The Influence of Energy System Model on Renewable Energy Policy Governance

Haijun Cao1,*, Yongjae An1,2, Cholu Kwon1,3

1 School of Humanities and Law, Northeastern University, Shenyang, China
2 Institute of Development Strategy of Science and Technology, State Academy of Sciences, Pyongyang, DPR Korea
3 Institute of Mechanical Engineering, State Academy of Sciences, Pyongyang, DPR Korea

*yuzhizhai@163.com

Abstract: Renewable energy is an effective way to realize the harmonious coexistence of human and environment as well as for sustainable economic development. A basic mission of Energy System Model is to help decision makers in solidly developing, implementing and assessing the impact of energy and climate mitigation policies. This paper focuses on the impact of energy system model on renewable energy policy and how to pay attention to it. That is, what is the influence of DPRK’s greenhouse gas (GHG) emission mitigation model on DPRK’s renewable energy policy governance? This paper describes the renewable energy policy established by GHGs mitigation model in DPRK, and provides a comparative analysis of DPRK’s renewable energy policy framework by 2030. We provide some policy recommendations for medium term renewable energy development in DPRK.

1. Introduction

Renewable energies are forms of natural energy source that cannot be depleted, especially including hydropower, wind and solar energy, biomass and geothermal energy. In addition, the renewable energy list includes a number of technologies that are still in the experimental stage or need to prove their economic feasibility, such as wave, tidal energy and dry hot rock.

Although DPRK has no natural gas or crude oil, it is rich in coal, peat and other fossil fuel. In terms of its natural and geographic circumstances, DPRK has abundant energy resources as hydropower, solar power, wind energy, geothermal and tidal energy. And also, DPRK has concentrated its national strength on such new energy development and has made many achievements, which will be further developed scientifically and sustainably in the future [1].

The purpose of the study is to prepare the necessary scientific basis for policy decision to adopt renewable energy policies in order to achieve DPRK’s GHG emission reduction targets by 2030. It also will provide a scientific and sustainable evidence basis for the future energy and climate change policy decision makers in DPR Korea.

This paper starts from the analysis of DPRK's energy policy and GHGs mitigation model. It introduces the existing energy situation and policies of DPR Korea, and describes DPRK’s GHGs mitigation model as the new challenges to reduce of greenhouse gases in DPRK. And also, it analyzed the influence of the mitigation model on renewable energy policy governance. Finally, by the analysis, some recommend are proposed for renewable energy policy governance.
2. Methodology
According to decisions 1/CP.19, 1/CP.20 and 1/CP.21 of the Conference of the Parties to UNFCCC, the DPRK has prepared the Intended Nationally Determined Contribution (INDC) [2]. INDC includes two components, which are a mitigation and an adaptation. The mitigation component includes both unconditional and conditional contributions. The unconditional contributions are measures that will be implemented using domestic resources that GHG emissions will be 8.0% lower than the BAU scenario by 2030. The conditional contributions are measures that could be implemented with the support of the international community, the national contribution can be increased up to 40.25% by 2030.

The adaptation component describes the adaptation needs raised in terms of institutional arrangement, financing, capacity building and technology transfer by 2030. It also proposes the prioritized adaptation measures.

2.1 DPRK’s GHGs mitigation model
This paper introduces the research methods of GHGs reduction model in DPR Korea. The model represents DPRK's energy system and its possible long-term evolution. Its applications are related to the analysis of polices designed to reduce GHGs from energy and materials consumption, and it contains a large number of energy supply side and demand side technical databases [3].

![Figure 1. A reference model for Energy System in DPR Korea (the model’s current focus is on GHG emissions [3])](image)

As shown in Figure 1, the actual system model includes all steps of the process chain from primary resource availability to energy service supply required by energy consumers through energy conversion, transportation, distribution and transformation to services. The supply sector (primary and secondary production, exogenous imports), demand sector (energy, IPPU, AFOLU, waste), and power generation sector (also including cogeneration) of DPRK's energy system reflect the characteristics and patterns of the national energy system.

