Energy Poverty in Democratic People's Republic of Korea: A Study of Evidence-Based Policy Making and Data Visualizations

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Abstract

The purpose of the paper is to demonstrate the power of evidence-based policy making in developing countries by combining multiples sources of data, leveraging data analytics, and conducting data visualization. As a case study, we investigate fundamentals of energy supplies and demands in the Democratic People's Republic of Korea (DPRK, also known as, North Korea) and provide information useful to policymakers with a goal to assess energy needs and solutions tailored to the Korean population. DPRK has been extensively relying on hydroelectric power and consumable energy such as coal and wood. The former has been quite unstable due to the outdated infrastructure of hydroelectric plants that is not amenable to drastic changes in weather like drought and floods. The latter has its limit to fill the energy needs of the population in DPRK due to limited resources. This paper examines energy poverty in DPRK with that of other countries to inform the process of energy policy making in DPRK and provides evidence-based policy implications to neighboring countries and the United Nations.

1. Introduction

DPRK's weather conditions tend to disrupt the state's ability to provide electricity to its citizens. For example, the droughts in 2015 hampered the nation's hydroelectric plants. With over 60% of its electricity produced by hydroelectricity and the general reliance on fossil fuel, housing units that are connected to the electric grid receive just a few hours of electricity per day. Electricity shortage and reliance on biomass for basic energy needs may lead to respiratory diseases and deforestation, among other consequences for health, the environment, and social development. Utilizing other fuels to produce electricity may alleviate the need to rely on hydropower, and consequently lift North Koreans out of energy poverty. However, economic underdevelopment and outdated electric grids may hinder the progress of energy development in DPRK.

2. Background and Literature Review

The purpose of the paper is to demonstrate the power of evidence-based policy making in developing countries by combining multiples sources of data, leveraging data analytics, conducting data visualization, and providing information useful to policymakers and stakeholders. As a case study, we study fundamentals of energy supplies and demands in DPRK with a goal to provide evidence that may inform energy policies by DPRK and its neighboring countries. Supply of electricity in DPRK is characterized by heavy dependence on hydroelectric sources, comprising 60% of total output. For example, severe droughts in 2015 caused extreme shortages of electricity, with the majority of households connected to the power grid receiving only a few hours of electricity per day.

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This drought exacerbated and brought into focus the ongoing issue of the North's precarious electricity situation. It is the objective of this paper to assess the complex problem of DPRK's electricity needs and explore pragmatic solutions to DPRK's electricity. Analysis is done at both the regional and national level to form a comprehensive picture. We combine data from the DPRK Census and international organizations such as the International Energy Agency, World Bank, and the United Nations (UN). Data-based evidence from this research may inform energy policy decisions of UN organizations, nongovernmental organizations, and neighboring countries as well as DPRK.

2.1. Definition of energy poverty

There are many definitions of energy poverty in the literature, and they point to the lack of frequent access to energy that leads to serious consequences in health, well-being, and income. In this paper, we use the definition set forth by Reddy (2000), which was further rigorously analyzed by Gonzalez-Eguino (2015). According to Reddy, energy poverty is "the absence of sufficient choice in accessing adequate, affordable, reliable, high-quality, safe and environmentally benign energy services to support economic and human development".

Through this definition, we can understand energy poverty in two aspects: 1) the lack of choice of energy sources, and 2) the lack of technologies that allow sufficient consumption of energy. In the first aspect, developed countries tend to have access to various sources of energy, including electricity, coal, oil, gas, biomass, and renewable energy, while developing countries tend to rely on biomass for basic needs. Indeed, 60% of energy need in developing countries is fulfilled by biomass such as wood, crop waste, and dung. These low-quality energy sources tend to be replaced with higher-quality fuels as income increases, according to the "energy ladder" theory (van der Kroon, Brouwer, & van Beukering, 2013).

In the second aspect, countries need adequate technologies and facilities to provide quality energy services. These services need to be "adequate"; they need to be suited to any distinct economic, geographical, and cultural characteristics of the countries of interest. These services also need to be affordable and reliable so that countries can maintain energy consumption without breaks. They need to be high-quality, safe and environmentally benign so that the health of the current population and the safety of future generations are ensured (Gonzalez-Eguino, 2015). Last but not least, the goal of these energy services is to "support economic and human development", which implies that investment in energy services is worthwhile to bring about progress in development in general.

2.2. Measurements of energy poverty

Part and parcel of defining energy poverty is measuring it. Pachauri and Spreng (2011) set forth three approaches to measuring energy poverty: the technological threshold, the physical threshold, and the economic threshold.

The technological threshold is rooted in the notion that energy poverty is a problem of access to "modern" energy sources. In this viewpoint, "modern" energy sources are high-quality, clean, and versatile sources, such as electricity. They are superior to

traditional energy sources like biomass, which places constraints on the access to basic energy services, such as cooking, heating, cooling, lighting, and transportation. As such, energy poverty is measured as the number of people without access to these energy services.

The physical threshold considers the minimum energy consumption required to facilitate basic necessities. The population that use less than the minimum consumption threshold is considered to be in energy poverty.

Finally, the economic threshold is the maximum percentage of income that should reasonably be used for energy spending. This measure is more often used in developed economies, in which the problem is not access to sources or quantities of energy, but the burden of purchasing this access.

3. Research Questions

We assess supply and demand of energy in DPRK by key characteristics, such as region and population types ─and investigate the extent to which various sources of energy may meet the basic needs of people in DPRK. We investigate energy challenges and opportunities DPRK faces in comparison to other countries. We turn key findings into energy policy recommendations useful and relevant to DPRK. For example, the connection of energy poverty to health, the environment and development would be assessed to inform the process of policy making.

Below are the research questions to address in this paper.

1. What is the distribution of the demands for electricity across DPRK by feasible units of analysis, such as geographic region, population density, and recipient types (e.g., urban vs. rural areas).
2. What is the distribution of the supply of energy DPRK produces by various sources, in comparison to other countries?
3. How is energy poverty related to health, the environment and development?
4. What policy recommendations would be offered to address DPRK's energy poverty based on evidence?

4. Methodology

We leverage data visualization as an analytical tool to investigate energy poverty and its consequences in health, environmental conservation, and social development. Our analysis is accomplished in three stages. First, we investigate key ideas in the literature about the constitution of energy poverty, namely, the lack of choice of energy sources and the lack of access to electricity. We utilize data from the International Energy Agency to plot the pattern of traditional usage of biomass for cooking and the electrification rate for developing regions in the world. Urban and rural areas are juxtaposed to reveal any disparity in energy development.

