MODELLING OF BALTIC REGION ENERGY DEVELOPMENT SCENARIOS

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Overview

This paper presents results from the economic analysis of the long-term sustainable energy supply for the Baltic Region including the possible role of nuclear power. For this task, a multiregional mathematical model of energy systems development and operation up to 2050 for four countries in the Baltic Region (Estonia, Latvia, Lithuania and Poland) was created. Analysis of energy sector future scenarios for the Region was performed in order to identify local energy development challenges and to determine which technologies could play an important role to overcome them. Applying the multiregional model permits the simultaneous optimization of the energy systems of all countries, allows determination of the global optimum, and facilitates the search for regional solutions by utilizing the strengths of local energy systems of different countries. This analysis presents technology development pathways as well as factors influencing economic attractiveness of power supply alternatives in the Region and reveals the main areas where attention has to be paid in future research. This work was carried out by an international team of experts from the Baltic Region in the context of the Euratom BRILLIANT project [1].

Methods

The MESSAGE modelling software applied in this work has been widely used for such type of analysis [2-4]. MESSAGE is a bottom-up techno-economic modelling tool designed for formulating and evaluating alternative energy supply scenarios for local, national or multi-regional energy systems. The fundamental principle of this modelling software is the optimization of an objective function, defined as total costs of energy system [5]. First, models of energy system evolution and operation of separate countries were developed. Experts from the Lithuanian Energy Institute (LEI, Lithuania) were responsible for the development of modelling concept and methods, for preparation of the Lithuanian energy system model as well as the multiregional model. Specialists from Poland, Estonia and Latvia were responsible for elaboration of energy models of their own countries. The mathematical models represent processes from the primary energy extraction or import to the supply of final energy of each country. However, the most significant efforts were devoted to represent electricity and heat supply systems in detail. Other sectors like fuel supply system or electricity transmission/distribution systems were modelled in a simplified way. Finally, the country energy models were hard-linked into the multiregional model (including Estonian, Latvian, Lithuanian and Polish energy systems). With such a model, it was possible to evaluate power exchange with external markets (Russian Federation, Germany, Nordic Region, etc.). Moreover, the developed model also enabled the analysis of power reserves, since intermittent Renewable Energy Sources (RES) technologies were modelled with time slices based on their probabilistic output patterns [6-7].

Results

The long-term illustrative analysis of sustainable energy supply for the whole Region, including the role of nuclear power was performed on the basis of the multiregional model described above. Four main scenarios were specified for that analysis, with the main factors determining them on the regional scale: the possible development of CO_2 prices (RENEWABLE scenario), the possible construction of conventional large-scale nuclear power plants in Lithuania and/or Poland (NUCLEAR scenario), and the requirement to keep 100% of installed firm peak capacity for possible local electricity generation within the Region (SECURITY scenario). All the results were compared to the REFERENCE scenario (without specific additional policy goals) for analysis. We could highlight few main trends from the analysis of results:

- Currently these four Baltic Region countries are very different in terms of energy supply: Lithuania relies on large-scale electricity import; Latvian electricity production is dominated by hydropower and imported natural gas while Poland and Estonia produce power mainly from local fuels (coal and oil shale, respectively). Our analysis shows that in the long-term the electricity generation in the whole Region shifts towards renewable energy. In 2050, renewable electricity share in the total electricity consumption reaches 35-60% (depending on scenario) in Lithuania; 73-87% in Estonia; 80% in Latvia and 31-53% in Poland;
- Looking only from economical point of view, the model does not inherently predict for the nuclear units (NPP) in Lithuania and Poland to be constructed (NPP units do not appear in the results after energy systems cost

optimization). This indicates that nuclear power at current set of assumptions is not an economically attractive option in the Region, in particular due to high investment costs and energy reserve requirements. In order to analyse a possible energy supply scenario with nuclear units, it was forced to construct NPPs in Poland and Lithuania– this was done in the case of the NUCLEAR scenario (NPPs starts explicitly defined operation in 2030 both for LT (1384 MW) and PL (up to 6 units of 1000MW)). Such a scenario leads to the highest total energy system development and maintenance costs compared to the other scenarios, as analysed for Lithuania. In addition, total investments in the energy sectors over the whole analysis period increase by 75% in Lithuania and by 33% in Poland if NPPs are constructed.

- Electricity import to the Region increases 1.8-2 times, export decreases up to 40% depending on scenario in 2030-2050. The import structure analysis has shown the following: Import from the Nordpool market (Sweden and Finland) increases the most; Import from the Russian market also has tendency to increase according to our calculations. This is because the physical flows are allowed in the model even after the foreseen synchronization of Baltic countries with grid of Continental Europe after 2025; The real volumes of electricity import from third countries (Russian Federation and Belarus) could be influenced by currently unknown political decisions regarding future capacities of interconnection lines and trade possibilities with third countries after synchronization [8-9].
- The CO_2 emissions from electricity and heat generation decrease by 30-80% in the Baltic Region until 2050 (depending on scenario). Compared to 2014-2015 statistics, the decrease is 50-75% in Lithuania, 90% for Estonia, 55-80% for Latvia and 27-80% for Poland.

Conclusions

The multiregional model consisting of four countries in the Baltic Region was built and used for the analysis of long-term energy systems development (including technical and economic attractiveness of nuclear power). Scenario approach applied allowed to analyse the implications of possible energy developments on system cost (investments, operation and maintenance cost, fuel cost, etc.), energy balances and electricity exchange between countries of the Region, security of electricity supply, environment, and other related issues. The results indicate that, according to current cost estimates for various electricity sources, a conventionally-designed large-scale nuclear unit in the Lithuanian and/or Polish electricity system may not be an economically attractive option, in particular due to high investment costs and energy reserve requirements. Moreover, taking into account only technical and economic criteria, the electricity import to the Region is expected to double from 2014 to 2050. Lastly, the power generation from renewables should increase by about 400% until 2050.

In addition, elaboration of these models with participation of experts from different countries made an important contribution for the capacity building and harmonization of approaches in Baltic Region in the field of modelling and technical economic analysis of energy systems development.

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