels, ground armaments, and particularly in military trucks, which serve so many purposes in the DPRK—transport of military goods, transport of civilian goods, transport of soldiers, and transport of civilians, often all at the same time—that it is difficult to categorize them as purely military infrastructure. Military energy use, as shown in Figure 2-11 for 2019 and 2020, also includes the use of coal, electricity, and also biomass in buildings (as military units have also, it is reported, had to scavenge for cooking and heating fuel in some parts of the DPRK), as well as in manufacturing military hardware, a subsector in which the line between industrial energy for civilian and energy use is also blurry in the DPRK.

Figure 2-11:





Energy use in the public and commercial sectors—essentially, in non-residential, non-military buildings—is mostly coal, district heat, electricity, some biomass, and some oil products, using an estimated 3 percent of all energy use and 13 percent of electricity use in 2019 and 2020. Energy use in this sector is likely to grow significantly when and if fuel and electricity supply restrictions in the DPRK are lifted, and economic development proceeds.

2.4 *Implications of Results for Energy Efficiency and Renewable Energy Options in the DPRK*

Although there have been some imports of modern goods, mostly from China, in recent years, the DPRK energy sector is likely still in large part characterized by the use of devices, ranging from residential appliances to industrial motors and boilers—that are old and/or based on designs that would be considered considerably outdated by international standards. As such, upgrading these devices, and the systems in which they operate, offers huge scope for increasing energy efficiency, and thus for providing the DPRK economy with the same or larger amount of energy services with much less use of energy. Buildings, including urban residential, commercial, and institutional buildings, and even some buildings, such as schools and clinics, found in more rural areas, are often concrete or brick shells with little insulation, poor weatherstripping to keep out drafts, inefficient heating systems, and leaky windows and doors. Improving the building "envelope" in those structures offer the prospects for both improvements in comfort and reductions in energy use.

Similarly, on the supply side the scale of investment required to repair, refurbish, and/or replace the elements of the DPRK energy system is considerable—bringing the electricity grid alone up to modern and fully operable standards will cost tens of billions of US dollars. Given the current isolation of the DPRK economy, it will be impossible for North Koreans to achieve this recovery without international assistance. At best, the DPRK can hope to continue to make do with existing infrastructure augmented with some small hydropower additions and tiny distributed generation systems for individual homes and businesses, resulting in very slow growth in energy availability. On the other hand, with the advent globally of mini-grid systems based on renewable energy (especially solar photovoltaic technologies), and often including energy storage and local distribution systems an alternative approach to rebuilding the grid in the DPRK may well be to start from the "bottom up", that is, to build micro- and mini-grids to support individual facilities, towns, or local areas with reliable electricity supplies, and knit them together with an updated central grid when it is possible to do so.

These demand- and supply-side options are, based on our experience both of keen interest to DPRK officials and technicians alike, as they conform with the DPRK's *juche* philosophy of self-reliance along with the DPRK's stated goals for its energy system. These options can potentially (and should) have significant potential for incorporating humanitarian elements—improving schools and clinics, for example—and have limited potential for military diversion, at least for armaments. Below we describe how energy efficiency and renewable energy options might be incorporated into one or more international engagement projects that "tick the boxes" of being useful, incorporating humanitarian elements, would be pilot projects for scalable replication, incorporate elements of peaceful economic development, and are likely to be successful demonstration projects that leaders from both the DPRK and the international community can point to, when working to convince their constituencies, as positive outcomes of engagement.

3 Key Engagement Project Elements

3.1 Project Overview, Potential Timelines and Interaction with Other Potential CTR+ Activities

A consortium-led, third-party-funded Pilot Energy-efficiency Renewable Energy Cooperative Threat Reduction "plus" (EE/RE CTR+) DPRK engagement project would be designed to have the following elements and attributes:

- A focus on **energy efficiency**, starting with building envelope/system efficiency (including in apartment buildings in Pyongyang, to enhance project visibility within the DPRK), but also potentially including to a lesser extent elements such as residential lighting improvements, improved industrial and irrigation motors, and heating system and agricultural equipment efficiency measures.
- A second focus on **renewable energy**, emphasizing solar photovoltaic (PV) power and microgrids, but also potential including small hydroelectric and wind power installations where applicable.
- Humanitarian measures in homes/schools/clinics (for both the EE and RE measures), and possibly in one or more rural villages (combined EE and renewable energy systems) where economic development is a need.
- Job creation in the DPRK during the project and afterward, both through the local expanded availability of energy services provided by the project and through replication of project successes elsewhere in the DPRK. This could include job creation for military and nuclear-sector workers whose current jobs could be displaced by a threat reduction agreement. For example, positions for technicians and researchers in the Yongbyon Nuclear Complex could be developed to allows those workers to provide research and development on energy efficiency and renewable energy topics, to investigate environmental problems in the DPRK (and their solutions), and to work on safeguarding DPRK nuclear material with the involvement and oversight of international colleagues (for example, from the International Atomic Energy Agency).
- CO_2 emissions reductions, which, depending on how the project is structured, Clean Development Mechanism (CDM) rules, and ROK laws, could possibly result in carbon credits for the ROK if ROK firms invest in the project.

- Materials provision to the DPRK that is not likely to violate the spirit of United Nations Security Council sanctions.
- The positive image of cooperation, which can be pointed to by both ROK/US and DPRK leaders, of cargo ships headed north across the line of demarcation bearing insulation and other EE/RE products for installation in the DPRK.
- The project can provide a first step toward rebuilding the DPRK transmission and distribution (T&D) grid from the bottom up, that is, by building and later linking micro- and mini-grids.
- The project can be designed to provide a pilot program for an ongoing effort that may take five years or more, to be deployed in parallel with progress in resolving the nuclear weapons issues in the DPRK.

A consortium-led, third-party-funded Pilot Energy-efficiency Renewable Energy (EE/RE) DPRK engagement project would be designed to have the following elements and attributes:

- A focus on **energy efficiency**, starting with building envelope/system efficiency (including in apartment buildings in Pyongyang, to enhance project visibility within the DPRK), but also potentially including to a lesser extent elements such as residential lighting improvements, improved industrial and irrigation motors, and heating system and agricultural equipment efficiency measures.
- A second focus on **renewable energy**, emphasizing solar photovoltaic (PV) power and microgrids, but also potential including small hydroelectric and wind power installations where applicable.
- Humanitarian measures in homes/schools/clinics (for both the EE and RE measures), and possibly in one or more rural villages (combined EE and renewable energy systems) where economic development is a need.
- Job creation in the DPRK during the project and afterward, both though the local expanded availability of energy services provided by the project and through replication of project successes elsewhere in the DPRK.
- CO_2 emissions reductions, which, depending on how the project is structured, Clean Development Mechanism (CDM) rules, and ROK laws, could possibly result in carbon credits for the ROK if ROK firms invest in the project.
- Materials provision to the DPRK that is not likely to violate the spirit of United Nations Security Council sanctions.
- The positive image of cooperation, which can be pointed to by both ROK/US and DPRK leaders, of cargo ships headed north across the line of demarcation bearing insulation and other EE/RE products for installation in the DPRK.
- The project can provide a first step toward rebuilding the DPRK transmission and distribution (T&D) grid from the bottom up, that is, by building and later linking micro- and mini-grids.

- The project can be designed to provide a pilot program for an ongoing effort that may take five years or more, to be deployed in parallel with progress in resolving the nuclear weapons issues in the DPRK.

The timeline of an EE/RE CTR+ DPRK Engagement project, like the scope of the project itself, could be scalable to meet the needs of threat reduction negotiations. For example, an initial rapid demonstration project including a limited number of measures could be carried out in 9 to 12 months, assuming good agreement and active/timely participation from all parties, with a more substantial and economic development-focused project carried out over five years or more, consistent with a negotiated timeline for nuclear weapons threat reduction by the DPRK and reduction/elimination of sanctions, economic and energy assistance, and other measures by the international community.

Key expected elements of an EE/RE DPRK CTR+ Engagement project follow.

3.2 Energy Needs Assessment

In order to properly tailor the project to the needs of DPRK citizens, an improved understanding of the status of the DPRK energy sector and energy needs will be needed—the discussion provided above is a start, but must be built upon with additional information. Such an understanding, which would be obtained, for example, through international-standard (but rapid) energy surveys in the DPRK, plus review of potential project sites (specific apartment building types, candidate schools or clinics for RE systems, and/or villages where pilot RE systems might be employed), will be needed to inform plans for project design and delivery.

3.3 Building Energy Efficiency Measures

The building energy efficiency measures that would likely be provided and installed under the project would include insulation (such as rigid foam insulation, assuming it will be installed in existing buildings), weather-stripping, heating system controls, multi-pane, well-sealed windows, lighting improvements/controls, and potentially other measures. These measures would be installed in Pyongyang apartments, and perhaps some other buildings in urban and/or rural areas, including the buildings where renewable energy measures will be installed (schools, hospitals, clinics, and/or rural village settings). Deployment of both EE measures and the RE measures/systems described below would include specifying, sourcing, purchasing, and delivering the relevant materials and equipment, as well as any tools needed for installation, and then to organize installation and install the measures, and commission (activate and test) the measures installed. Examples of Pyongyang apartment buildings are provided in Figure 3-1.