In the second stage, we deconstruct the demand and supply of electricity in our case study, DPRK. To characterize DPRK's electricity demand, we map the population density along regional characteristic. We then break down the usage of energy for cooking and heating in North Korean households based on energy sources, with an emphasis on electricity. To characterize North Korean electricity supply, we conduct a

comparative analysis of the North Korean case with other nations of interest: China, South Korea, and the US. For all nations, we break down electricity production based on energy sources in order to provide an understanding of the common challenges in electricity production, and to reveal smart solutions utilized by OECD nations like South Korea and the US.

In the last stage, we investigate the consequences of energy poverty in maternal health, environmental conservation, and social development. (Due to the lack of data in respiratory diseases, we analyze maternal health instead of respiratory diseases in DPRK.) We utilize data from the United Nations' database for the Millennium Development Goals Indicators to demonstrate the effect of energy poverty on DPRK's progress over more than two decades. We choose maternal mortality ratio, a statistic widely used by international organizations such as WHO and the United Nations, as a proxy for maternal health. We choose the proportion of land area covered by forest as a proxy for environmental conservation. Finally, we choose the usage of the internet and cell phones as a proxy for social development, since these services lead to human interactions and access to information, which in turns lead to the dissemination of ideas, development and growth.

Through these research stages, we provide an understanding of the constitution of energy poverty and its consequences on development. We show the extent to which a nation's growth can be propelled when its energy challenges are resolved by smart solutions. Such an approach in policy making may contribute to developmental goals set forth by the United Nations, NGOs, and governmental agencies.

We use data from the following sources:

- CIA Fact Book 2002 (via United States Military Academy)
- Democratic People's Republic of Korea (DPRK) 2008 Population Census, developed by DPRK Central Bureau of Statistics, with technical support and funding from the United Nations Population Fund
- Global Administrative Areas' shapefile for map visualizations
- International Energy Agency's World Energy Outlook 2016 (data for year 2014)
- International Energy Agency's data for electricity and heat
- The United Nations' database of Millennium Development Goals Indicators
- World Bank's World Development Indicators

5. Findings

In this section, we leverage interactive data visualizations to illustrate energy poverty in DPRK and its consequences. To that end, we present our data visualizations in three sub-sections, which reflect the three stages of our research as presented in the Methodology section. In the first sub-section, we investigate key ideas in the literature about the constitution of energy poverty, namely, the lack of choice of energy sources and the lack of access to electricity. In the second sub-section, we deconstruct the demand of electricity in DPRK by mapping population density and North Korean households' usage of energy sources for basic needs. To understand the supply of electricity in DPRK, we conduct a comparative analysis of the North Korean case with other nations of interest: China, South Korea, and the US. In the last sub-section, we

investigate the consequences of energy poverty in maternal health, environmental conservation, and social development.

5.1. Energy access in DPRK, compared to developing regions in the world

Electricity is one of the cleanest and most versatile energy sources. According to our data visualization of the electrification rate in 2014 (figure 1), both urban and rural DPRK display the lowest percentages of its population with access to electricity, coming in last place among four other parts of the world surveyed, with 36% and 11% respectively. These figures lag far behind the world's electrification rates, which are 95% and 71% for urban and rural areas respectively. On the other hand, Latin America shows the highest percentages of its population with access to electricity, as 98% of its urban population has access to electricity, and 85% of its rural population has access to electricity, thus showing an average of 91.5% of its whole population with access to electricity. For all developing regions, urban areas have higher electrification rate than rural areas.

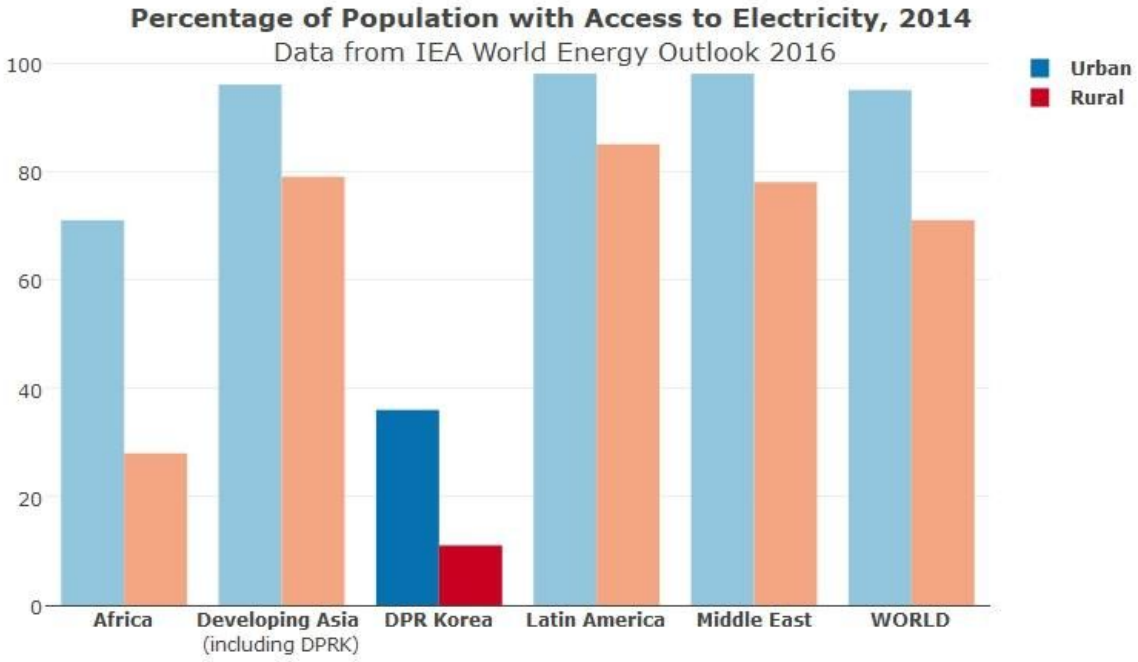

Figure 1: Percentage of Population with Access to Electricity, 2014
Data Source: The International Energy Agency's World Energy Outlook 2016

In addition, DPRK shows the third highest percentage of population relying on traditional use of biomass after Africa (figure 2). Specifically, Africa reportedly has 69% of its population that relies on traditional use of biomass, developing Asia has 50%, and DPRK comes in third with a close number of 47%, according to data reported in 2014. DPRK's rate is also higher than the world average, which is at 38%

