LONG-TERM PREDICTIONS OF THE ENERGY DEVELOPMENT Possibilities and Challenges

by

***Gligor KANEVCE*[*a], *Aleksandar DEDINEC*[a], *Aleksandra DEDINEC*[b], and *Ljubica KANEVCE*[a]**

[a] Research Center for Energy and Sustainable Development, Macedonian Academy of Sciences and Arts, Skopje, Macedonia
[b] Faculty of Computer Science and Engineering, University St. Cyril and Methodius, Skopje, Macedonia

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In this paper the possibilities, disadvantages, and benefits of long-term planning of energy development, are analysed. The factors influencing the development of energy and the factors influencing the accuracy of forecasting of the future development of energy are presented. The uncertainties that make the differences in modelling on a global scale, as well as the uncertainties that make the differences in modelling of the energy development of the Republic of Macedonia are also presented. Sensitivity analysis of the influence of different factors on the development of energy in the Republic of Macedonia was carried out. For those purposes the energy development of the Republic of Macedonia for the period up to 2035 year is calculated by using market allocation model. The main features of the market allocation model are also presented.

Key words: *energy development planning, market allocation, sensitivity analysis*

Introduction

Modeling of complex processes, like drying and inverse approaches [1, 2], air pollution [3-5], or heat and mass transfer modelling in ablative composites [6], regardless of perfection of the physical and mathematical model and the software used, can only be successful if the modeled processes are well known by the ones who performed the modelling.

However, much more complex than all of that, is the modeling of processes that will unfold in the future, where the medium-term and the long-term energy development predictions belong. Bearing in mind the inherent uncertainty of unfolding of the future and that the trends of development of the events in the past cannot be taken as the trustworthy indicators of the future events *you can be certain of only one thing – that all predictions about future energy, like all medium-term economic forecasts, will be wrong* [7].

From the reason of high uncertainty of the prediction of future energy development it is recommended different scenarios to be analyzed. However, we have to be aware that *scenarios are alternative images of how the future might unfold …* [8].

* Corresponding authors'; e-mails: kanevce@manu.edu.mk

Energy development and the ability of planning

Factors influencing the development of energy

Energy development in the future depends primarily on:
- economic development gross domestic product (GDP) growth,
- population growth,
- available energy sources and movement of their prices,
- available technologies for the production, transmission and consumption of energy, their energy efficiency and their cost,
- implementation of certain policies (increase in energy independence, reducing emissions of CO_2, SO_2, PM, and NO_x, stimulants for improving of energy efficiency, incentives for utilization of renewable energy, and subsidizing the poor), and
- the geopolitical events.

Factors influencing the accuracy of forecasting of the future development of energy

The accuracy of forecasting of the energy development depends of:
- the accuracy of the planning of all the factors listed in *Factors influencing the development of energy*,
- software used for planning energy development and its ability to encompass the factors that influence the development of energy,
- the accuracy of input data, and
- the set of assumptions and limitations.

The uncertainties that make the differences in modeling on a global scale

When analyzing the different energy consumption predictions on a global scale can be observed differences, primarily arising from differences in planning of the:
- penetration of energy efficiency measures,
- increase in GDP,
- energy consumption growth rate,
- penetration of renewable energy sources (RES),
- policies related to CO_2 price and subsidies for RES,
- changes in prices of technologies for the utilization of RES,
- changes in prices of energy sources,
- prices for the accumulation of energy (reversible hydropower plants, batteries, *etc.*),
- prices for balancing the changing power sources (accumulators of energy, capacity of power plants for balancing and their prices, interconnection capacities, legislation for balancing larger regions, *etc.*), and
- spheres of interest implementers modeling (whether and how is connected with businesses in the energy sector, manufacturer or dealer of energy or equipment or wants to influence global trends of energy development in the geopolitical interests).

The uncertainties that make the differences in modeling of the energy development of the Republic of Macedonia

The accuracy of the energy consumption predictions for the Republic of Macedonia mostly depends on the predicted:

- increase in GDP,
- policies related to penetration of energy efficiency measures,
- policies related to CO_2 price and subsidies for RES,
- prices of technologies for the utilization of RES,
- prices of energy sources, especially of natural gas, and of electricity,
- prices for the accumulation of energy (reversible hydropower plants, batteries, *etc.*),
- prices for balancing the changing power sources (accumulators of energy, capacity of power plants for balancing and their prices, interconnection capacities, legislation for balancing larger regions, *etc.*),
- uncertainties about the construction of main gas pipelines and connection options,
- uncertainty about economically feasible coal reserves for thermal power plant (TPP),
- uncertainty about the nuclear power plant PP (European policy and the development of the 4^{th} generation),
- utilization of the Vardar valley (Vardar waterway ?, relocation of the railway ?),
- still undefined potential of wind energy, and
- uncertainty about the geopolitical events, especially concerning on the Balkan area.

Energy development modelling by MARKAL model

By using the Market allocation (MARKAL) model detailed analysis of energy development in the Republic of Macedonia is made, in multiple time intervals, while analyzing different segments. The impact of renewable energy and energy efficiency policies until 2030 is analysed [9]. Also by 2030, the consequences of not building new facilities for the production of electricity from hydro power plants and reducing the availability of lignite from domestic mines [10], and low emission development pathways [11] are analysed. Three groups of mitigation scenarios until 2050, reflecting different types of targets with different levels of ambition regarding CO_2 emissions reduction are developed [12].