The key inputs to the energy model consist of the supply component (resource potential and costs), the demand component (demand for energy services), the policy component (scenarios) and the techno-economic component (alternative technologies and associated costs). The number of energy service demands (ESD) may vary between different models and the level of detail of data available for
each sector. The demand component is driven by 32 different ESD, namely 11 for the energy sector, 13 for IPPU (Industrial Processes and Product Use), 4 for AFOLU (Agriculture, Forestry and Other Land Use), 4 for waste in the model. A key input to the DPRK’s GHG emissions mitigation model on the supply side is the present and future sources of primary energy supply their potentials and fuel prices (only refer to imported fuels). In 2020, domestic coal will also account for 61.1% of the total primary energy supply. In 2030, the installed capacity of new hydropower is 1000MW, and the potential of solar thermal power station is 1000MW. In 2030, the capacity of on-shore and off-shore wind is limited to 1000MW, and the potential of nuclear power plants is set at 2000MW.

2.2 Model sets and assumptions
The time span of the DPRK GHGs emission reduction model used here is 40 years. From the base year 1990 to 2030, the time resolution is four seasons, including day, night and peak period.

The current version of DPRK GHGs emission reduction model does not have a flexible demand module, so the energy system can cope with the emission restrictions here by changing energy efficiency and energy supply technology, rather than by reducing demand.

The model also embeds some constraints to improve the authenticity of the future energy pathways. In fact, the inherent characteristics of linear programming model can provide extreme technical transformation in many cases. Physical constraints, such as a lack of infrastructure, should be considered when designing constraints. In addition, although this paper does not consider the detailed modeling of transmission, frequency and inertia, and voltage stability, the constraints are set in the power system to reproduce the operation constraints. The model also includes a limited number of diffusion constraints to control the growth rate of some sectors, such as power generation and IPPU sectors.

2.3 Scenario definition
For the purpose of this study, this paper develops and discusses the main energy system configuration: introduces BAU scenario to provide the starting point for measuring two GHGs emission reduction scenarios (i.e. CO2-8 scenario and CO2-40 scenario).

(a) The BAU scenario for DPRK’s GHG emissions is based on the assumption of economic growth without climate change policies. By 2030, the national energy forecast is used as a benchmark [2]: it provides a starting point for comparison with other scenarios.

(b) In the CO2-8 scenario, DPRK will use domestic resources by 2030 to reduce greenhouse gas emissions by 8.0% compared with the BAU scenario.

(c) In the CO2-40 scenario, if international support is obtained through international cooperation (including financial support under the Paris Agreement), DPR Korea can achieve an additional contribution equivalent to 40.25% of GHG emissions in the BAU scenario by 2030.

3. Policy Impacts
DPRK has concentrated its national strength on such renewable energy development and has made many achievements, which will be further developed scientifically and sustainably in the future.

3.1 Solar Energy
Solar energy can be used as an energy source to reduce primary energy consumption, achieve DPRK’s 2030 target and minimize its carbon footprint.

There are two main ways of using solar energy: solar photovoltaic and solar heating. Solar PV converts solar radiation into electric energy, and solar heat converts solar radiation into heat, which is used for heating and hot water in residential and commercial space.

The sunshine duration in DPRK are about 2280-2700 hours per year, even more than 200 hours per month in summer and rainy season, and more than 200 hours in spring and autumn [4]. Especially in autumn, the sunshine is long. The annual sunshine rate in the country is 45-60%, with little regional difference. In most areas, including the West Sea coast and East Sea coast, as well as the northern
inland areas, the proportion of sunshine in winter is very high. In the most regions of the country, the sunshine rate in January is more than 60%.

By 2020, solar energy will account for 10% of DPRK’s renewable power generation capacity, equivalent to 500MW of installed capacity.

3.1.1. Supply of cooking, heating and hot water by solar energy
In DPRK, some places are more suitable for building solar power plants than others. Solar radiation is one of the most important requirements, and initially it is important to conduct a desktop assessment to determine whether there is enough solar potential on site.