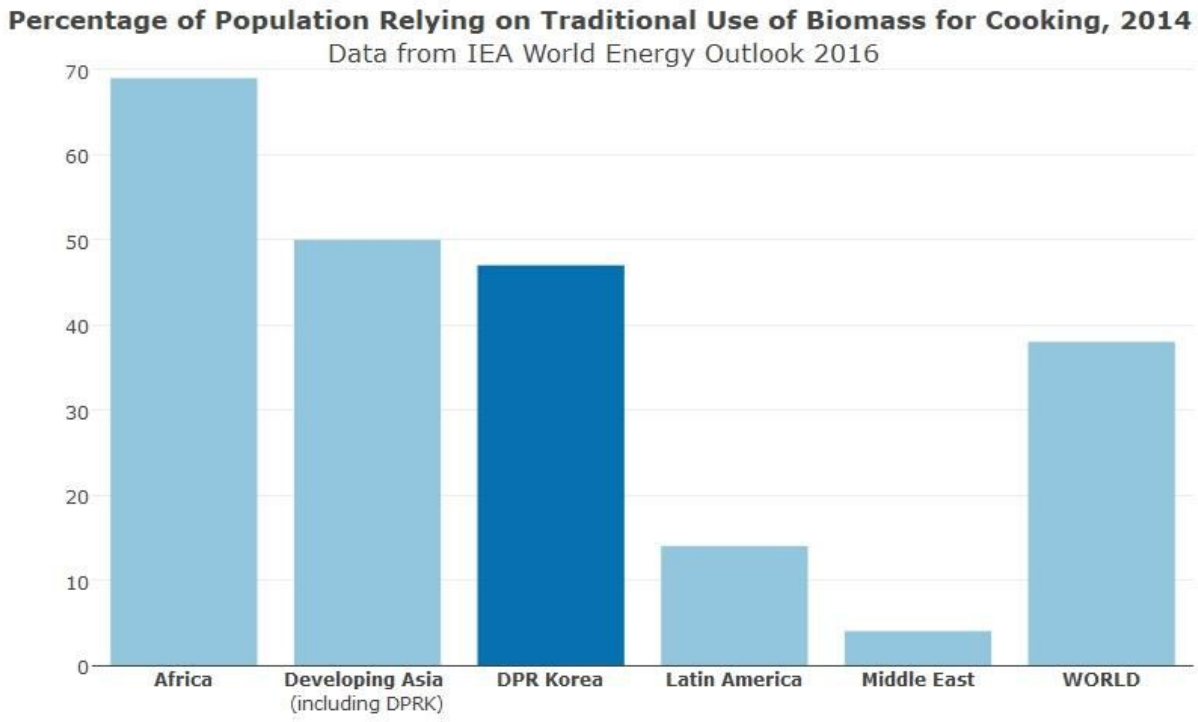

Figure 2: Percentage of Population Relying on Biomass for Cooking, 2014
Data Source: the International Energy Agency's World Energy Outlook 2016

5.2. Energy demand and energy supply in DPRK

5.2.1. Population density as a proxy for energy demand

According to our interactive data visualization of energy usage in DPRK (figure 3), the capital of DPRK, Pyongyang, has the highest population density (over 4,000 per sq mile), while two northern provinces, Jagang and Ryanggang, have the lowest density (under 200 per sq mile). Southern provinces are denser, perhaps due to the mountainous structure of the north.[2]

5.2.2. Electricity usage for cooking and heating

Usage of electricity for cooking is extremely low in all provinces. In seven out of ten provinces, less than 1% of households use electricity for cooking. The highest rate of electricity usage is capped at 6.5% in Pyongyang.

The situation is not much better when it comes to heating. The highest rate of electronic heating is little more than 4% (North Hamgyong). In six out of ten provinces, less than 2% of all households use electronic heating.

5.2.3. Wood and coal usage

In nine out of ten provinces, coal and wood are the most popular sources of energy for cooking and heating. In seven out of ten provinces, wood ranks as the most widely used

[2] The interactive data visualization can be found at http://gnguyen.shinyapps.io/energy

means for cooking and heating. This indeed supports the idea in literature that developing countries tend to rely on biomass for their basic energy needs.

In Pyongyang and its neighboring province, South Phyongan, wood is used but not the most widely used form of energy source. This is especially evident in Pyongyang. Here, more gas and petroleum are used for cooking, and central/local heating is also used more.

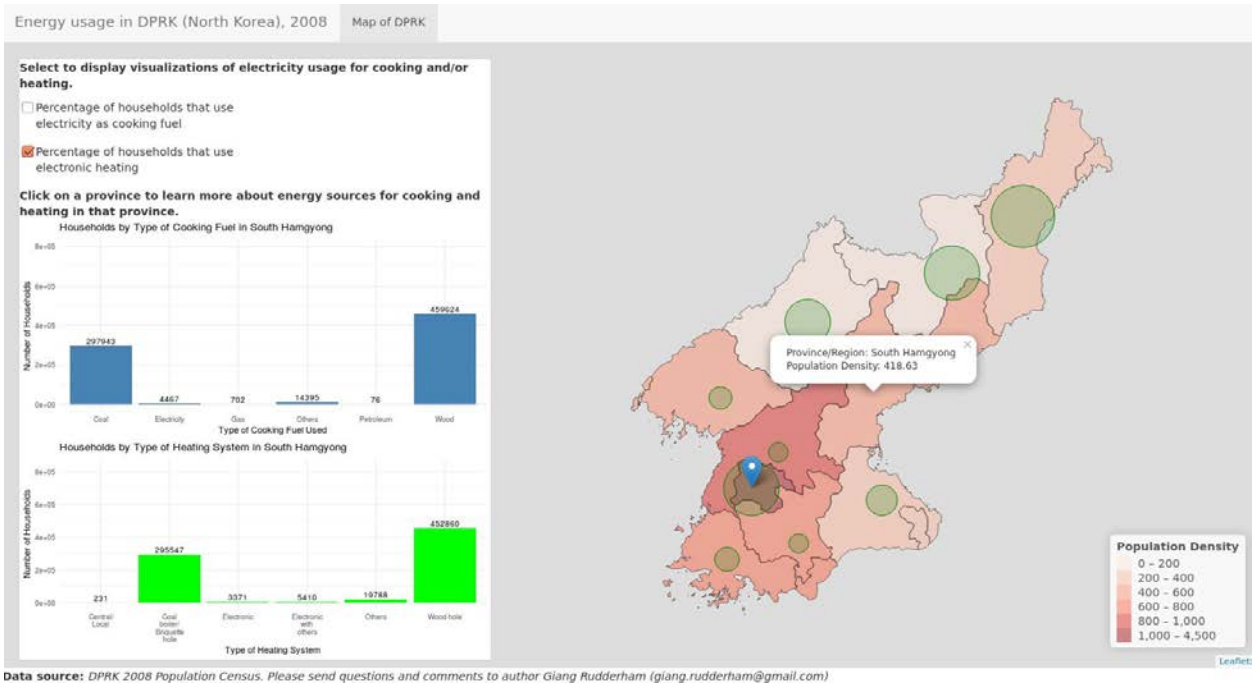

Figure 3: Snapshot of Interactive Data Visualization. Energy Usage in DPRK, 2008. Data Source: DPRK 2008 Population Census

5.2.4. Electricity production in comparison with other countries

According to our interactive visualization of electricity production per capita in four countries (DPRK, South Korea, China, and the U.S.) in figure 4, DPRK is the only country whose electricity production significantly decreases over the period 1990-2014. Specifically, for DPRK, electricity production from coal drops from 594.4 kWh in 1990 to only 172.7 kWh in 2014. Furthermore, electricity production from hydropower drops from 772.5 kWh in 1990 to 519.4kWh in 2014.[3]

Hydropower, coal, and oil are the only fuels used to produce electricity in DPRK. Of these three fuels, hydropower accounts for around 60% or more of electricity production in the period 1990-2014.

