An Overview of Ireland's Energy System Model and the Thinking for DPR Korea

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Abstract: The Ireland’s Energy System Model, Irish TIMES model involved building, developing, calibrating, testing and running a partial equilibrium energy systems optimization model for Ireland. Ireland is an island country surrounded by the sea, so it has abundant water and wind resources. DPR Korea is also surrounded by the sea on three sides, with a total coastline of about 17,300 km (3,169 km for Ireland), so there are abundant resources of hydropower, wave power, tidal energy and wind power. On the basis of geographical conditions, DPR Korea's energy system can learn from Ireland's energy system model to achieve "good model" of energy policy modelling problems. The two key new perspectives this research project gives are: (i) a full energy-systems modelling approach and (ii) a focus on the GHGs mitigation for DPR Korea by 2030.

1 Introduction

Ireland is rich in renewable energy resources, mainly composed of solar energy, wind energy, water energy, biomass energy and so on. Ireland established the Ireland Energy Centre in 1994 to support the development of energy efficiency and energy management in all sectors of the national economy [1]. DPR Korea has research institutions of various central institutions, such as the State Commission of Science and Technology, the State Academy of Sciences and the Academy of Agriculture, as well as including the Kim Il Sung University and the Kimchaek University of Industry, which are actively developing the introduction of environmentally sound technologies and constantly innovating. Under such favorable geographical conditions and research capacity, DPRK has made many achievements in environmental protection and new energy development in recent years, increasing energy efficiency and actively developing new energy. In this process, in order to establish a scientific energy system, it is urgent to construct energy system model that can ensure the complete and sustainable economic development [2].

According to the global innovation index (GII) ranking in 2018, Ireland ranks 10th among 127 economies in the world [3]. The global innovation index in 2018 analyzes the global energy innovation trend in the next decade and identifies breakthroughs in energy production, storage, distribution and consumption. Thus, they have explored a number of more effective energy modelling ways and experience in practice.

The purpose of this paper is to increase the necessary evidence base to inform policy discussions within DPR Korea regarding the choice of GHG emissions reduction target for medium term and long term. From a technical perspective, the particular focus is on the feasibility of the GHG emissions reduction target for DPRK by 2030. Meanwhile, it is to build research and development capacity to adapt to climate change, train technical personnel and experts through various opportunities and processes such as university education, training and practice, and focus on research, development and introduction of advanced adaptation technologies and methods to contribute to improving people's lives and sustainable development of the country. And also, it is to encourage effective efforts to address the negative impacts of climate change, attract the participation of all members of society, and actively accelerate bilateral and multilateral cooperation with international organizations and other countries.

This paper analyzes the Irish TIMES model, which is a representative energy system model to reduce the greenhouse gas (hereinafter referred to as GHG) emissions in Ireland. As a result, a research methodology for DPR Korea’s GHGs mitigation model is proposed by analyzing Irish TIMES model.

2 Method

2.1 MARKAL Model [4]

MARKAL (an acronym for ‘market allocation’) is a demand-driven, multiperiod, LP model of energy supply and demand. Its intended application is at the level of an entire nation. This model is driven by useful energy demands, optimizes over several time periods collectively, and allows multi objective analyses to be
performed quite easily. Here, the technical structure of MARKAL model is described, and are defined the functions determined when satisfying the model’s relations and the parameters that must be supplied to give the model content.

MARKAL is a model that represents a linear-programming problem of the general sort [5].

\[
\text{minimize } \sum_i c_i X_i
\]

subject to

\[
\sum_j a_{ji} X_i \geq b_j \quad \text{and } X_i \geq 0
\]

The coefficients \(c_i\) for the objective function and \(a_{ji}\) and \(b_j\) for the constraints are the known parameters; the vectors \(X_i\) are the unknown quantities to be found, i.e. the solution of the problem.

MARKAL was designed to help in understanding these aspects of the behavior of possible future national energy systems: (a) the relative attractiveness of existing and new energy technologies and energy resources in satisfying plausible future demands for useful energy; (b) the time evolution of the introduction of and investment costs for new technologies and resources and the time evolution of the decline in use of existing resources, especially imported petroleum; (c) the sensitivity of future energy systems to different goal choices and ordering, with system cost, the amount of imported petroleum, and the relative contributions of nuclear, renewable, and fossil resources being the criteria of interest; and (d) the long-range effect of conservation and efficiency improvements on the energy system.