Figure 3-1: Examples of Pyongyang Apartment Buildings[33]

3.4 Mini-grid/Renewable Energy Efficiency Measures

The project would include, in fulfilling its mission as a pilot project, a selection of renewable energy systems, but would probably, for ease and speed of deployment (and low cost), focus mostly on the installation of solar PVs, possibly with some wind power systems where applicable, as the wind resource in most of the territory of the DPRK is only fair. The addition of some micro-hydro systems and possibly some energy storage (battery or pumped-storage hydro, for example) are also possible. These RE systems could, depending on discussions with North Korean counterparts, be installed in mostly grid-connected or partially grid-connected formats—for example, for schools and clinics in urban areas, possibly with local micro-grids for the buildings—and/or could include a few mini-grid system(s) for more remote villages/towns and/or humanitarian applications.

[33] Photo taken in Pyongyang by D. von Hippel, September 2009.

3.5 Capacity Building

Capacity-building will of necessity be an integral part of the pilot project, in that A) a large number of North Koreans will be needed to accomplish several of the project tasks, and B) a major goal of the project should be to place as many North Koreans as possible in a position to interact with an learn from international project participants, and vice versa. For the latter, the contacts between DPR Koreans and international participants can be expected to help demystify through familiarity each group for the other. Training will likely need to be provided first in energy assessment, building energy analysis, and EE/RE measure specification and design, probably to a relatively small group of DPRK scientists and technicians (dozens, perhaps), with following broader training on measure installation and maintenance/troubleshooting (for hundreds of installers), and ongoing data collection from completed EE/RE installations.

3.6 Follow-up

Immediate follow-up to the project would include, for example, surveys of apartment dwellers, technicians, and others as to their experience with using and installing the measures, the analysis of data collected from selected installations (and arranging for same) either directly or remotely, and planning for an expansion of the program, as applicable (and as possible), with DPRK counterparts.

3.7 Linkages to Future Economic Development

A key element of the pilot EE/RE CTR+ project, in order to make its lessons and the engagement it will promote sustainable (and attractive to DPRK counterparts), will be to use the project results to help identify opportunities (and processes) for in-country production of selected materials so that the project elements (those types of EE and RE deployment that are proven to work best in the DPRK) can more cost-effectively be replicated elsewhere in the DPRK. Examples might include domestic production of magnesium oxide (MgO) wallboard, as the DPRK has large reserves of the mineral magnesite that could serve as the raw materials for MgO board. Other possible spin-off businesses could be energy-efficient design and building energy analysis for new apartment buildings and other buildings, installation crews for solar PV systems, ramped-up production of solar PV panels and ancillary equipment in the DPRK (probably using imported PV cells, at least in the first decade or so), provision of energy audit services, and other new local businesses.

4 Key Tasks for Project Planning and Delivery

Consistent with the project elements above, the key tasks for planning and delivery of a consortium-led, third-party-funded Pilot Energy-efficiency Renewable Energy Collaborative Threat Reduction-plus (EE/RE CTR+) DPRK engagement project would be as follows.

4.1 Negotiate Funding and Permissions

In order to be implemented, the project must be designed in detail and funded. This work will involve preparing a detailed "proposal", identifying funding sources, and applying for any required permissions (or waivers) as needed from the UNSC and/or from any of the countries from which materials or know-how will be sourced. Possible funding sources for elements the project may include non-governmental organizations and foundations, institutes affiliated with governmental agencies (for example, in the ROK), private donations—in cash, as material donations, and/or in the form of labor/expertise—from companies or individuals, and perhaps in some instances, bilateral aid programs. The group tasked with preparing the project proposal, and/or a group responsible for outreach on the project, will need to secure (or at least substantially secure) funding **before** DPRK counterparts are contacted and engaged to participate.

Depending on how the project is developed, and to what extent it is developed with the input and consultation from the highest levels of government (particularly in the ROK and US), it may well be necessary to apply for permission to engage the DPRK and/or waivers from bilateral or international sanctions. High-level support will be necessary to assure that any such applications are approved in a manner sufficiently timely to deploy a successful project.

4.2 Survey of DPRK Energy Use

In order to meet the needs of the apartment dwellers and other DPRK citizens that will be the beneficiaries of EE/RE measures under the project, it will first be necessary to undertake rapid surveys of energy use and infrastructure in the candidate buildings (or building types) in which EE measures will be installed. Doing so will mean working with DPRK counterparts to select several types of apartment buildings, schools, and/or clinic on which to carry out the surveys, choose (preferably through random selection, but in practice probably with the input of DPRK authorities) an adequate sample of apartment units and other buildings to carry out surveys on, design and carry out the surveys, and process and interpret the survey results. The surveys will include questions and measurements to determine, for example, the size of apartments in different candidate building types, the number and size and types of windows and doors, the construction materials used in the buildings, the level of existing insulation and weather-stripping used, the heating systems used and the controls used for same, typical existing and desired levels and timing of heating, and type, level, and timing of use of lighting and other electrical (or other) energy end-uses. Similar surveys will be undertaken in candidate types of non-residential buildings that might be involved in the project. The surveys should be designed based on best practice energy assessments commissioned in other nations worldwide, for example, by the World Bank and others, and should ideally, to prevent surprises, be reviewed by DPRK colleagues before they are deployed. Surveys of potential sites/locations for mini-grids and renewable energy systems outside of urban areas (that is, in villages and towns) will also need to be designed and undertaken. It is likely that surveys will involve and be guided by (as well as spot-checked by) international survey experts, equipment installers, and EE/RE experts, but will be largely implemented by DPRK technicians trained for the purpose. The planning for surveys of DPRK energy use will likely need to start well before a "time zero" when the funded project is agreed upon by DPRK authorities and the international community, as surveys will be the first element of the project to be implemented in-country, and the timing of all other project elements will depend on when the surveys are completed, compiled, and evaluated, as deployment of measures will depend in large part on survey findings.

4.3 Modeling of Building Energy Performance and Design of EE Measures

With data on typical DPRK buildings and building energy use in hand from the surveys/energy assessments described above, the next task will be to select a suite of candidate EE measures—likely focusing on those most easily installed and most likely to be cost-effective--and model their efficacy in application to DPRK buildings. This will involve the use of building energy modeling software, and the numerical description within that software of typical DPRK buildings that might be involved in the project. It is likely that a start to this modeling effort, probably staffed initially by experts from the international community, would also need to be made well before "time zero" of the project. Initial models of DPRK buildings will therefore likely need to be built based on existing photos and descriptions by visitors, then updated when actual energy survey data are available.

4.4 Training of DPRK Counterparts in Building Energy Surveys and Building Energy Modeling

Shortly after the project is agreed to by DPRK authorities, it will be necessary to train a set of DPRK scientists/technicians/engineers in the conduct of building energy surveys and in the process of building energy modeling. This training process will need to be relatively rapid and could be accomplished in part through study tours of DPRK counterparts to centers of expertise internationally, and/or through visits of international experts to Pyongyang. Developing training materials, schedules and approaches in advance of "time zero" will be desirable.

4.5 Finalize Building and EE Measure Selection, and Mini-grid/RE Site and Measure Selection

This task will involve selecting and refining cost estimates for EE and RE measures and related materials (such as caulk, wiring, switches and fixtures) and equipment needed to install the measures. Measure specification would be done based on the results of energy surveys and the modeling of building energy efficiency options undertaken in previous tasks. Specifying and identifying vendors for equipment may involve seeking donations of some materials. This process of specifying quantities and brands/vendors of measures/materials/equipment may well be iterative in nature, for example, if it is found that the number of apartment buildings and schools addressed by the project must be scaled to fit project budgets.

4.6 Prepare Plans to Install Measures, and Train Installers

As materials are being specified, plans should be made as to how measures will be installed in each of the several (probably less than 10) types of Pyongyang apartments to be addressed by the project, and at RE/mini-grid project sites. This would involve probably first, selecting a small group of seasoned international contractors (insulation installers/weatherization specialists, window installers, electricians/renewable energy installers, plasterers/wallboard installers, painters, and others) and walking through installations with that group either on-site in Pyongyang or possibly with a virtual or real mock-up of Pyongyang apartments to identify approaches and phases for measure installation. Once plans for installation are as clear as possible, the next step will be to train installers—first a select group of international installers, and then, with their help, a much larger group of DPRK technicians.

4.7 Order and Ship Project Materials and Equipment

Once the materials and equipment needed for the project are specified, they would need to be ordered from vendors and shipped to the project site. The materials and equipment needed, as noted above, would include insulation, weather-stripping, heat controls, windows and doors, datalogging equipment, mini-grid equipment (switches, wiring, batteries and other electricity storage devices, inverters, and data collection/display hardware, RE generation equipment (wind, solar, and/or mini-/micro-hydro), grid intertie equipment, and equipment to install and test all of the above. It is possible that some materials/equipment can be obtained for free or at concessional prices from, for example, ROK or other international firms willing to contribute to the project. In some, probably infrequent, cases materials might be sourced from DPRK vendors. One possible example might be micro-hydro turbines, which a Nautilus delegation saw in a factory in Pyongyang in 1998, and seemed well-made (see Figure 4-1). Penstocks and other micro-hydro equipment may also be available in the DPRK, but most items for the project will likely need to be imported to the DPRK.