In comparison with DPRK, coal is a major fuel used to produce electricity in the remaining countries. Moreover, South Korea and the U.S. utilize many other sources for electricity production, such as biofuels, gas, nuclear, solar, waste, and wind. Regardless

[3] The interactive data visualization can be found at https://gnguyen.shinyapps.io/electricity-production-dprk/

of this diversity, renewable resources such as biofuels, geothermal, solar, tide, and wind are still used very little in all countries.

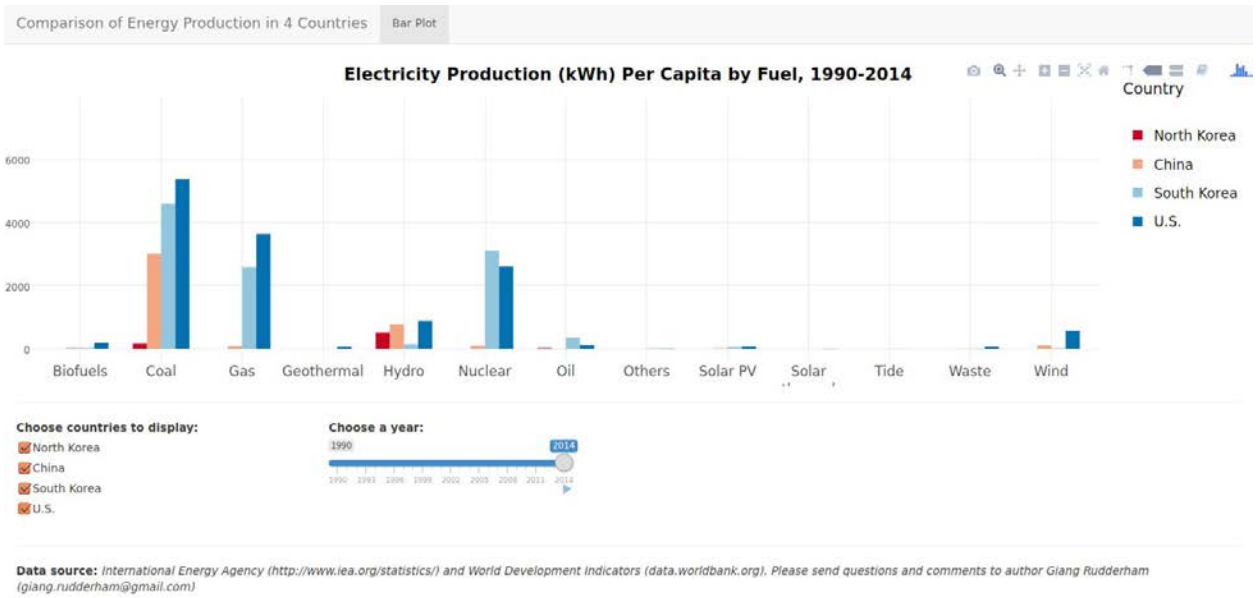

Figure 4: Snapshot of Interactive Data Visualization. Energy Production by Fuel, 1990-2014.
Data Source: International Energy Agency and World Bank's World Development Indicators

5.3. Consequences of energy poverty in health, environment and social development

In this section, we investigate the consequences of energy poverty in maternal health, environmental conservation, and social development. We choose maternal mortality ratio, a statistic widely used by international organizations such as WHO and the United Nations, as a proxy for maternal health. We choose the proportion of land area covered by forest as a proxy for environmental conservation. Finally, we choose the usage of the internet and cell phones as a proxy for social development, since these services lead to human interactions and access to information, which in turns lead to the dissemination of ideas, development and growth. Any correlation between energy poverty and a decline in maternal health, environmental conservation, or internet and cell phone usage is described below.

5.3.1. Maternal mortality rate as a proxy for health

Schools, hospitals, and offices all need electricity to function. Given the shortage of electricity in DPRK, we want to investigate its impact on health. Maternal mortality rate (MMR) is chosen as a proxy for health, since it is a metric commonly used by international agencies like WHO to measure mothers' health. In our time series plot of MMR per 100,000 live births in DPRK for the period 1990-2015 (figure 5), we observe a decline in MMR in the last 20 years. However, in 2015, MMR remains high in DPRK, with 82 maternal deaths per 100,000 live births. Our second visualization of MMR (figure 6) is created with data for 183 countries in 2015. Countries are arranged in

increasing order of MMR, and we highlight DPRK (red) to emphasize its progress compared to the rest of the world. DPRK does not fall into either ends of the spectrum, but rather belongs in the middle of the range of countries.