The site selection criteria are as follows:
- Flooding (must be outside recognized flood zones),
- Land use (must be outside of built up areas or woodland areas),
- Land type (agricultural, ex-industrial landfill, or brownfield),
- Designation (must be outside of protected areas),
- Public access (not crossed by a public footpath, right or way or bridal way),
- Aspect (level or sloping South/SE/SW, not overlooked by housing),
- Shading (not shaded by trees, buildings or terrain),
- Solar radiation (must receive at least 1050 kWh/m² of solar radiation),
- Grid connection (must be within 1km of existing power distribution lines),
- Access (access for vehicles for construction) and
- Site size.

In recent years, the introduction of solar energy cauldrons, solar water heaters and passive solar heating systems across the country is speeding up. At present, solar energy cauldrons have been introduced into Hongwon County in the South of Hamgyong Province, Phyongwon County in the South Phyongan Province, North Phyongan Province tideland reclamation complex, and passive solar heating system with energy saving up to 50% also has been generalized in Sapyong-ri, Anphyon County, and Kangwon Province and other units.

In particular, in 2011, a new solar energy equipment production center specialized in the development, production and promotion of solar energy equipment was established. The center that produces thousands of sets of all glass vacuum tube-type solar water heaters every year, according to the experience of introducing solar water heaters into several buildings in Pyongyang City such as Mangyongdae district, actively accelerates the work of mass production and promotion of solar water heaters in the future.

3.1.2. Visual impact
Solar panels installed on the ground may require large areas to collect solar radiation, causing some visual effects (however, visibility does not necessarily mean that they are invasive, for example, farms may be blocked by trees or other factors that cannot be ignored).

In solar power plants, the main visual impact comes from the central receiving system and the grid connection. In DPRK, 5.5 acres of land per Megawatt of solar power are needed. One megawatt of solar energy on 5.5 acres produces 876MWh of electricity a year, enough to power 300 households for a year.

3.1.3. Agriculture
Solar farms cover less than 30% of the leased area and allow land use, such as grazing small livestock such as geese, chickens, goats and sheep, to adapt to the livestock density that supports rural commerce.

As for geese and chickens, they can graze and shelter around solar panels and live safely in the area. Solar farms allow energy production without emissions, moving parts and noise.

 Likewise, solar farms will not reduce the number of sheep that can be herded in the area. Solar panels provide shelter for bad weather and airborne predators.
At the end of the solar farm's life, the steel frame can be easily pulled out of the ground, and the land will remain the same - the construction is 100% reversible.

3.1.4. Planning
With good planning, solar energy can be deployed with minimal disruption and full reversibility, after a project life of 15 to 20 years. Through sensitive planning, solar energy can provide a net planning and biodiversity benefits.

3.1.5. Community benefits
Solar energy can play an important role in the transition from energy to a low-carbon future, especially in rural communities, as a way to ensure energy independence through the implementation of energy cooperatives.

- A strong community energy industry will:
  - Reducing carbon emissions from the energy sector,
  - Provide local investment opportunities,
  - Ensure that local investment funds remain in local communities,
  - Create local jobs,
  - Building strong and resilient community networks, and
  - Help DPRK achieve its renewable energy goals.

3.1.6. Environment and footprint
Compared with fossil energy, solar energy technology has lower greenhouse gas emissions, so solar energy can be used instead of fossil fuel, and can significantly reduce greenhouse gas emissions.

Solar photovoltaic power generation has little impact on the environment because land can be used for agricultural purposes. It produces no pollutants and is one of the cleanest energy sources in the world. At the same time, it can contribute to the 2030 goals and reduce DPR Korea's carbon footprint.

3.1.7. Health
Air and water pollution from coal and natural gas plants is related to respiratory problems, nerve damage, heart disease and cancer [5]. According to the U.S. Department of Energy [6], burning fossil fuels for energy adds pollutants to the air, leading to children asthma and other health and environmental problems.

The use of renewable energy sources rather than fossil fuels for power generation can provide significant public health benefits. It helps to reduce carbon dioxide emissions and other pollutants in the atmosphere, and reduce overall medical costs [5].