As noted above, permissions from U.S. and other governments may be needed to ship some of the required materials and equipment to the DPRK, and for those items the process of seeking authorization will need to begin early, perhaps before a full list of project inputs is actually known.

Shipping the materials and equipment needed for the project to Pyongyang and other project sites will likely, for bulky materials such as insulation, involve loading a cargo freighter at Incheon or another port, and shipping the materials to Nampo. From there, they may be transferred to a barge or smaller ship that can navigate upriver to Pyongyang, and/or they may be loaded onto DPRK trucks for the trip to the capital. In either case, project staff will need to negotiate with DPRK freight transport providers, probably through DPRK officials, to secure transportation services, and to be able to track the materials from place to place. This will also be the case for moving materials (and personnel) around Pyongyang and to other project sites.

Figure 4-1: DPRK-made Micro-hydro Turbine Generator Unit (Nautilus photo, 1998 or 2000)

4.8 Install Measures

Once delivered and inventoried, teams of installers will install EE and RE measures at project sites. Teams for EE measure installation in Pyongyang apartments will likely be composed mostly of North Koreans, but with some international workers included as well to model techniques and provide informal on-the-job quality control. Oversight of the teams will be a matter for negotiation with DPR Korean partners, but the teams would ideally be supervised by a set of foremen, possibly consisting of international and North Korea foremen working in pairs (for both organizational and language reasons). Additional project personnel will likely be needed for liaison and scheduling with apartment residents and with other recipients of measures under the project (school/clinic authorities and village leaders and residents, for example). Translators will likely also be required. Installers for the apartment EE work will likely be split into teams, each of which would undertake a targeted subset of the required tasks in each apartment unit. So, for example, there might be one team focused on installing insulation, one on removing and installing windows and weather-stripping, one on heating controls, one on wallboard installation and plastering, and one on painting, each cycling through each apartment covered by the project, and then moving on in sequence to other units and other buildings under the guidance of an overall manager, and probably aided by electronic communication tools.

4.9 Quality Control/Quality Assurance for Installations, Monitoring, and Training of Users

As apartment installations of EE measures, and installations of renewable energy systems, are completed, it will be necessary to perform "quality assurance/quality control" (QA/QC) inspections on installations, requiring a trained group of inspectors (probably teams of international and North Korean technicians), to make sure that the quality of implementation is adequate and likely to perform as expected.[34] Part of the QA/QC process will likely be to monitor some subset of installations for parameters like inside and outside temperatures, heat inputs (if possible) and electricity use. To accomplish this type of monitoring, it will be necessary to work out agreements and protocols for sharing of data with DPRK counterparts. This could be organized as a follow-up to the energy assessments carried out as above. Part of this task will also include the training of apartment dwellers in how to use and maintain newly-installed measures and equipment (such as heat and ventilation controls), and also to train the users of mini-/micro-grids and RE systems, and the technicians who will maintain them, in the proper operation and maintenance of the systems. It is likely that some "voice of customer" surveys will also need to be undertaken to determine the satisfaction of residents and RE system users with the measures installed.

4.10 Communicate Results of Project to Policyholders, Plan Next Steps

As installations are completed and QA/QC processes have been carried out, the results from monitoring together with a digest of interviews with project participants (both North Koreans and international participants, including both residents/users and installers) should be compiled. These compiled project results will help to identify challenges and problems that were addressed (or were not addressed) as the project moved forward, and the benefits of the project to different parties, and to find ways in which the project could have been improved upon. These results will be communicated to project stakeholders (including funders and government organizations in the ROK, the DPRK, and other countries), and used to make plans to build on the results and findings of the pilot project.

4.11 Overall Project Management

A single firm or a group of well-coordinated firms, probably overseen by an advisory committee of some kind (see below), will need to be in charge of the day-to-day operation of the project, including coordinating between contractors, project staff, vendors, and shippers, overseeing installation foremen and survey staff, reporting on expenditures and

[34] QA/QC will be of particular importance if there is a mechanism whereby greenhouse gas emissions savings from the project can be claimed as a credit by international partners, including the ROK. The value of these credits may be considerable, as shown below.

budgets, keeping an inventory of materials and equipment, scheduling project activities, and liaison with DPRK counterparts, among a host of other of other responsibilities.

5 Types of Organizations and Individuals Needed for Project

The different tasks described above will call for the involvement of a consortium of different organizations and individuals. What follows in an indicative list of the types of partners, on the international community side, that might be needed to team up to develop and deliver the project. This list is keyed to the tasks described in the section above.

5.1 Obtain Funding and Permissions

In order to obtain funding for the project, a group or groups experienced in working with DPRK-related agencies in the US and the ROK, and possibly Europe, will be required. That group (or an associated group or individuals) will also have to know how to navigate the applications and procedures required to obtain permission to work with and provide goods and training for entities in the DPRK. The group seeking funding and permissions will need to have experience in, or be advised by a group or individuals with experience in, working with North Koreans and in the DPRK itself. It is likely that one of the first organizational structures to be formed under the project will need to be a type of "Advisory Committee" of stakeholder organizations, which could include representatives of governmental, quasi-governmental (including national institutes), NGO (non-governmental organization) and private actors. The initial proposal for funding would be prepared by members of this Committee or with input and review by the Committee, and Committee members would be expected to help with raising funds and direct inputs to the project, as well as periodic reviews of project performance.

5.2 Survey of DPRK Energy Use

Surveys of DPRK energy use would likely be carried out by individuals or a firm experienced in doing building energy and energy use audits to international standards. Possible candidates might include representatives from US or European NGOs (either national or regional) focusing on energy efficiency, and/or private contractors/academics in the US, Europe, the ROK or China, including those with experience doing such surveys for bilateral or multilateral aid groups (such as for the World Bank, UNDP, or the Asian Development Bank—ADB), and/or academics with extensive field experience in carrying out energy surveys.

5.3 Modeling of Building Energy Performance and Design of EE Measures

Modeling of building energy performance and the design of energy efficiency installations for DPRK situations would be done by individuals or groups with building energy modeling expertise. Examples include, but are not limited to, U.S. national laboratory (such as Lawrence Berkeley National Laboratory) staff or former staff who have worked on building energy modeling, private firms routinely doing building energy modeling, and/or NGOs with that expertise. Similarly, the design of renewable energy installations could be done by private or NGO contractors with experience developing solar PV solutions for various urban and rural settings, including those consulting on renewable energy installations in aid- and loan-recipient countries for the UN, World Bank, USAID, and others.

5.4 Training of DPRK Counterparts in Building Energy Surveys and Building Energy Modeling

Training for DPRK counterparts in carrying out energy surveys and in EE/RE modeling would likely be done by the more academic of the groups in the two categories above. That is, it would involve those with expertise in both carrying out and providing capacity-building for energy surveys and audits and (probably separately) for building energy modeling.

5.5 Finalize Building and EE Measure Selection, and Mini-grid/RE Site and Measure Selection

Both the finalization of selection of building energy efficiency measures and the selection of mini-/micro-grid RE development locations will both ultimately involve consultations with North Korean counterparts, who will have their own reasons for advocating particular locations, some of which may well be un-knowable to international counterparts in advance. These reasons may well vary depending on which organizations the DPR Korean counterparts represent. Finalization of EE versus RE measure selection may require individuals or groups with different skills. This task will probably involve someone experienced in working in the DPRK to provide guidance on the unique aspects of working there, as well as EE/RE experts, for example, from NGOs and/or National Laboratories/Institutes and/or academia.

5.6 Prepare Plans to Install Measures, and Train Installers

The preparation of plans to install measures and train installers, including installers drawn from both the DPRK and from outsider the DPRK, will require involvement of some of the individuals and groups working in measure/site selection (above), probably with the input of representatives of contractors who routinely do those jobs, and review by DPRK counterparts. This task will likely ultimately need to be managed by a firm—either for-profit or NGO, and likely private—experienced in carrying out big infrastructure projects rapidly, with experience in the DPRK a plus, but probably not a requirement, since relatively few such firms exist.

5.7 Order and Ship Project Materials and Equipment

The ordering and arrangement for shipping of project materials and equipment will probably be undertaken by the same lead firm as chosen above, with advisors from previous tasks consulted for continuity to assure that the materials and equipment chosen meet the required specifications. Here, as throughout the project, members of the Advisory

Committee for the consortium designing and implementing the project would be expected to use their knowledge and influence to help identify vendors (including those willing to donate or provide goods or services and concessional prices) appropriate for providing materials and shipping in a timely and efficient manner.

5.8 Install Measures

The installation of EE and RE measures under the project would ideally, as noted above, involve teams of a few North Koreans (perhaps four each for work on individual EE tasks in Pyongyang apartment buildings) supported and joined on a regular basis by a few individuals from other countries. Installers from outside the DPRK would be experienced and carefully chosen professionals, fully vetted and briefed about what makes working in the DPRK different from working in most other countries, plus translators, to work together on individual apartments under an international foreman or foremen (with the use of the word "foremen" by no means meant to exclude the possibility/probability of having women as well as men in those roles) coordinating with DPRK counterparts. These foremen will in turn ultimately be under the direction of the same lead firm as above.