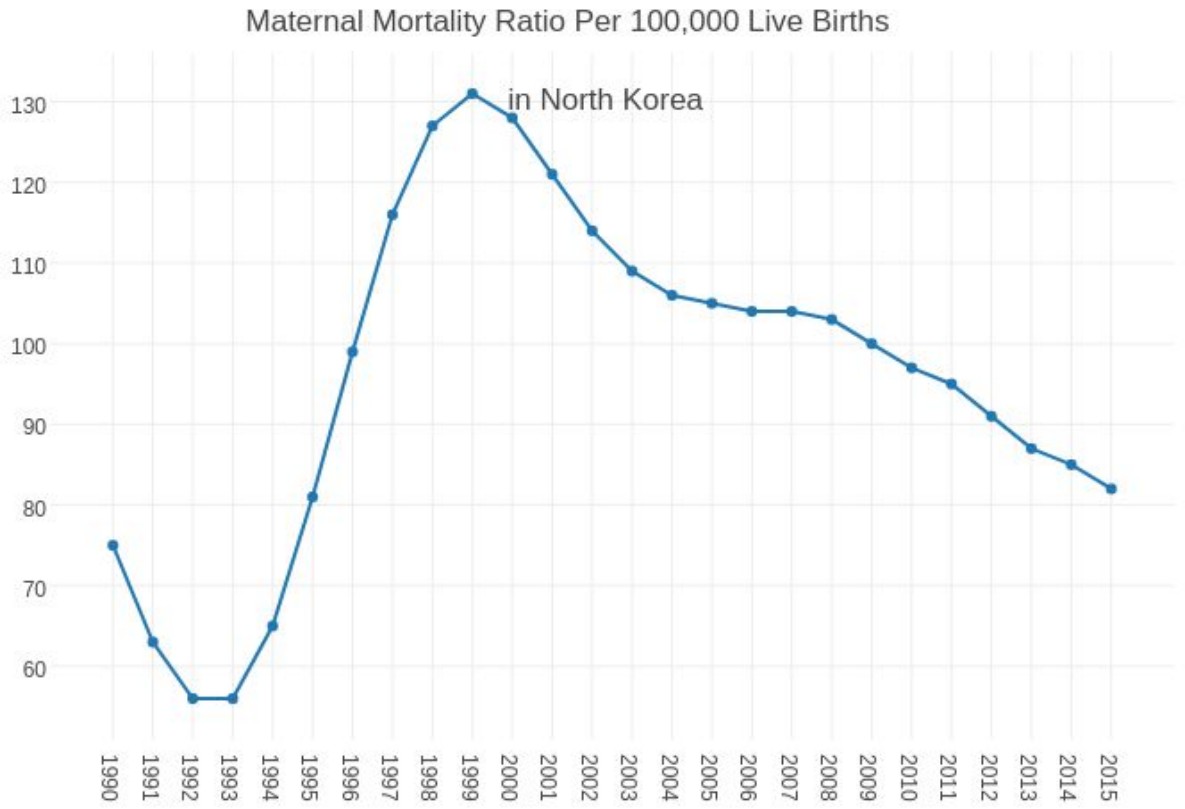

Figure 5: MMR in DPRK, 1990-2015.
Data Source: the United Nations' database of Millennium Development Goals Indicators

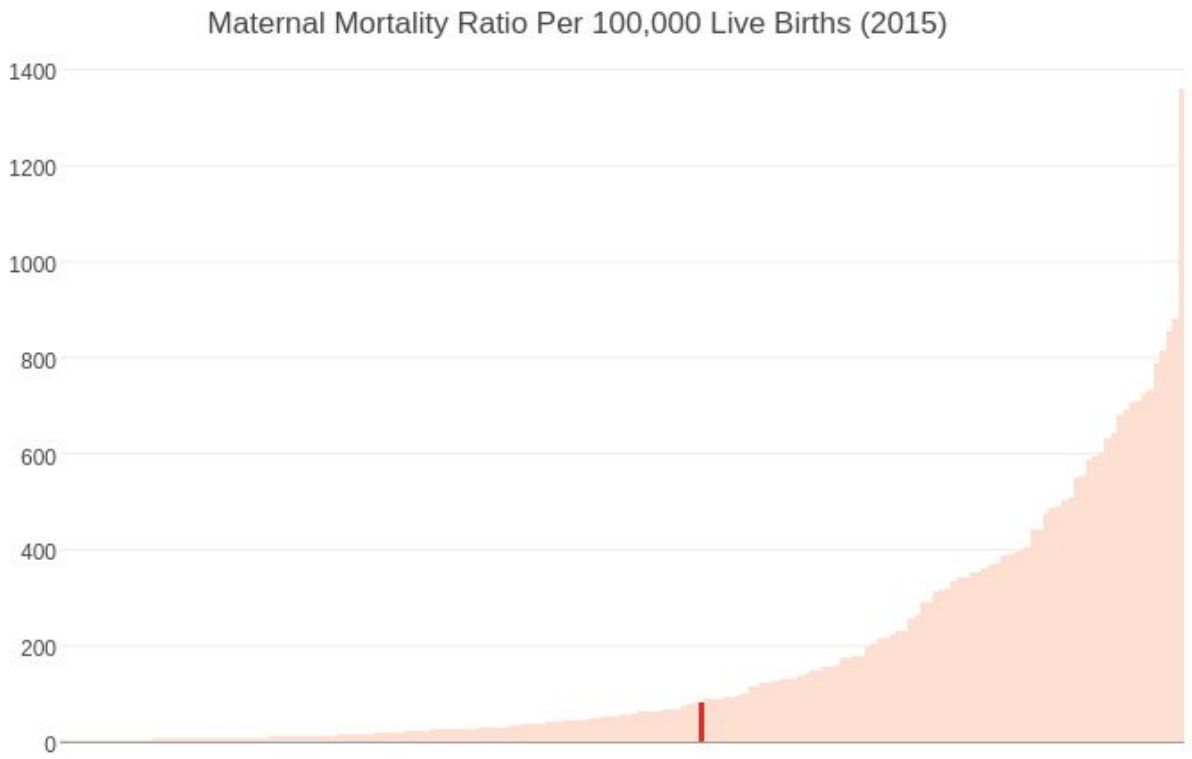

Figure 6: MMR in 183 Countries, 2015.
Data Source: the United Nations' database of Millennium Development Goals Indicators

5.3.2. Forest coverage as a proxy for environmental conservation

Our previous data visualization in section 6.b shows that North Koreans rely heavily on wood for their cooking and heating needs. The purpose of the following data visualizations is to investigate the potential impact of burning wood on the environment. To that end, we investigate forest coverage in DPRK.

In this data visualization, we plot the percentage of land covered by forest for 223 countries in 2010, in increasing order (figure 7). We highlight DPRK (red) to emphasize its progress compared to the rest of the world. We observe that DPRK does not fall into either ends of the spectrum, but rather belongs in the middle of the range of countries. However, our second plot of forest coverage (figure 8) shows that forest proportion fall steadily in DPRK in the period 1990-2010, from nearly 70% to below 50%.

