FORECASTS FOR ENERGY DEVELOPMENTS IN CHINA, JAPAN, AND KOREA BASED ON THE GLOBAL ENERGY MODEL

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Overview

[The modified global energy model developed in Moscow's Energy Research Institute and in Irkutsk's Energy Systems Institute is used for making long-term forecasting for the world of 10 mega-regions till 2050 year. One of this mega-regions is Japan & Korea, another is China. In this paper the results of the different scenario calculations for these two mega-regions are presented.]

Methods

[The Global Energy Model is a linear quasi-dynamic optimization model with detailed description of many technologies in extraction, conversion, transportation, import/export and consumption of energy and also pollution removement. The model has a set of constraints (resources, ecology, finance, and energy needs) and forecasts long-term tendencies in the global and mega-regional energy developments: extent of the energy technologies developments, energy consumption and energy production structure, emisiions (CO_2, Ash, NOx, SOx) etc.

The model is given by following formulas:

$$Z = \sum_{t=2010}^{2050} \sum_{r=1}^{10} \sum_{j \in J} c_{rj} x_{rj} \to \min \text{ s.t. regional and global constraints}$$

Regional constraints are:

- $\sum_{j \in J_1} a_{rij} x_{rj} \le b_{ri}$ - extractions constraints for primary energy, $i \in I_1$, $r \in R$, $j \in J_1$;
- $\sum_{j \in J_1} a_{rij} x_{rj} + \sum_{j \in J_2} a_{rij} x_{rj} - \sum_{j \in J_3} a_{rij} x_{rj} - \sum_{j \in J_4, J_5} a_{rij} x_{rj} = 0$ - balance equations for primary energy, $i \in I_1$, $r \in R$, $j \in J_{1,2,3,4,5}$;
- $\sum_{j \in J_4} a_{rij} x_{rj} + \sum_{j \in J_2} a_{rij} x_{rj} - \sum_{j \in J_3} a_{rij} x_{rj} - \sum_{q \in J_{4,5}, q \ne j} a_{riq} x_{rq} = 0$ - balance equations for secondary energy, $i \in I_2$, $r \in R$, $j \in J_{2,3,4,5}$;
- $\sum_{j \in J_5} a_{rij} x_{rj} \ge b_{ri}$ - final energy production constraints, where $i \in I_3$, $r \in R$, $j \in J_5$;
- $\sum_{j \in J_4} a_{rij} x_{rj} - \sum_{q \in J} a_{riq} x_{rq} \ge b_{ri}$ - electricity production constraints, $i \in I_4$, $r \in R$, $j \in J_4$, and $q \ne j$;
- $\sum_{j \in J_4} a_{rij} x_{rj} + \sum_{r \in R} \sum_{j \in J_2} a_{rij} x_{rj} - \sum_{p \in R} \sum_{j \in J_3} a_{pij} x_{pj} - \sum_{q \in J} a_{riq} x_{rq} = 0$ - electricity consumption balance, $i \in I_{3,4}$, $j \in J_{2,3,4}$, $q \ne j$, $p \ne r$;

- $-\sum_{j\in J_6} a_{rij}x_{rj} + \sum_{q\in J_{1,2,3,4,5}} a_{riq}x_{rq} \le b_{ri}$ - pollution constraints, $i\in I_5$, $r\in R$, $j\in J_6$, and $q\neq j$;

- $\sum_{j\in J_{1,2,3,4,5,6}} a_{rij}x_{rj} \le b_{ri}$ - investments constraints, $i\in I_6$, $r\in R$, $j\in J_1$;

- $lb_{rj}^{\min} \le x_{rj} \le ub_{rj}^{\max}$ - lower and upper bound constraints.

Global constraints are:

In this formulation I_1 is the set of the primary energy resources, I_2 is the set of the secondary energy resources, I_3 is the set of the final energy (mechanical, chemical, electrical, heat), I_4 is the set of electricity production regimes, I_5 is the set of the pollution types (Ash, NO_x, SO_x, CO_2), and I_6 is the set of the investments resources. At the same time J_1 are extraction technologies, J_2 / J_3 are energy import / export technologies, J_4 are conversion to secondary energy technologies (including electrical energy accumulation), and J_5 are final energy production technologies, J_6 are pollution removal technologies, $q\neq j$, R is the list of the mega-regions.

We used the simple linprog method of Matlab solver (Mathworks product) for solving the corresponding linear optimization model. Objective function was the cost of using the given technology in the given region in the given time period. The lower bounds were all zeros; the upper bounds were usually set to 1000 GWe for technology's capacity initially, and the adjusted to different levels in different scenarios. The constraints were for: resources extraction, investments, ecology, and demography and energy consumption; in total, 81 balance inequalities blocks and 19 balance equations blocks.]

Results

[As the results the model delivers the capacities for analysed energy technologies. This allowed: 1. Analysing the different scenarios of the mega-regional energy developments (different levels of final energy consumption, different levels of nuclear energy constraints, different levels of ecological or financial constraints); 2. Studying specific details in energy sectors developments in mega-regions (China vs. Japan-Korea) and interregional energy connections (regional peculiarities in energy resources usage for the electrical, heat and mechanical energy production; details of interregional fuel exchange); 4. Exploring possibilities for sustainable developments (costs of different pollution removal strategies for global energy system and global economy developments, influences of different emissions trade mechanisms on global and regional energy sector and economy).

The main result from the model regarding the Japan-Korea is: without the energy import this mega-region could not satisfy its energy demand needs. The main result from the model regarding China is: without the interactions with outside world this mega-region could not stay within sustainable ecological limits.]

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