3.2 Wind Energy
In DPR Korea, land and sea wind capacity is limited to 1,000MW by 2030. DPRK is rich in wind energy resources due to its natural and geographical conditions. The annual average wind speed in most regions of the country is about 2-4m/s [4].

The annual average wind speed in the coastal area is more than 3m/s, and that in Rason city in the northern area of East Sea coast and Cholsan County in the West Sea coast is up to 4m/s. The annual average wind speed in the coastal flat area is 2-3m/s, and that in the inland area is less than 2m/s. Kowon area which is one of the windy areas in the South of Hamgyong Province, the wind speed is 3-4m/s, faster than that in the coastal area.

Technologies for small wind turbine have been developed and introduced into several units in DPRK. As an international training of technology transfer, seven wind turbines in a rural area in the West Sea coast were set up in 2012, and have accepted 1-5kW wind energy technology as Small Wind Energy Development and Promotion in Rural Areas (SWEDPRA) project.

The machines currently used comprise of a single mast with a three bladed rotor attached laterally.
The size of both mast and blades can vary greatly and this level of variation in design reflects the amount of research and development undertaken within the industry particularly in recent years. By 2030, DPRK will use favorable geographical condition (fast wind speed including sea wind) to set up 500 MW wind turbines in on-shore areas and off-shore areas respectively.

3.3 Hydropower Energy
DPRK has abundant groundwater resources and is rich in rivers and streams. The reservoirs built throughout the country are well supplied with water.

Because DPRK is rich in water resources, the precipitation is mostly mountainous. Changjin River, Pujon River, Hocho River, upper reaches of Sodu River, the north of Han River, upper reaches of Rimjin River, upper reaches of Changja River and Chungman River and the main stream areas of Amnok River, Tuman River and Tadong River are rich in water resources [4]. From the perspective of topographic characteristics, the transformation from the river basin on the West Sea coast to the East Sea coast makes it possible for northern and central area to obtain a large amount of energy.

In DPRK, there are about 100 lakes. There are 5 lakes with an area of more than 5km², among which the water volume around Mt. Paektu lake is the first (1.96km³) [4]. There are about 1800 man-made lakes for the purpose of hydropower generation, irrigation, flood control, industrial water, drinking water, freshwater fish farming and landscaping [7]. The reservoirs of large-scale hydropower stations include Suphung Lake, Unpong Lake, Changjin Lake, Pujon Lake, Taechon reservoir, etc., and the irrigation reservoirs include Unpha Lake, Manphung Lake, Sohung Lake, Yonphung Lake, etc.

DPR Korea is developing and using water resources systematically according to one’s own strategy for economic development, and it will create new hydropower generation capacity of 1,000MW including hydropower Clean Development Mechanism (CDM) projects. Chongchon River, which is located in western area of DPR Korea, has rich water resources and great potential for generating electricity.

From 1995 to 2009, a number of large, medium and small hydropower stations with abundant water resources have been built in DPRK. The proportion of hydropower generation in the total power generation (42.9TWh in 2009) has gradually increased from 52.3% to 64.8% during this period.

According to its economic development strategy, DPRK is systematically developing and utilizing water resources, and will create 1,000MW of new hydropower generation capacity, including hydropower CDM projects. Chongchon river is located in the west of DPR Korea, with abundant water resources and great power generation potential.

Chongchon River Cascade Hydropower Generation Project is as follow in Table 1.

| Table 1. Chongchon River Cascade Hydropower Generation Project |
|---------------------------------------------------------------|
| **Background** | If the Cascade Hydropower Generation Stations are built in the western region of Chongchon River with more thermal power stations, the GHG emissions in this region will be less than the baseline scenario. |
| **Objectives** | • Supply renewable energy to the local grid for power generation.  
• Reduce GHG emissions from the local grid.  
• Contribute to local sustainable development. |
| **Activities** | • 10 units of 10MW hydropower stations will be built along the Chongchon River.  
• Supply the generated electricity to the local grid |
| **Outputs** | • The dependence of electricity production on fossil fuels is reduced.  
• GHG emissions reduction of 280,000 tCO2/yr. |
| **Executing Agency** | MEI and relevant agencies. |
| **Budget** | US$ 80 million, including Government US$ 78 million |