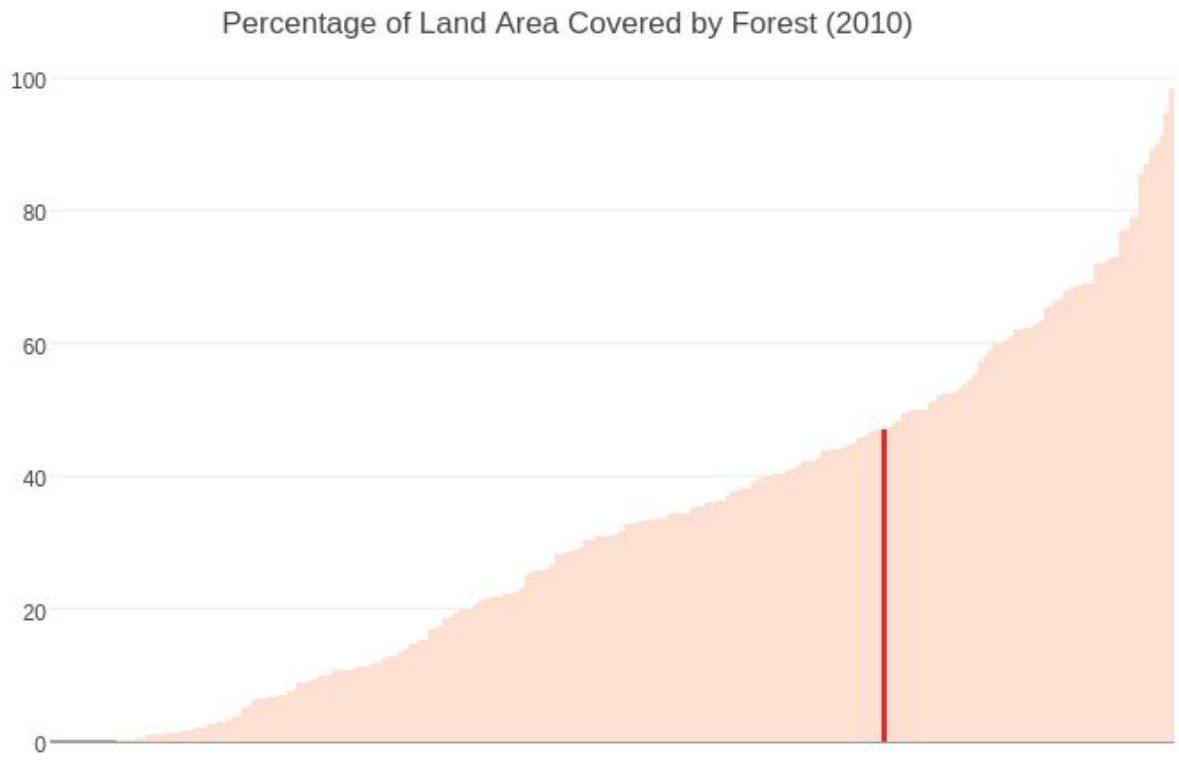

Figure 7: Percentage of Land Area Covered by Forest for 223 Countries, 2010.
Data Source: the United Nations' database of Millennium Development Goals Indicators

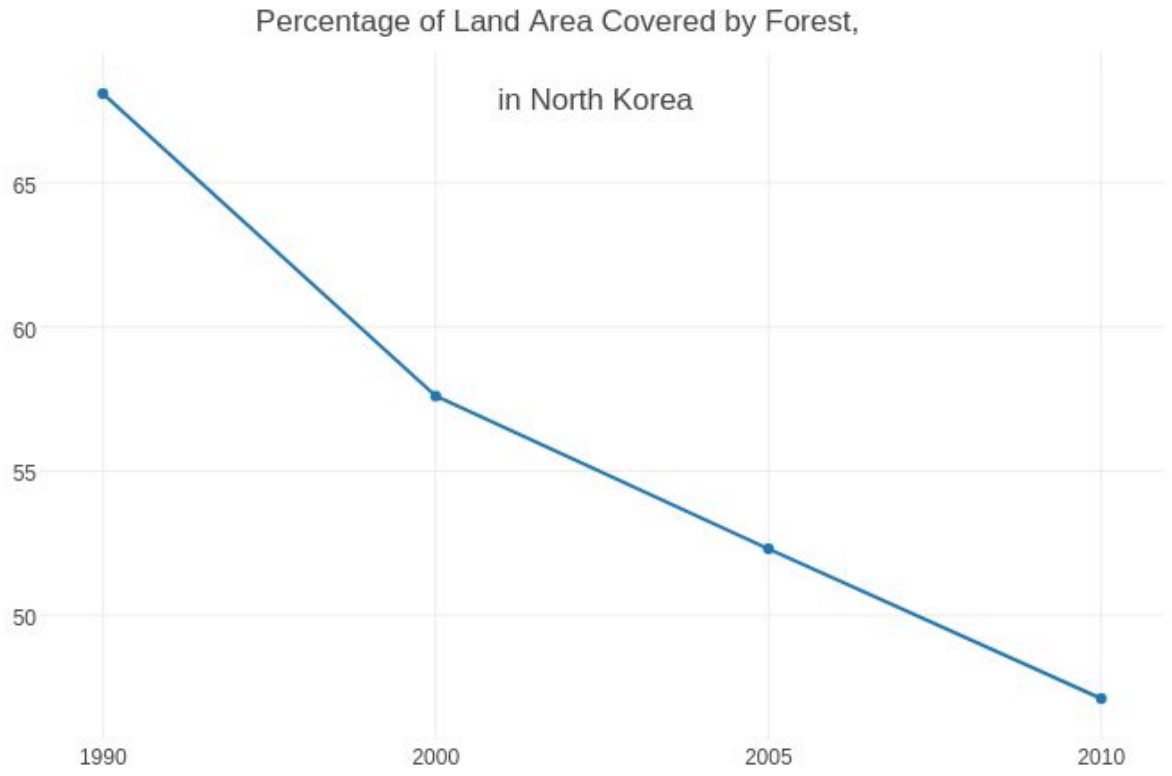

Figure 8: Percentage of Land Area Covered by Forest in DPRK, 1990-2010.
Data Source: the United Nations' database of Millennium Development Goals Indicators

5.3.3. Cell phones and internet usage as a proxy for social development

According to data for 2014, only 11% of North Koreans used cell phones, and the number of internet users was virtually zero (figures 9 and 10). Of the 208 countries included in this data set, DPRK ranks as one of the lowest in both cell phones and internet usage. A time series plot of cell phones and internet usage in DPRK reveals that the percentage of cell phones subscriptions steadily increases from 0% in 2009 to 11% in 2014, while the percentage of internet users remains at 0% in two and a half decades (figure 11).