5.9 Quality Control/Quality Assurance for Installations, Monitoring, and Training of Users

QA/QC would be undertaken by a separate firm that works on QA/QC for these types of projects. Ideally such a firm would have experience working for multilaterals (World Bank, ADB) and can provide QA/QC to the level those clients would require, as a way of starting to prepare the DPRK for funding of future infrastructure investments by multilateral donors/lenders, assuming improvements in relations between the DPRK and the international community. Firms with experience in, for example, providing QA/QC on demand-side management programs for US utilities or government organizations are also a possibility.

5.10 Communicate Results of Project to Policyholders, Plan Next Steps

Compiling and communicating project results would involve incorporating and distilling the raw information from the tasks above, but the resulting compilations and summaries would need to be synthesized into summary document and presentations by a group or groups with experience communicating with policymakers on DPRK issues, probably with input and review from the project Advisory Committee that oversees the activities of the project consortium.

5.11 Project Management

Overall project management would probably be undertaken by the same lead firm the same lead firm with primary responsibility for implementing the project (5.6 through 5.8 above), but with coordination/oversight from the Advisory Committee of individuals and representatives of groups with DPRK experience. The Advisory Committee should involve international stakeholders committed to engagement with the DPRK as a means of resolving the DPRK's standoff with the international community, as without that commitment on the part of all members it is unlikely that the project will be able to move forward in a timely manner. Similarly, the lead firm would need to be chosen so as to assure that it has both the required skills for the project and the required attitude and flexibility to work effectively in DPRK settings.

6 Illustrative Budget and Project Timing

In the following section, we present a budget and project timing for a consortium-led, rapid EE/RE CTR+ engagement project in and with the DPRK. Note that both the budget and timing are illustrative in nature, since the project can be scaled in both size and time to deploy (the latter, within practical limits) as needed. The timing laid out below reflects the assumption of a well-planned rapid deployment project where the tasks go smoothly and are not interrupted by external influences, including (particularly) political influences. It is almost inevitable, however, that such interruptions may need to be dealt with, and will cause delays and changes in costs. Our working assumptions in laying out an illustrative project with a level of funding of about $100 million and a time frame of a year or less are that it would take a relatively large project to deliver the kind of large-scale, highly-visible symbols of cooperation that the leaders of (at least) the DPRK, ROK, and United States will need to be able to point to as markers of success in engagement, and deliver it in a time-frame meaningful on a political scale, and thereby to "sell" engagement to their (in some cases skeptical) constituent groups. But, as we say, it may be possible to get sufficient symbolic impact from a project that is of a different size or time-frame, particularly if media outreach is effective in cataloging project successes as the project moves along.

6.1 Project Budget

We have set the target cost for a project that can be completed in 12 months or less, as about 100 million (M) US dollars ($). This cost, as noted above, is purely illustrative and can be scaled as needed to fit the requirements of the project and the funding available, but please note that any adjustments (particularly downward) to the budget should be made **before** offering the project to DPRK officials as an engagement proposal, as any reduction in the budget following making the offer of the project will be seen as a lack of dealing in good faith by North Korean counterparts.

Rough estimates of funding required by category are provided below. Some of the key assumptions as to project outputs and inputs used to produce these estimates include:

- 36,200 Pyongyang apartments retrofitted—amounting to over 4 percent of the units in the city;
- 174 schools or clinics receive solar PV systems, the equivalent of about 16 percent of the schools in Pyongyang; and
- Over 1500 direct DPRK jobs are involved in the project during the period of installation (on the order of 4 months).

Of the total budget, the main budget items include (all values rounded and rough approximations—see the Annex to this paper for details of estimates):

- Building energy efficiency hardware, materials: $64 million
- Solar PV systems, materials: $18 million
- Labor costs (DPRK and international): $3.7 million
- Administration costs for installation and follow-up: $8.4 million (at a rough estimate of 10 percent of direct costs), plus $3 million for overall management
- Shipping costs: $0.25 million
- Initial project/program preparation costs: $3.2 million

= Total Project Costs: ~$100 million.

Assuming that the project saves heat produced in coal-fired heating plants, and produces electricity from renewable sources that otherwise would have been produced in coal-fired power plants, over the lifetime of the measures and equipment included in the project a total of 2.6 million tonnes of carbon dioxide equivalent (CO_2e) would be saved, worth $85 million at current (2020) South Korean Emissions Trading System (ROK ETS—the ROK's carbon market) prices.[35]

In addition to the number of participating apartment units and RE installation sites, some of the key uncertainties driving project costs include:

- The cost of materials and equipment. Our estimates are based loosely on costs for key components as listed in Alibaba.com, and thus are consistent with the upper end of Chinese FOB (freight on board) prices, but if the materials are sourced elsewhere, and/or prices have changed notably, costs could be different (either higher or lower).
- The cost of labor in the DPRK and for international installers. We have assumed an average cost for DPRK labor, $150 per month, that is about 50 percent higher than paid to Kaesong workers in approximately 2016, but this value is likely to be a point of negotiation with DPRK counterparts. For international installers we have assumed an average of about $40 per hour, which is about double what an average installer of insulation, solar PV systems technician, or painter would receive in the US, Australia, or the ROK (for example). Even with a relatively high ratio of DPRK to international installers, the international labor costs dominate the total installer plus foremen labor budget for the project.
- The assumed rate at which individual installations can be carried out. We have assumed a total average of 16 person-days per apartment for the EE installations, and about 360 person-days per RE installation (an average-sized school), including both installation of RE systems, EE measures, and ancillary elements such as training, wiring, and grid interconnections (if applicable). We would guess that

[35] See, for example, World Bank (2020), Carbon Pricing Dashboard" (Korea ETS data, described as "nominal prices, April 1 2020"), available from https://carbonpricingdashboard.worldbank.org/map_data.

these estimates are probably more likely to be too high than too low for a well-designed program where installations are for many similar units and buildings, and crews rapidly become experienced and efficient.

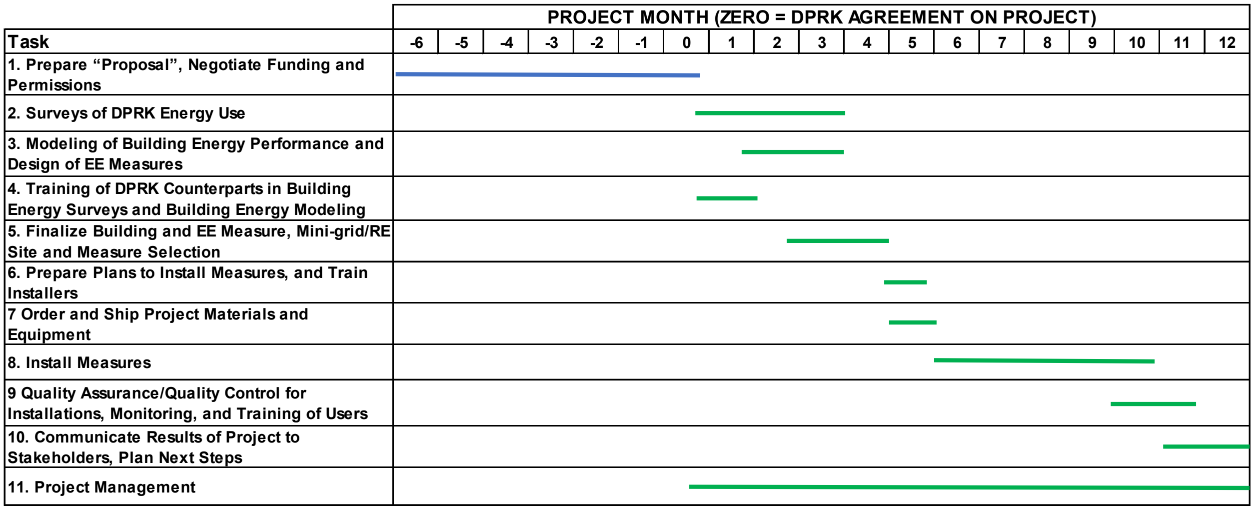
As a more detailed proposal for a consortium-led rapid deployment EE/RE project in the DPRK is developed, it will be necessary to refine all of these estimates with the input of building sector professionals.

6.2 Project Workplan/Timeline

As noted above, we have predicated the design of this project on a 12-month timeline from agreement to completion. It is possible that the project could be completed slightly faster, if all project tasks go extremely smoothly, but just as possible (perhaps more so) that unforeseen delays will result in slower-than-expected deployment. A rough project timeline is provided below and in Figure 6-1. For this timeline, note that we consider "month zero" to be the date on which the DPRK agrees to the project, at which point we assume that the project will need to be ready for rapid implementation in order to sustain the momentum of engagement.

- **Months minus 6 (approximately) to 0** (that is, a six-month period prior to when the DPRK says "Yes"): Initial project/program preparation, including forming Advisory Committee, securing funding, identifying potential teams/firms participating, and preparing a detailed project design
- **Month 0 to 4**: Finalize the consortium team structure, choose a lead firm or organization, obtain program permissions from governments as required, negotiate details of project with DPRK counterparts, perform energy surveys, select sites, and prepared detailed designs and schedules of installations
- **Month 5**: Order and obtain shipment of materials, hire and train workers
- **Months 6 - 10**: Deploy workers, install materials/systems, train users
- **Months 11 – 12**: One month or so for contingency in case schedule slips; perform QA/QC of installed materials and systems, project evaluation and reporting, planning for follow-up.