2.2 Irish TIMES Model

TIMES (The Integrated MARKAL–EFOM System) is a widely applied linear programming tool supported by ETSAP (Energy Technology Systems Analysis Program), an Implementing Agreement of the International Energy Agency (IEA) [6]. TIMES is an economic model generator of local, national or multi-regional energy systems, which provides a technology-rich basis for estimating the long-term energy dynamics. It is usually applied to the analysis of the whole energy sector, but it can also be applied to the detailed study of individual sectors. It takes into account the environment and many technical constraints in the whole time to maximize the total surplus, which is equivalent to minimizing the total discounted energy system cost. This cost includes various costs over the period using the following formulas:

\[
\text{ESC(energy system cost)} = (\text{IC}(\text{investment costs}) + \text{OMC}(\text{operation & maintenance costs}) + \text{IFC}(\text{the costs of imported fuels})) - \text{EFC}(\text{the costs of exported fuels}) - \text{VT}(\text{the residual value of technologies at the end of the horizon})
\]

Figure 1 shows in schematic form how the TIMES model works. The core model includes a large energy supply-side and demand-side technology database. The model designs the best energy system to meet the demand of energy service at least cost in the whole time, and shows the best combination of technology and fuel, emission, mining and import activities and the equilibrium level of energy demand in each period.

![Figure 1. TIMES Model Schematic (Remme et al., 2001[7]).](image-url)
energy use, mainly because TIMES optimizes the energy system and provides the lowest cost solution.

At present, the widest applications of TIMES analyzed policy to reduce GHG emissions from energy and material consumption. Because TIMES model describes individual technologies, it is particularly useful for assessing policies that promote the use of more efficient technologies in energy or materials, or the development and use of new technologies. It provides the economic costs of climate mitigation strategies and the impact of climate change policies on economic growth.

Irish TIMES is a single regional model of the whole Irish energy system, which was originally extracted from Pan European TIMES (PET) [8]. It has been used to establish a series of energy and emission policies to explore the power behind the transfer to low-carbon energy system, analyze energy security [9], assess the impact of limited bioenergy resources [10], and explore new modelling methods [11].

The model is driven by exogenous demand as defined by the list of demand for each energy service, the actual value of the base year (calibration) and all milestone year values (forecast) up to 2050, as well as environmental or other constraints (such as Ireland and EU goals). More details can be found in the full Irish TIMES report [8].

3 An approach for DPR Korea’s energy system model

DPR Korea ratified the UNFCCC (an acronym for the United Nations Framework Convention on Climate Change) on 5 December 1994, the Kyoto Protocol on 27 April 2005 and the Paris Agreement on 1 August 2016. In accordance with decisions 1/CP.19, 1/CP.20 and 1/CP.21 of the Conference of the Parties to UNFCCC, the DPRK government decided to reduce GHG emissions by 8.0% by 2030 compared to the Business as Usual scenario (BAU), and if additional international financial support, will increased up to 40.25% by 2030[12].

In this paper, we referred to the Irish TIMES energy system model, and then studied a research methodology for DPRK’s GHG mitigation model. The model represents the energy system of DPRK and its possible long term evolution, and its applications are related to the analysis of polices designed to reduce GHGs from energy and materials consumption. It contains large database of energy supply side and demand side technologies.

As shown in Figure 2, the actual system model includes all steps from primary resource availability to energy service supply required by energy consumers, through the process chain of energy conversion, transportation, distribution and transformation into services.

The characteristics and patterns of DPRK’s energy system are reflected in its supply sector (primary and secondary production, exogenous import), power generation sector (also including cogeneration) and demand sector (energy, IPPU, AFOLU, waste). The key inputs to the DPRK’s GHG emission mitigation model are the demand component (demand for energy services), the supply component (resource potential and costs), the policy component (scenarios) and the techno-economic component (alternative technologies and associated costs).

The number of energy service demands (ESD) can vary between different models and the level of detail of data available for each sector. In DPRK’s GHG emission mitigation model, the demand component is driven by 32 different ESD (specified by the list in Table 1), 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.

Figure 2. A reference model for Energy System in DPR Korea (the model’s current focus is on GHG emissions)
Higher levels of detail are used in the energy sector, in which fuel combustion activities and fugitive emission from fuels are classified according to 11 different types. In IPPU sector, standard production chains have been used to design specific sectors such for example Cement and Iron and Steel. In AFOLU sector, anthropogenic GHG emissions and removals occurring on managed land where human interventions and practices have been applied to perform production, ecological or social functions should be estimated. Main emission/removal sources in AFOLU sector in the country are divided into 4 categories such as Livestock, Land, Aggregate Sources and Non-CO2 Emissions Sources on Land and other. Main GHG emission sources in waste sector are classified according to 4 types such as Solid Waste Disposal, Biological Treatment of Solid Waste and so on.