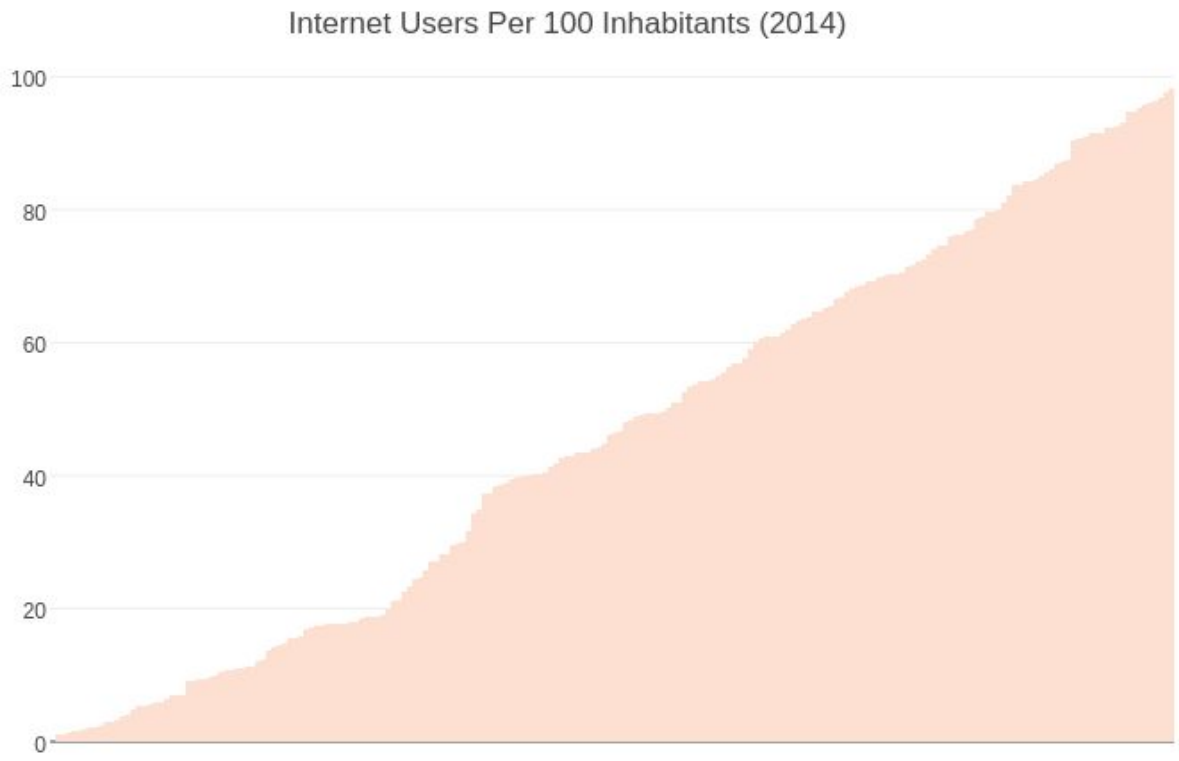

Figure 9: Internet Users per 100 Inhabitants for 208 Countries, 2014.
Data Source: the United Nations' database of Millennium Development Goals Indicators

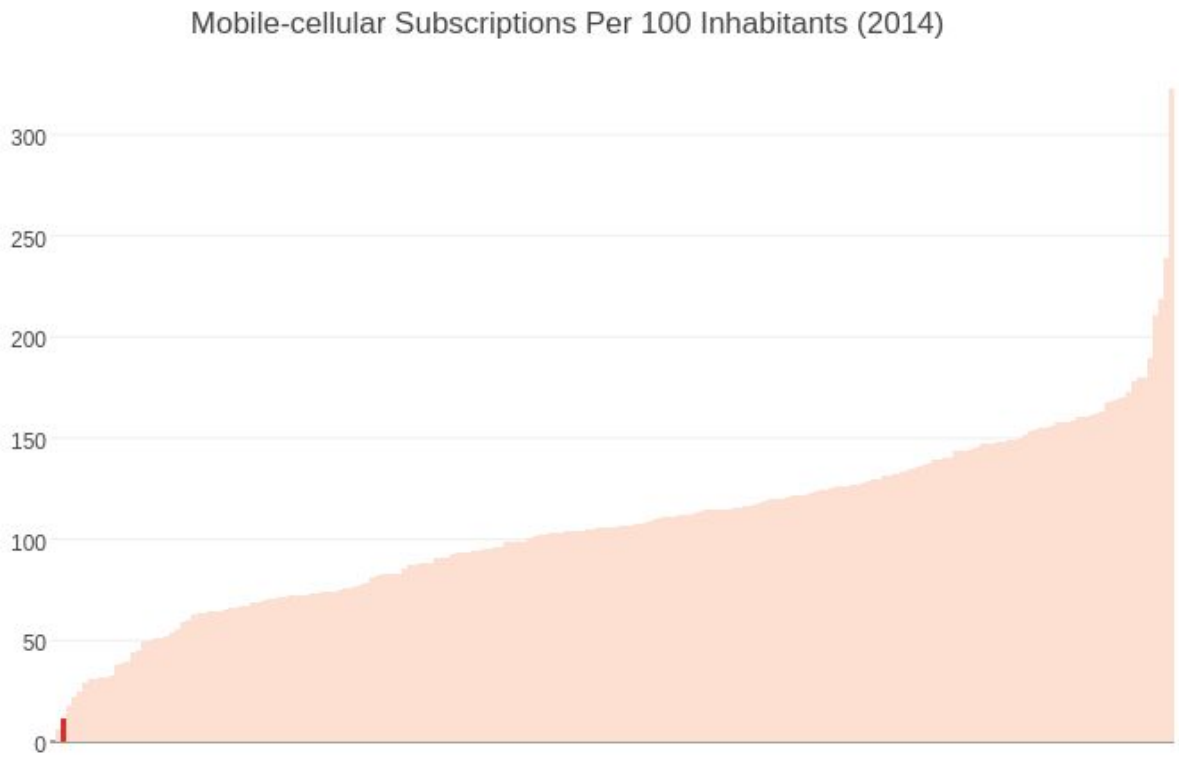

Figure 10: Cell Phone Subscriptions for 208 Countries, 2014.
Data Source: the United Nations' database of Millennium Development Goals Indicators