Figure 6-1: Illustrative Schedule for Rapid Deployment EE/RE Project in the DPRK



7 Organization and Composition of Project Development/Deployment Consortium Team

Fielding a project like that described above in a DPRK setting will be a unique undertaking. As described above, project success will require the experience and skills of a networked consortium of diverse organizations and individuals, communicating clearly and frequently

7.1 Concept of a Humanitarian- or Development-networked Consortium

A humanitarian- or development-networked consortium would be assembled solely for the purpose of implementing funded projects in the DPRK as part of engagement activities related to addressing tensions on the Korean Peninsula and beyond. As such, it should not be the aim of the consortium to establish an on-going social or commercial presence in the DPRK, rather to be a vehicle for carrying out complicated international projects in an efficient and transparent manner that reports and receives input from all parties but is not under the control of any individual government.

As such, a consortium approach is required to develop and deploy substantial technical assistance in the DPRK rapidly for a major project, due in large part to the variety of skills and experience needed to carry out the project.

Even if it is funded principally by a ROK agency or NGO, it should be noted that the consortium might need to include mostly non-ROK participants in order to secure DPRK approval, at least for an initial period (probably lasting years) while DPRK/ROK negotiations and rapprochement are in process.

7.2 Why a Consortium Approach would be Required to Develop and Deploy Project

A consortium approach will be needed for this project due to the challenges in working in the DPRK in general, and the challenges specific to working in the DPRK to deploy a pilot project in the context of denuclearization efforts. Some of the challenges for working in the DPRK range from logistical challenges such as lack of local materials and problems in moving materials from place to place, to organizational challenges associated with working in multiple DPRK agencies that do not normally interact much (a problem not unique to the DPRK), with lines of authority that cross and individuals who may be very sensitive to how their actions and decisions are perceived by superiors. A consortium approach is also necessary in order to deploy substantial technical assistance in the DPRK for a major project, because the skills needed, ranging from supplying academic training to on-the-ground installation of EE and RE measures, will be beyond the scope of most any individual organization, and because many different countries and groups within countries will have major political and (eventually) economic stakes in the project outcome.

7.3 Skills Needed for Consortium

The consortium will need a mix of skills and organizational capacities, and will need to be composed of individuals and organizations of acceptable (mostly to the DPRK, but also to other stakeholders) national origins to make working in the DPRK relatively smooth from inception in a rapid humanitarian and development project. As such, the project will require energy efficiency and renewable energy technical skills at the planning, training, and implementation levels, diplomacy skills, experience working with DPRK officials, technicians, and other DPR Korean counterparts, economic development experience, logistical skills, and organizational and management skills, as well as many other capabilities.

The authors have not yet made an significant study of models for consortium-led projects that may be applicable to the rapid deployment EE/RE DPRK project described here, but the literature does include a number of examples where consortium-based approaches have been deployed, for example, for emergency aid provision following natural disasters,[36] war zone recovery,[37] or other initiatives. The process of assembling a proposal for funding for the project described here should include a review of the lessons learned in carrying out these previous consortium-led aid efforts.

[36] See, for example Sneha Krishnan (2017), "Humanitarian consortia approaches: evidence from Eastern India", *Environment & Urbanization*. Vol 29(2): 459–476, available as https://journals.sagepub.com/doi/pdf/10.1177/0956247817718430.

[37] See, for example, Reliefweb (2018), "Access consortium launched new humanitarian programme to support over 120,000 conflict-affected people in Eastern Ukraine", dated 12 Sep 2018, and available as https://reliefweb.int/report/ukraine/access-consortium-launched-new-humanitarian-programme-support-over-120000-conflict.

7.4 Types of Organizations Involved in Consortium, and Potential Management Structure

The consortium will have a mix of non-profit and for-profit contractor firms and institutions, including a consortium "convener" or "management team", which might be a private firm, skilled in assembling and running such a group.

7.5 Types of Capacities for Engagement with Governments Required

For the project to succeed, the project consortium will need to have groups and individuals with the diplomatic capacities and political connections to engage each of the nations that have a stake in resolving conflict issue on the Korean peninsula. This would include, for example, each of the "six parties" previously involved in talks (the US, Russia, China, the ROK, the DPRK, and Japan), as well as European authorities, both national and Europe-wide. One or more consortium members will need to have the capacity to engage various supplier countries, as well as to work with sanctions review and licensing agencies, especially in the US.

7.6 Inclusion of Institutions as "Advisors" to Consortium, if not Direct Participants

Inclusion of key national and international institutions as advisors to the project consortium, even if those institutions are not direct participants in the project, would likely be beneficial for both the initial project and to plan/fund follow-on development. Whether through a formal role on the Advisory Committee or as informal advisors, staff from major intergovernmental organizations (IGOs), multilateral development lenders, and bilateral aid agencies could advise or serve as representatives in consortium management.

Examples of such institutions might include UNDP, the World Bank, ADB, possibly the Chinese Exim Bank and likely also KOICA (the ROK's Korea International Cooperation Agency), and national and international European Union aid organizations. Involving such organizations in the project early-on, even if they do not contribute to funding for the pilot project (which they likely wouldn't, for a rapid deployment effort), would pay dividends when it is time to build on the success of the project to continue and expand economic development/engagement activities with the DPRK.

8 Conclusions

Nautilus Institute's experience in working with the DPRK delegations and in the DPRK has included the following insights:

- It is important to design projects that can be built upon with future engagement activities, also that also can be used as models for peaceful redevelopment activities by the DPRK itself.

- Good projects should start relatively small, so as to be tractable for initial funding and deployment while experience is gained, but should be scalable based on needs and funds available.
- Good projects should be designed to build and take advantage of the growing technical/organizational capacity of DPRK partners. These capabilities can be expected to growth through the participation of individuals from the DPRK in engagement activities, but also as a result of the gradual uptake of new technologies into DPRK society as its economy becomes more market oriented.
- Good projects should meet the needs of several different DPRK constituent groups, as well as the needs of project participants and supporters in ROK and elsewhere.
- Good projects should be constructed so as to contribute toward peaceful, sustainable improvements in the DPRK economy.

These insights should be taken into account when developing and undertaking the type of consortium-led, rapid EE/RE CTR+ engagement project discussed here. In addition, below we discuss the types of support that will be needed to enable the project, key project risks and how those risks might be mitigated, how the project might be built upon as negotiations continue, and the benefits and perils of mounting multiple engagement projects.

8.1 Types of Support Needed to Enable Project

In order to be successful, a consortium-led, rapid EE/RE engagement project in and with the DPRK will require support from the international community, certainly meaning through funding and in-kind contributions, but also in terms of political support to enable the project to move forward in a timely fashion, and to encourage the right partners to participate in the project.

Potential sources of funding for the project include ROK institutions and foundations, US/European foundations, and other donors. Funders must, however, be willing and able to move rapidly so that opportunities to move forward with the project can be captured before the political impetus to do so wanes (or reverses).

Similarly, key organizations in the nations in the international community that are involved in discussions with the DPRK geared toward addressing its nuclear weapons program and tensions on the Peninsula must likewise be willing to move rapidly to address or ease barriers in their own nations that might stymie the project. These barriers may include direct “red tape” (licensing and permit requirements) that keeps the project from being rapidly developed and implemented, regulations or perceived biases that might keep capable potential consortium members and/or experts with skills needed by the project from joining the project, and domestic political obstacles that may not be directly related to the project, but which affect the level of support for the project that leaders can provide.

8.2 Key Project Risks/Risk Mitigation

As with any project involving the DPRK, and, indeed, most development-oriented projects in many countries, there are several risks that may keep the project from succeeding or delay project implementation or completion. These risks include, but are certainly not limited to:

- Delays in obtaining the necessary approvals (tacit and/or official) from governments;
- Delays in obtaining adequate funding (and/or that funding will be withdrawn if there is a shift in the political winds);
- Delays in assembling cooperation mechanisms with DPRK counterparts;
- Delays in material delivery through delays in ordering, customs delays, and/or transport/unloading delays;[38] and/or
- Delays due to disruption in support in one or more stakeholder nations due to political events (sometimes not directly related to DPRK issues, such as the needs of policymakers to appeal in a particular way to their domestic supporters at a particular time), elections, or international events that divert attention and funding to other venues.

Of these, delays in approvals and or in reaching agreement with DPRK counterparts may be reduced through good communications, logistical delays can be minimized through good planning and development of contingency plans, and the risk of project disruption by outside events can be reduced by attempting to insulate the project from politics by the mutual agreement of stakeholders. But no matter what risk reduction measures are implemented, risks of project disruption will still exist, and the consortium implementing the project will need to be ready to deal with disruptive events and circumstances when (probably not if) they occur.

8.3 How Project Might be Built Upon as Negotiations/Engagement Continues

The consortium-led, rapid engagement EE/RE CTR+ project described in this paper, depending on its success in implementation, might be built upon in many ways as negotiations between the DPRK and the international community, and engagement of the international community with the DPRK, continue. Just a few of the ways that the project might be built upon in the short- to medium-term include:

- Work with the DPRK to develop co-manufacturing of materials for further EE/RE applications (such as MgO board made in the DPRK from DPRK magnesia resources

[38] Nautilus Institute's Unhari humanitarian wind power project (which included missions to the DPRK in 1998 and 2000), for example, was very nearly delayed beyond recovery when the shipping container holding virtually all of the material and equipment for the project could not be off-loaded in the DPRK port of Nampo due to there being a very few working dockside cargo cranes at the time. Only heroic and politically muscular intervention by the main DPRK counterpart for the project convinced the port authorities to prioritize the unloading operation, which finally took place the day before the Nautilus team arrived at the project site.

or expanded in-country assembly of solar PV panels), and related economic development.