MEI here means an acronym for 'Ministry of Electricity Industry'.
3.4 Tidal Energy

DPRK has rich and diverse marine resources. Hundreds of thousands of hectares of tidal line on the West Sea coast can be reclaimed as farmland, reed field, salt farm, etc [4]. DPRK's West Sea is the largest sea area in the world with a tide rise and fall of more than 5 meters. Its coastline is mostly uneven and there are many islands. It has favorable conditions for the development and utilization of tidal energy resources.

The technology is more progressed in the case of tidal energy in the world. Most standard ocean energy systems involve the use of a dam or barrier combined with sluices and turbines.

DPRK is now officially investing in the country and doing research to develop tidal power generation. The turbines, which are located within the sluices, generate power as the water is pushed through them by the force of the tidal flow. The sluices operate by opening during rising tide, allowing the dammed area to fill with water, and are subsequently closed during high tide. The water is then trapped until low tide when it is released through the turbines.

The technology itself is sufficiently advanced for the generation of energy to be technically feasible. The difficulty with implementation remains that the difference in load between high and low tide is not adequate to produce enough pressure for the system, as its present state of development stands, to be commercially viable.

3.5 Geothermal Energy

DPR Korea is rich in geothermal resources, with average and low temperatures [4]. As a typical area of geothermal energy production, the temperature of mineral water gushing out of Ongjin and Paechon area is about 100°C and 70°C respectively.

Geothermal electricity generation involves the harnessing of energy in the form of heat, hot water and steam below the surface of the earth among other deeper sources such as hot dry rock, geo-pressure and magma with the latter group remaining to be exploited due to the lack of appropriate technology. These geothermal reserves can be used to produce heat directly or in the generation of electricity and the technology itself has been in existence since the early 1900’s when it was developed in Lardello, Tuscany, Italy. This system has also been in use in DPRK for quite some time and has the advantage over other similar types of renewable energy production of being neither seasonal nor intermittent. It remains, however an underdeveloped source of renewable energy in DPRK.

DPRK attaches great importance to the use of geothermal energy to cool and heat buildings, provide people with convenient living conditions, and maximize energy conservation.

In recent years, with the large-scale introduction of geothermal air conditioning system in Huichon Ryonhwa Machinery Plant, and the active development of geothermal utilization projects in Chongchun Street stadium, Chongbansan food factory and other units, Ryongsong machinery plant has begun to develop and produce large capacity geothermal equipment in batches.

4. Conclusions & Future Works

This paper presents a study that recognizes the value of DPRK’s energy system modelling tools in guiding policy makers in formulating energy and climate mitigation policies in DPRK. This study not only shows the value of quantitative assessment of major challenges and decision-making faced by governments in the field of energy and climate policy. It also provides insights that can help overcome key barriers to acceptance of the transition to a low carbon future in DPRK.

We need to promote the reform of the layout of energy research. The current situation of a country that depends on oil and gas imports (for example, DPR Korea's economic development mostly depends on coal) urgently needs to develop new energy and improve energy efficiency. And also, we should strengthen national and international support and support for renewable energy development and application activities. This activity is an important means and contribution to international environmental protection.

The energy system model facilitates the transition from a silo based approach that focuses on a single technology set or specific sector to a holistic system approach that analyzes a variety of
technology sets, sectors and regions in a robust and integrated manner. These studies show how energy system models can support policies, point out the feasibility of implementing challenging climate and energy goals, and help governments, stakeholders and public opinion change their views on these challenges. However, the development of these modeling tools is extremely complex and time-consuming, and the generation and analysis of scenes only represent a small part of the process. In order for the model to continue to expand and enhance its capability and robustness, continuous resources need to be allocated to establish and maintain a dedicated modeling team to ensure continuity.

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