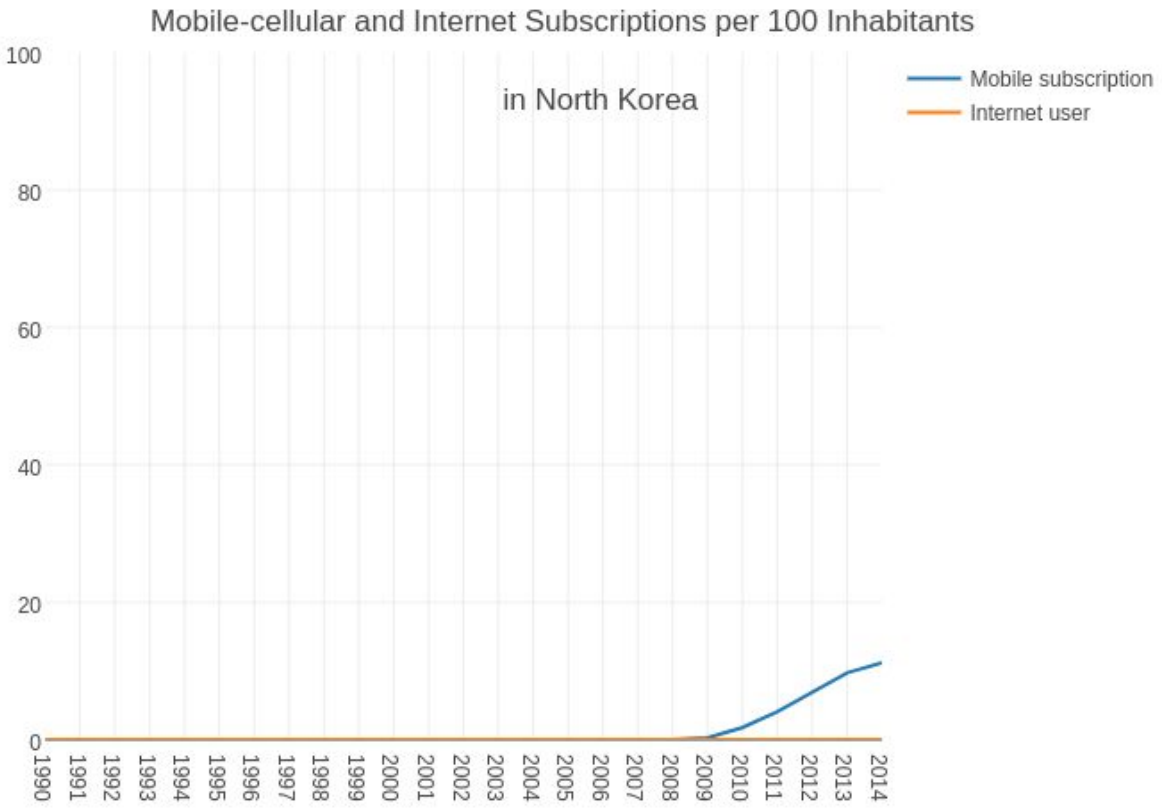

Figure 11: Internet and Cell Phone Usage in DPRK, 1990-2014.
Data Source: the United Nations' database of Millennium Development Goals Indicators

6. Discussion

6.1. Energy poverty in DPRK

Data since 1990 show DPRK's extensive reliance on hydropower to produce electricity. However, the country's outdated infrastructure cannot accommodate drastic changes in weather like droughts and floods. As a consequence, North Koreans suffer from low electrification rate. In 2014, less than 40% of citizens in urban areas had access to electricity. This percentage was even lower for rural areas, at just over 10%.

Without access to electricity, North Koreans are limited to consumable energy sources like coal and wood to fulfill their cooking and heating needs. Using these resources typically involves a burning process, which may lead to deforestation and respiratory diseases, especially among women and children.

6.2. Consequences of energy poverty in DPRK

Due to the lack of data in respiratory diseases, we choose MMR as a proxy for mother's health in DPRK. In our data visualizations of MMR, we do not observe a direct correlation between energy poverty and MMR. However, there might be other variables that lead to the decrease in MMR over time, which might offset any negative impact of

electricity shortage. For example, the United Nations has led initiatives to fight back maternal deaths for decades. The United Nations Millennium Development Goals dedicated goal 5 to improving maternal health. As a result, between 1990 and 2015, maternal mortality worldwide dropped by about 44%, according to WHO. In addition, reducing MMR is included as part of the Sustainable Development Goals. The target is to reduce the global maternal mortality ratio to less than 70 per 100 000 live births between 2016 and 2030.

The proportion of land area covered by forest in DPRK steadily declined over two decades, indicating a possible correlation between burning wood and deforestation. In addition, energy poverty seems to have a detrimental effect on the use of cell phones and the internet. Lack of access to cell phones puts a damper on human interactions, while lack of access to the internet restricts access to information and technology. These restrictions can have serious consequences for education and economic development in DPRK.

6.3. Implication of the energy issues in DPRK and policy recommendations

Other developing regions in the world also suffer from energy issues. Our data visualizations show that nearly 70% of Africans relied on the traditional use of biomass for cooking, and only about 70% of Africans living in urban areas had access to electricity in 2014. This figure is less than 30% for Africans living in rural areas.

The damage of energy poverty is not confined within the border of DPRK. Lack of electricity and extensive use of biomass may result in serious consequences for health, environmental conservation, and social development. Yet in many developing regions, biomass might be the only choice of energy sources available. We recommend that energy-related policies focus on expanding the choices of energy resources for developing regions, in order to preserve their citizens' health and the environment, and propel development.

Last but not least, renewable energy remains an underused resource, even in OECD countries like South Korea and the U.S. We recommend that policymakers acknowledge this challenge, faced by non-OECD and OECD countries alike, and utilize this untapped potential in policies about energy development.

7. Conclusions

In our research, we leverage data visualization as an analytical tool to aid evidence-based policymaking. We create data visualizations to aid the United Nations and non-governmental agencies in making evidence-driven decisions about developmental programs. However, such data visualizations represent correlation rather than causation. It is also important to acknowledge the differences in culture, history, topography, politics, and economic situations in developing countries. Understanding of the specifics of a developing country is essential before any policy about that country is made.

Even though we made an effort to present accurate and updated data, we are limited in the availability of data for DPRK. There are also limitations in data for regions that are stricken with wars, migration, and poverty.

Our future research agenda includes case studies of countries and regions that lag behind the world's progress in indicators such as mothers and children's health, forestation, and education. We plan to conduct an investigation of the consequences of electricity shortage in these countries and regions in order to provide policy recommendations that may induce economic and social development.

References

Central Bureau of Statistics. (2009). *DPR Korea 2008 Population Census National Report*. Pyongyang.

Global Administrative Areas. Shapefile. Retrieved June 30, 2017, from http://www.gadm.org/country

González-Eguino, M. (2015). Energy poverty: An overview. *Renewable and Sustainable Energy Reviews*, *47*, 377–385. https://doi.org/10.1016/j.rser.2015.03.013

International Energy Agency. Statistics. Retrieved June 30, 2017, from http://www.iea.org/statistics/

Jacobson, Mark. (2011). Providing all global energy with wind, water and solar power. Energy Policy, https://web.stanford.edu/group/efmh/jacobson/Articles/I/JDEnPolicyPt1.pdf

Pachauri, S., & Spreng, D. (2011). Measuring and monitoring energy poverty. *Energy Policy*, *39*(12), 7497–7504. https://doi.org/10.1016/j.enpol.2011.07.008

Palka, E. J., & Galgano, F. A. (2003). *North Korea: A Geographical Analysis*. United States Military Academy, West Point Department of Geography & Environmental Engineering, Building 600, West Point, NY 10996. Retrieved from https://eric.ed.gov/?id=ED476015

Reddy, A. K. N. (2000). *Energy and Social Issues, in "World Energy Assessment", UNPD, New York*. ISBN 92-1-126-126-0.

United Nations. Millennium Development Goals Indicator. Retrieved July 27, 2016, from http://mdgs.un.org/unsd/mdg/Data.aspx

van der Kroon, B., Brouwer, R., & van Beukering, P. J. H. (2013). The energy ladder: Theoretical myth or empirical truth? Results from a meta-analysis. *Renewable and Sustainable Energy Reviews*, *20*, 504–513. https://doi.org/10.1016/j.rser.2012.11.045

World Bank. World Development Indicators. Retrieved June 30, 2017, from http://data.worldbank.org/data-catalog/world-development-indicators

World Energy Council (2013). Energy Resources: Hydro. Retrieved September 6, 2018, from https://www.worldenergy.org/wp-content/uploads/2013/10/WER_2013_5_Hydro.pdf