- Work with the DPRK to develop related projects, such as electricity grid rehabilitation via (or including) broad dissemination of mini- and micro- grids based on renewable energy, and broader assessments of energy needs and implementation of energy and environmental planning (including sustainable development planning) in the DPRK.
- Apply the lessons learned during the project to make progress on long-standing energy interconnection proposals involving the DPRK, including electricity grid interconnections from the ROK through the DPRK to Russia and/or China and Mongolia, including linkages for improving the DPRK's energy security (and reducing its energy insecurity) to foster future economic development and economic engagement with the Northeast Asia region and the international community.
- Seek opportunities to find meaningful employment for scientists and technicians currently working in nuclear and related fields in the DPRK as the DPRK nuclear weapons programs are gradually put under international supervision and wound down as engagement proceeds.
- Use the project as a springboard to cooperative activities in other areas, such as biodiversity corridors along the Korean Peninsula and across the demilitarized zone, as well as to further educational exchanges in the energy and environment sector and beyond.

8.4 The Benefits (and Perils) of Multiple Approaches

Although the rapid engagement EE/RE CTR+ project described here is designed to incorporate flexibility in the event that elements of the project do not go as planned, it will probably be wise to implement other engagement projects concurrently or nearly so, to offer successes that leaders can point to in the event that one of the projects, despite the best efforts of all involved, end up failing. Multiple different projects offer the benefit of involving more DPRK officials, technicians, and ordinary citizens with their counterparts on international team, but will add some complexity to negotiations. As a consequence, it may be that only a few projects can be pursued at any one time, until additional experience is gained in working with DPRK colleagues. In addition, there will be a tendency, at least at first, for DPRK officials to want to limit interactions between North Koreans and foreigners, which will in turn probably limit the number of projects that can be carried out.

Annex: Detail of Budget and Timeline

ROUGH ESTIMATE OF COST AND PERFORMANCE OF BUILDING ENERGY EFFICIENCY AND SOLAR PHOTOVOTAIC "MICRO-GRID" MEASURES AS ENGAGEMENT OPTIONS FOR ROK/DPRK NEGOTIATIONS

Prepared by	David von Hippel and Peter Hayes, Nautilus Institute
Date Last Modified	9/11/2020

Key Inputs/Summary Costs and Impact Results, Building Energy Efficiency Program

Parameter	Value	Notes/References
Number of Apartments Covered	36,200	Initial Assumption
Fraction of Pyongyang Apartments Covered	4.29%	Calculated
Program Materials Costs	$ 63,669,767	Calculated
Program Labor Costs	$ 3,475,200	Installer costs only, does not include administration
Program Administrative Costs	$ 6,366,977	Calculated
Shipping Costs	$ 200,000	Calculated
Total Program Costs	**$ 73,711,943**	Calculated
Number of Shipments for Material	10	Calculated: 500 TEU Container Ships, Incheon to Nampo
DPRK Direct Jobs Created by Program	1448	Calculated: Over program lifetime only, and installation labor only; does not include administration tasks
Lifetime million tonnes of Coal saved by program	0.85	Calculated
Lifetime million tonnes CO2e saved by program	1.76	Calculated

Key Inputs/Summary Costs and Impact Results, Humanitarian Solar PV Program

Parameter	Value	Notes/References
Number of Schools (and/or Health Clinics) Covered	174	Initial Assumption
Equivalent Fraction of Pyongyang Schools Covered	16.2%	Calculated
Capacity of Solar PV Systems Installed (MW)	14.09	Calculated
Program Materials Costs	$ 17,617,500	Calculated
Program Labor Costs	$ 380,695	Installer costs only, does not include administration
Program Administrative Costs	$ 2,002,773	Calculated
Shipping Costs	$ 49,690	Calculated
Total Program Costs	**$ 20,050,658**	Calculated
Number of Train Cars for Material	99	Calculated
DPRK Direct Jobs Created by Program	143	Calculated: Over program lifetime only, and installation labor only; does not include administration tasks
Lifetime million tonnes of Coal saved by program	0.38	Calculated
Lifetime million tonnes CO2e saved by program	0.80	Calculated

Key Inputs/Summary Costs, Initial Program Preparation and Management Fee

Parameter	Value	Notes/References
Professional Labor, tasks 1 through 5 ("Prepare "Proposal", Negotiate Funding and Permissions" through "Finalize Building and EE Measure Selection, and Mini-grid/RE Site and Measure Selection", person-months	90	Initial Assumption. Would include planners, analysts, outreach professionals, engineers, survey staff, and others.
Average professional labor costs per month	$ 25,000	Initial Assumption
Implied total labor costs for initial program preparation	$ 2,250,000	Calculated
Travel and other costs associated with initial program preparation	$ 900,000	Initial Assumption, would include trips to Korea (North and South) for surveys, coordination, outreach, plus trips for meeting of project personnel, software costs, modest equipment costs, and other related costs. Rough estimate of $10,000 per person-month of labor.
Initial costs of program preparation	$ 3,150,000	Calculated

Management fee for delivery program in addition to administrative costs included above	$ 3,000,000	Initial Assumption. Payment to firm managing overall program delivery (in addition to more general administrative costs)

Total Cost of Building Energy Efficiency and Solar PV Programs	**$ 99,912,601**	Calculated based on Above

Korea Emissions Trading Scheme (ETS) carbon price as of September 2020	$33.00	per tonne CO_2 equivalent--see https://carbonpricingdashboard.worldbank.org/map_data
Implied potential value of carbon allowances based on lifetime CO_2e reductions from the two programs above (million dollars)	**$ 84.50**	Calculated. Note that it is unclear to us at this time whether, or how, these programs would qualify to participate in Korea's ETS, so this should be considered an illustrative figure.

ROUGH ESTIMATE OF COST AND PERFORMANCE OF BUILDING ENERGY EFFICIENCY MEASURES AS ENGAGEMENT OPTION FOR ROK/DPRK NEGOTIATIONS

Prepared by	David von Hippel and Peter Hayes, Nautilus Institute
Date Last Modified	9/11/2020

Building Population and Average Apartment Configuration Assumptions and Calculations

Parameter	Value	Notes/References
Population of Pyongyang	3,222,000	As of about 2015 or2016; http://worldpopulationreview.com/countries/north-korea-population/cities/
Persons per Household	3.817	Nautilus analysis for 2014, persons per urban household nationwide, based roughly on 2008 DPRK Census
Number of households	844,118	Calculated
Fraction of Households in Apartments that are Candidates for Insulation Upgrades	75%	Rough Estimate--excludes single family and smaller buildings, and newer buildings
Number of households that are candidates for Insulation Upgrades	633,089	Calculated
Number of Apartments in Pyongyang to be covered by program	36,200	Rough Estimate--Input on Summary Tab
Implied Fraction of Pyongyang households covered by program	4.29%	Calculated
Average Floor Area of Pyongyang Apartment, square meters	75	Rough Estimate, but right answer is probably between 60 and 100 square meters
Exterior perimeter of Average Pyongyang Apartment, meters	17	Rough estimate based on corner apartment--average could be less
Average Wall Height, meters	3	Rough estimate, average is likely somewhat less
Implied average wall surface area, including windows (square meters)	51	Calculated
Estimated average thickness of foam core insulation ("XPS" type) to be applied, cm.	7.5	Would provide the equivalent of R-15 (~3 inch in US), which is approximately what would be needed to insulate masonry walls in colder US climates to "2009 International Energy Conservation Code (IECC)" standards (see https://www1.eere.energy.gov/buildings/publications/pdfs/building_america/measure_guide_rigid_foam.pdf)
Implied volume of foam core boards (and windows) required per household (cubic meters)	3.825	Calculated
Number of windows per apartment	6	Rough Estimate
Average size of windows, square meters	1.5	Rough estimate, 1.5 m x 1.0 meter--probably likely an over-estimate, on average
Implied area of windows per apartment, square meters	9	Calculated
Additional foam core insulation beyond wall area, not including windows	10%	Accounts for cutting waste
Total volume of foam core insulation board needed per apartment, cubic meters	3.47	Calculated
Thickness of MgO Wallboard used (mm)	8	Assumption--a range of thicknesses from 3 mm to 20 or more mm are available.
Implied volume of MgO Wallboard per Apartment (cubic meters)	0.408	Calculated

Insulation and Windows Installation Labor and Materials Costs Assumptions and Calculations