### Table 1. List of exogenous energy service demands in the DPRK’s GHGs mitigation model

| Code       | Description                            | Unit(*) | Code       | Description                            | Unit(*) |
|------------|----------------------------------------|---------|------------|----------------------------------------|---------|
| Energy(11) |                                        |         | IPPU(13)   |                                        |         |
| EAEHP      | Main Activity Electricity and Heat Production | PJ      | ICP        | Cement Production                       | Mt      |
| EPRE       | Petroleum Refining                      | PJ      | ILP        | Lime Production                        | Mt      |
| EIST       | Iron and Steel                          | Mt      | IOPUC      | Other Process Uses of Carbonates       | PJ      |
| ENFM       | Non-Ferrous Metals                      | PJ      | IAP        | Ammonia Production                     | Mt      |
| ECHE       | Chemicals                               | PJ      | INAP       | Nitric Acid Production                 | Mt      |
| EMAC       | Machinery                               | PJ      | ICP        | Carbide Production                     | Mt      |
| EMQU       | Mining and Quarrying                    | PJ      | IPCBP      | Petrochemical and Carbon Black Production | Mt      |
| ECON       | Construction                            | PJ      | IFCP       | Fluorochemical Production              | Mt      |
| ETRA       | Transport                               | Mt+km   | IISP       | Iron and Steel Production              | Mt      |
| EOSE       | Other Sectors                           | PJ      | IFP        | Ferroalloys Production                 | Mt      |
| EFEF       | Fugitive Emissions from Fuels           | PJ      | IAP        | Aluminium Production                   | Mt      |
| Waste(4)   |                                        |         | IPPU(13)   |                                        |         |
| WSWD       | Solid Waste Disposal                    | PJ      | IZP        | Zinc Production                        | Mt      |
| WBTSW      | Biological Treatment of Solid Waste     | PJ      | AFOLU(4)   |                                        |         |
| WIOBW      | Incineration and Open Burning of Waste  | PJ      | ALS        | Livestock                              | PJ      |
| WWTD       | Wastewater Treatment and Discharge      | PJ      | AL         | Land                                   | PJ      |
| ASNCES     | Aggregate Sources and Non-CO2 Emissions Sources on Land | PJ    | AO        | Other                                  | PJ      |

(*) PJ here means ‘PJ of final energy in the base year’.

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 2000, DPR Korea has relied on domestic coal for 60.3% of total primary energy supply and hydropower and imported crude oil for the rest. Attaining 2020 in future, domestic coal in the country also will be in charge of 61.1% of total primary energy supply [2]. For the year 2030, the capacity for new hydropower energy is 1,000MW, and the potential for solar thermal power plants set at 1,000MW. The capacity limit for onshore and offshore wind energy for the year 2030 is 1,000MW, and the potential for nuclear power station set at 2,000MW[12].

The DPRK’s GHGs mitigation model used here has a time horizon of 40 years that ranges from 1990, the base year, to 2030, with time resolution of four seasons with day-night time resolution, the latter comprising day, night and peak time-slices.

The current version of the DPRK’s GHGs mitigation model does not have a flexible demand module, so the energy system can cope with emissions constraints here through energy efficiency and energy supply technology change but not through demand reduction.

The model also embeds several constraints to improve the authenticity of the future energy path ways. In fact the inherent nature of a linear programming model could otherwise deliver in many cases extreme technology switches. Constraints are designed with physical limitations in mind, such as the lack of infrastructure. In addition, although the detailed modeling of transmission issues, frequency and inertia issues of voltage stability is not considered in this analysis, the constraints are set to reproduce the operation constraints in the power system. The model also includes a limited number of diffusion constraints to control the growth rate of certain sectors such electricity generation and IPPU sectors.

Finally it is worth nothing that all constraints designed in this model are applied in all scenarios, and no constraints are imposed to maintain systems until the end of their lifetime.
4 Conclusion & Future works

This paper proposed a reference model for DPRK energy system by 2030. Especially, in order to reduce GHG emissions, it put forward a research methodology by analyzing Irish TIMES model. This work indicates that challenging emissions reductions can be technically achieved in DPRK, and energy efficiency and renewable energy technologies will have a determining role to deliver the target at least cost. The applications of a proposed model are related to the analysis of policies designed to reduce GHG emissions from energy and materials consumption. The model proposed in this paper will provide some help to the producers of DPRK’s future energy policies and contribute to international activities related to reducing GHGs. Of course, the model put forward on this paper is not complete, and it will be completed through continuous learning process and simulation courses. In the future, based on the above model, we should analyze the predicted GHGs by 2030, prove the practical and theoretical basis of relevant policies, and will build a theoretical system for the future energy system of DPRK Korea.

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