Parameter	Value	Notes/References
Cost of Insulation per cubic meter	$ 100.00	Example--toward the upper end of range of XPS board from China, see https://www.alibaba.com/product-detail/Fire-proof-xps-foam-baord-Polystyrene_60506654477.html?spm=a2700.galleryofferlist.0.0.1b9dc90e4sVtPG&s=p or https://www.alibaba.com/product-detail/2400X1200X450-cm-Xps-insulation-board_62028190084.html?spm=a2700.galleryofferlist.0.0.1b9dc90e4sVtPG.
Implied cost of insulation per household	$ 346.50	Includes window area, so may be slight over-estimate (but there will be some scrap)
Cost of Windows, per square meter	$ 70.00	Window costs can vary widely, with many types and styles, and windows will need to be customized to individual types of buildings (requiring inspection/measurements). Example of double-glazed, PVC-frame Chinese-built units from https://www.alibaba.com/product-detail/PVC-double-glass-window-with-inside_60074799018.html?spm=a2700.7724838.2017115.162.401877a6UcbK5C
Implied cost of windows per household	$ 630.00	Calculated
Cost of MgO board (wallboard) to cover insulation, per square meter	$ 2.22	Estimate based, for example, on https://www.alibaba.com/product-detail/Fireproof-and-Waterproof-MgO-Board-For_60359931157.html?spm=a2700.galleryofferlist.0.0.538918a69G6iQE. There are a number of options. In practice, it is also possible to buy "sandwich" boards that include both XPS insulation and a wallboard product.
Implied cost per household of wallboard	$ 113.33	Calculated
Cost of Paint (per kg, latex interior)	$ 2.00	Estimate based, for example, onhttps://www.alibaba.com/product-detail/Odorless-acrylic-house-interior-decorative-latex_60332317490.html?spm=a2700.7724838.2017115.38.4fa0200dflhsCB&s=p
Coverage of paint (square meters/kg)	12	Estimate based on source above
Number of coats	2	Assumption
Implied cost of paint per apartment	$ 17.00	Calculated--note that only new walls are assumed to be painted
Cost of other building energy efficiency materials	$100	Rough estimate--could include adhesive for XPS/wallboard, fasteners, simple radiator valve, weather-stripping, caulking, wallboard tape and plaster….
Implied total materials cost of building energy efficiency upgrades for apartments (per apartment)	$ 1,206.83	Calculated--note that only new walls are assumed to be painted
Estimated number of DPRK person-days to install measures, per apartment	16	Would include insulation, windows, wallboard, painting. Could be separate crews.
Estimated number of international person-days to install measures, per apartment	1.43	Assumes one international worker per sixteen DPRK workers, plus one international foreman per 40 total workers
Implied total number of DPRK person-days for installations	579,200	Calculated
Implied total number of International person-days for installations	51,585	Calculated
Assuming that active installation period for program is (months)	4	Assumes approximately two months from program "go" for planning, design, organization, hiring, and delivery of first shipment of materials.
Number of DPRK installer jobs would be	1,448	Calculated--there would likely be additional jobs for coordination/administration/translation.
Costs of DPRK Installers ($/month)	$ 150.00	Estimate based on Kaesong worker costs from https://www.38north.org/2016/02/rfrank021916/, as paid to workers at Kaesong, plus 50% assuming more skilled labor (and rising labor costs).
Implied costs of DPRK Installers ($/day)	$ 6.00	Assumes work six days per week
Assumed costs of International installers (per hour)	$40	Note that this is about twice the average pay for a painter, wallboard installer, or insulation installer in the US or Australia, and about three time the average pay for construction workers in general in the ROK (see, for example, https://www.salaryexpert.com/salary/job/construction-worker/south-korea/seoul), and about 10 times the pay of a senior construction worker in China (see https://www.salaryexpert.com/salary/job/construction-worker/china).
Implied Labor costs for installation, per apartment, DPRK labor	$ 96.00	Calculated
Implied Labor costs for installation, per apartment, international labor	$ 456.00	Calculated
Total direct costs per apartment	$ 1,758.83	Calculated
Costs for administration of program as a fraction of direct costs	10%	Rough estimate of costs for, for example, design of measure application/engineering, training, accounting, ordering of materials, crew coordination, quality control, monitoring and evaluation….
Total direct and indirect costs per apartment	$ 1,934.72	Calculated
Total direct and indirect costs, all apartments	$ 70,036,743	Calculated

Shipping of Building Energy Efficiency Measures: Assumptions and Calculations

Parameter	Value	Notes/References
Assumed number of apartments per building (average)	120	Rough Estimate: 20 stories, 6 units per floor.
Implied number of buildings retrofitted	302	Calculated
Total volume of windows, wallboard, and insulation per apartment	4.55	Calculated
Additional required volume of materials as a fraction of volume of wallboard, windows, and insulation	10%	Rough Estimate
Average void space in packed shipping contai	10%	Rough Estimate
Required shipping container volume per apartment (cubic meters)	5.50	Calculated
Volume of a standards shipping container (TEU), cubic meters	39	For one 20-foot Equivalent Unit (TEU)
Implied total number of shipping containers required for materials	5,108	Calculated
Assumed size of ship required for transit from Incheon to Nampo (TEU)	500	Ports.com (http://ports.com/north-korea/port-of-nampo/) describes Nampo as being capable of handling ships over 500 feet in length, and having an anchorage depth of about 15 meters. As such, it should nominally be able to take ships larger than the "small feeder class" (see https://en.wikipedia.org/wiki/Container_ship#Size_categories) that is implied here, as a 500 TEU vessel would likely be less than 500 feet in length.
Implied number of ship journeys needed to carry building materials for program	10	Calculated
Leasing cost for small feeder class ships (daily)	$ 5,000	Rough estimate--see for example https://theloadstar.co.uk/charter-market-provides-welcome-boost-owners-smaller-containerships/. Assumed to include crew and fuel costs, subject to check.
Number of round-trip days, Incheon to Nampo	4	Distance from Incheon to Nampo is on the order of 120 nautical miles, implying travel time of well under a day, so days assumed includes some waiting time to unload and unloading time.
Implied cost per journey	$ 20,000	Calculated
Implied total sea transport cost	$ 200,000	Calculated

Assumptions and Calculations: Estimate of Energy and GHG Savings from Building Energy Efficiency Measures Applied

Parameter	Value	Notes/References
Fractional savings from insulation addition, window replacement, and other building energy efficiency measures	35%	Rough estimate. Greater than the 20% assumed by Nautilus in our earlier work for relatively low-cost windows and insulation measure from older literature sources reporting on applications for China, but the materials and techniques used here would be greatly superior.
Annual energy use per unit floor area before retrofit (kg coal equivalent)	23	A 2016 publication entitled "China Building Energy Use" (https://berc.bestchina.org/Files/CBEU2016.pdf) gives a "northern urban heating" energy use for the northern region of China of 22.8 kgce per square meter for 2001 in China. How much is used (when available) in Pyongyang is hard to know, but the Chinese value probably represents a reasonable target for comfort, and the efficiency of heat supply to Pyongyang apartments is probably lower, on average, than it was in China as of 2001.
Implied energy savings per apartment (kgce)	603.75	Calculated--represents coal savings at power plant.
Implied annual energy savings per apartment (GJ)	17.69	Calculated
Implied lifetime energy savings per apartment (GJ)	442.25	Calculated
Energy Content of DPRK Coal (GJ/tonne)	18.83	Calculated
Implied tonnes of coal saved per apartment/yr	0.94	Calculated
Implied annual tonnes of coal saved by Program	34,012	Calculated
Implied lifetime tonnes of coal saved by Program (million)	0.85	Calculated
Value of Coal saved at 2016 China import costs for DPRK coal ($/tonne)	53.00	Estimated from Comtrade statistics
Value of Coal saved at 2016 China import costs for DPRK coal ($ million)	$ 45.07	Calculated
Carbon Dioxide Equivalents kg per GJ coal	110.1	As used in Nautilus DPRK Energy Analysis, includes "upstream" emissions from coal production.
Implied annual CO2e savings per apartment (tonnes)	1.95	Calculated
Assumed average lifetime of apartment retrofit measures (years)	25	Assumption
Implied lifetime CO2e savings per apartment (tonnes)	48.69	Calculated
Implied annual CO2e savings for apartments in program (thousand tonnes)	70.51	Calculated
Implied lifetime CO2e savings for apartments in program (million tonnes)	1.76	Calculated
By way of comparison, a coal-fired power plant of	100	Megawatts (assumed)
Operating at a capacity factor of	60%	Relatively high for the DPRK in recent years
At an efficiency of	25%	Not atypical for the DPRK in recent years
Would produce output of	525.6	GWh/yr
From fuel input of	2102.4	GWh/yr
which is	7,568,640	GJ/yr input
or the equivalent of	0.40	million tonnes of DPRK coal per year

If, as an alternative to providing heat with a coal-fired system, one were to consider a system where individual households or buildings purchased diesel generators to provide power to provide heat, and paid local costs for diesel fuel to do so, the avoided energy costs would be as follows:		
Assumed average efficiency of heat production and delivery from coal-fired system	65%	Assumption
Implied use of heat per apartment saved by application of building energy efficiency measures (GJ)	11.50	Calculated
Assuming the use of diesel generation set with a delivered electricity efficiency of	20%	Assumption, includes generator efficiency and transmission and distribution losses.
And electric heating efficiency of	100%	Assumption--Resistance heater
Implies avoided diesel fuel use of (GJ/apartment)	57.49	Calculated
With diesel fuel energy content of (MJ/liter)	35.00	Assumption
This implies use of diesel fuel (for heating via electricity) of (liters per apartment year)	1,642.63	liters (Calculated)
Or for the full program	59,463,251	liters (Calculated)
At September 2017 (probably near-maximum) in-country retail cost of	$ 2.82	per liter (based on a reported price in September, 2017, of "30 euros per 15kg coupon" from https://www.nknews.org/2017/09/petrol-prices-up-by-43-in-north-korean-capital-source/, converted to USD per liter).
This represents an annual savings to DPRK residents (IF they were to provide heat in this way) of	$167,896,239	per year (Calculated)
At April 2018 in-country retail prices of	$ 2.48	per liter (based on anecdotal report by a recent visitor, as of early April, 2018, of "25.5 euros per 15kg", converted to USD per liter).
This represents an annual savings to DPRK residents (again, IF they were to provide heat in this way) of	$147,468,863	per year (Calculated)
Equivalent delivered MWh of resistance heat that the program would avoid per apartment	3.19	Calculated
Equivalent delivered total GWh of resistance heat that the program would avoid per apartment	115.62	Calculated
Assuming distribution losses from diesel generation sets (assumed to be on-site or near to apartment buildings) at	5%	Assumption
Implied MW of diesel generator capacity required to produce this heat assuming full-time operation would be	13.86	Calculated
But space heating occurs mostly during peak heating season, so assuming that heating is used the equivalent of	20%	of the time (Assumption)
The implied capacity of diesel generators needed to produce the same amount of home heating services provided by the energy efficiency measures (MW) is	69	Calculated

ROUGH ESTIMATE OF COST AND PERFORMANCE OF HIMANITARIAN SOLAR PHOTOVOLTAIC "MICRO-GRID" SYSTEM DEPLOYMENT
AS ENGAGEMENT OPTION FOR ROK/DPRK NEGOTIATIONS

Prepared by	David von Hippel and Peter Hayes, Nautilus Institute
Date Last Modified	9/11/2020

Average School and Clinic Size and Electricity Use Assumptions and Calculations

Parameter	Value	Notes/References
Population of Pyongyang	3,222,000	As of about 2015 or2016; http://worldpopulationreview.com/countries/north-korea-population/cities/
Fraction of Population as school-aged children	20%	Guess--can be refined by looking at DPRK census
Implied number of Children	644,400	Calculated
Average number of children per school	600	Assumption--elementary will be lower, high school more--this is probably a reasonable average for a middle school
Implied number of schools in Pyongyang	1,074	Calculated
Building footprint of average school (square meters)	600	Assumption--based on Nautilus visit in 2009 to "June 9th Secondary Middle School"
Number of rooms per floor	15	Assumption--based on Nautilus visit in 2009 to "June 9th Secondary Middle School"
Number of floors	5	Assumption--based on Nautilus visit in 2009 to "June 9th Secondary Middle School"
Maximum lighting power per room (watts)	240	Assumption--based on Nautilus visit in 2009 to "June 9th Secondary Middle School"
Implied Estimated lighting use per building (watts)	18000	Calculated
Ratio of total power requirements to lighting maximum power	3	Assumption--but probably assumes no electric heating
Total maximum kW of school power demand	54	Calculated
Estimated equivalent hours of operation at peak power demand	1500	Assumption--could be less as is probably reduced by daylighting
Implied annual electrical energy demand per school (MWh)	81	Calculated

Average Solar Energy System Operating Parameters and Costs: Assumptions and Calculations

Parameter	Value	Notes/References
Number of Schools (and/or Clinics) covered by program	174	Rough Estimate--Input on Summary Tab
Full-power equivalent hours per year of operation of solar panels in Pyongyang	1,300	Estimate
Conversion losses in solar PV/battery system	30%	Assumption
Implied gross generation requirements per system (MWh)	105.3	Calculated
Implied capacity required per system (kW)	81.00	Calculated
Efficiency of solar PV system	17%	Assumption; for example, Chinese system on Alibaba at https://www.alibaba.com/product-detail/Bluesun-off-grid-photovoltaic-panels-20kw_60665965806.html?spm=a2700.7724838.2017115.41.1cff1996OLwSBy&s=p
Full-sun solar input (kW per square meter)	1	Assumption--essentially, the solar constant
Implied required minimum square meters of mounting area per system	476	Calculated
Cost per kW of capacity	$ 1,000.00	Assumed to include panels, mounts, batteries, inverter, and most other materials directly associated with PV system. Cost is at high end of Alibaba Chinese solar vendor (see https://www.alibaba.com/product-detail/Bluesun-popular-home-power-system-100_60829396820.html?spm=a2700.details.deiletai6.8.42d45ce32wTUmK, or https://www.alibaba.com/product-detail/2020-10000w-high-efficiency-solar-energy_1600086183009.html?spm=a2700.details.pronpeci14.2.5a622495ssPTKH), assuming that systems would be sourced from ROK if possible.
Additional costs of materials associated with installation (per kW)	$ 250.00	Assumption
Implied total capital costs of PV installations	$ 17,617,500	Calculated
Estimated number of person-days to install system, per school	364.5	Calculated. Starts with estimate for installation of 20 kW system by supplier above (24 hours, but number of workers not stated, assumed to be 6), increases to account for larger size of system, then multiplies by five to include requirements for training, tasks such as interior wiring, grid interconnections.
Implied total number of person-days for installations	63,423	Calculated
Fraction of person-days for international labor (includes workers and foremen)	10%	Assumption
Assuming that active installation period for program is (months)	4	Assumes approximately two months from program "go" for planning, design, organization, hiring, and delivery of first shipment of materials.
Number of full-time installer jobs would be	159	Calculated--there would likely be additional jobs for coordination/administration.
Costs of DPRK Installers ($/month)	$ 150.00	Estimate based on Kaesong worker costs from https://www.38north.org/2016/02/rfrank021916/, as paid to workers at Kaesong, plus 50% assuming more skilled labor (and rising labor costs).
Implied costs of DPRK Installers ($/day)	$ 6.00	Assumes work six days per week
Costs of international installers ($/hr)	$ 40.00	Assumes a rate twice the average in the US (see, for example, https://www.bls.gov/oes/current/oes472231.htm)
Implied Labor costs for installation, per school or clinic, DPRK labor	$ 2,187.90	Calculated
Implied Labor costs for installation, per school or clinic, international labor	$ 11,664.00	Calculated
Total direct costs per school or clinic	$ 115,102	Calculated, includes DPRK and international labor.
Costs for administration of program as a fraction of direct costs	10%	Rough estimate of costs for, for example, design of measure application/engineering, training, accounting, ordering of materials, crew coordination, quality control, monitoring and evaluation….
Total direct and indirect costs per school/clinic	$ 126,612.09	Calculated
Total direct and indirect costs, all school/clinics	$ 22,030,504	Calculated

Shipping of Solar PV Systems: Assumptions and Calculations

Parameter	Value	Notes/References
Estimated kW per school or clinic	81	As calculated above
Estimated shipping volume of systems	10	cubic meters per 20 kW (estimated from information provided by vendor above)
Total volume of material per school or clinic (cubic meters)	40.50	Calculated
Volume of a standards shipping container (TEU), cubic meters	39	For one 20-foot Equivalent Unit (TEU)
Average void space in packed shipping containers	10%	Rough Estimate
Implied number of TEU containers per school or clinic	1.14	Calculated
Implied total number of shipping containers required for systems	198.76	Calculated
Number of TEUs per train car	2	Assumption
Number of train cars required	99.38	Calculated
Estimated Shipping cost per train car	$ 500	Placeholder estimate.
Implied total rail transport cost	$ 49,690	Calculated

Assumptions and Calculations: Estimate of Energy and GHG Savings from Solar PV Systems Deployed

Parameter	Value	Notes/References
Assumed efficiency of coal-fired power generation	21%	Assumption based on Nautilus Analysis
Assumed T&D losses for supplying grid electricity to schools/clinics	20%	A 2016 publication entitled "China Building Energy Use" (https://berc.bestchina.org/Files/CBEU2016.pdf) gives a "northern urban heating" energy use for the northern region of China of 22.8 kgce per square meter for 2001 in China.
Implied annual avoided coal use per school or clinic system (GJ)	1,666	Calculated--represents coal savings at power plant.
Estimated solar PV system lifetime, average (years)	25	Rough Estimate
Implied lifetime coal energy savings per school or clinic (GJ)	41,657	Calculated
Energy Content of DPRK Coal (GJ/tonne)	18.83	Calculated
Implied tonnes of coal saved per school or clinic per year (tonnes)	88.50	Calculated
Implied annual tonnes of coal saved by Program	15,399	Calculated
Implied lifetime tonnes of coal saved by Program (million)	0.38	Calculated
Value of Coal saved at 2016 China import costs for DPRK coal ($/tonne)	53.00	Estimated from Comtrade statistics
Value of Coal saved at 2016 China import costs for DPRK coal ($ million)	$ 20.40	Calculated
Carbon Dioxide Equivalents kg per GJ coal	110.1	As used in Nautilus DPRK Energy Analysis, includes "upstream" emissions from coal production.
Implied annual CO2e savings per school or clinic (tonnes)	183.46	Calculated
Implied lifetime CO2e savings per school or clinic (tonnes)	4,586	Calculated
Implied annual CO2e savings for schools/clinics in program (thousand tonnes)	31.92	Calculated
Implied lifetime CO2e savings for schools/clinics in program (million tonnes)	0.80	Calculated

ROUGH ESTIMATE OF COST AND PERFORMANCE OF HIMANITARIAN SOLAR AS ENGAGEMENT OPTION FOR ROK/DPRK NEGOTIATIONS

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Illustrative Project Schedule by Task