The MARKAL

The MARKAL is a model that organizes a comprehensive view of the energy system of one or several regions [13]. The MARKAL was developed in a co-operative multinational project over a period of almost two decades by the energy technology systems analysis programme (ETSAP) of the International Energy Agency. The model encompasses an entire energy system from resource extraction through to end-use demands. It meets the demand for useful energy of the end-users (in the residential, industrial, transportation, commercial, and agriculture sector) over a multi-period horizon and on the bases of information of available conversion and end-use technologies determines from where the demanded energy would originate. It computes energy balances at all levels of an energy system: primary resources, final energy, and useful energy. The MARKAL determines the least-cost mix of resources and technologies used for the entire analyzed period, to satisfy energy demand.

Estimates of end-use energy service demands are developed by the user on the basis of economic and demographic projections and the constraints, such as limits on technology, minimal penetration of RES, maximal availability of RES, caps on various emissions. In addition, the user provides estimates of the existing stock of energy related equipment, and the characteristics of available future technologies, as well as new sources of primary energy supply and their potentials.

Some of the uses of MARKAL program are [14]:

- to identify least-cost energy systems,

- to identify cost-effective responses to restrictions on emissions,
- to perform prospective analysis of long-term energy balances under different scenarios,
- to evaluate new technologies and priorities for research and development (R&D),
- to evaluate the effects of regulations, taxes, and subsidies,
- to project inventories of greenhouse gas emissions, and
- to estimate the value of regional co-operation.

Sensitivity analysis

By using the MARKAL model, the development of the energy system of Macedonia is analyzed in the period until 2035. In order to see how certain assumptions, affect the final results several scenarios are analyzed:

- reference scenario (reference),
- scenario with improved energy efficiency on the demand side (EE),
- scenario with electricity deficiency in the region (EE and El. Def.),
- scenario without new coal fired thermal power plants (EE without new coal TPP), and
- scenario with electricity saturation in the region (EE and El. Sat.).

In each of the scenarios, except for the reference scenario, improved energy efficiency is assumed on the demand side.

Furthermore, each of these scenarios is examined by using three different average GDP growth rates – 2.24%, 4.5%, and 6.94%.

Reference scenario

In the reference scenario it is assumed that there is no buying of new technologies with greater energy efficiency that the technologies that exist in the base year 2012 on the demand side, with a possibility of changing the fuel type of a technology.

Except for the existing technologies, on the supply side, a possibility of including the following new technologies is also taken into account:

- domestic lignite TPP and imported high-calorific coal TPP,
- natural gas TPP, up to the capacity of the existing natural gas pipelines, and
- renewable energy sources with feed-in tariffs (hydro, wind, photovoltaic, and biogas) up to the capacity for which the Energy Regulatory Commission of the Republic Macedonia has already issued at least a decision for temporary preferential producer.

In the reference scenario a construction of new large hydropower plants is not assumed (due to lack of interest of investors and/or resistance of non-governmental organizations (NGO) and the local population).

Scenario with improved energy efficiency on the demand side

This scenario is mainly focused on the demand side. An analysis of how much the final energy consumption is going to change by buying new technologies with greater efficiency than those in the base year 2012 is made, as well as by the fulfilment of certain standards in terms of the needs for heating and cooling for new and renovated buildings.

The supply side is defined in the same way as in the reference scenario.

Scenario with electricity deficiency in the region

In this scenario it is analyzed whether Macedonia could play a significant role in the region when electricity demand is constantly increasing, while there is not enough generation capacity in the region. This scenario assumes that Macedonia will join the new natural gas pipeline and that new large hydropower plants can be built.

Scenario without new coal fired thermal power plants

The uncertainty in the coal provision is the main reason why this scenario is made. Therefore, the consequences of this problem are analyzed here. In this scenario there is no possibility of building a new coal thermal power plant.

Scenario with electricity saturation in the region

In this scenario, a case where the electricity demand increase and the closure of the already dilapidated facilities is accompanied by opening of a sufficient number of new facilities abroad, which would mean that there is no room for electricity export is analyzed.

Results and discussion

Figure 1 clearly shows the dependence between the final energy consumption, the assumed GDP growth and the envisaged measures for energy efficiency improvement on the demand side that are applied in each of the scenarios except in the reference scenario.

The average growth rate of final energy consumption in the reference scenario is 1.3%, 2.7%, and 4.3% when the GDP growth rate is 2.24%, 4.5%, and 6.94%, respectively. The introduction of the energy efficiency measures contributes to final energy demand reduction by 12%-13%.

The impact of the GDP growth rate and the energy efficiency measures on the total primary energy is similar to the impact on the final energy consumption (fig. 2).

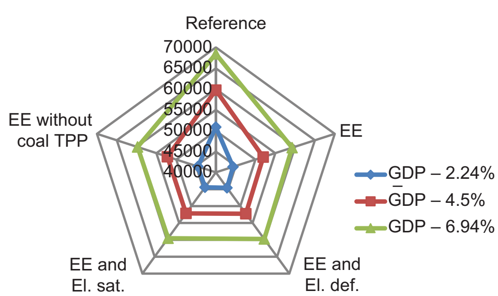

Figure 1. Cumulative final energy consumption [Ktoe]

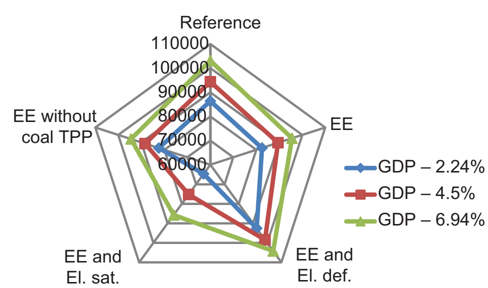

Figure 2. Cumulative primary energy [Ktoe]

In fig. 2 the difference in the projected primary energy for the cases with electricity saturation and electricity deficiency in the region is presented. In the first case a certain quantity of electricity is imported and the primary energy decreases. On the other hand, in the second case, there is electricity export and additional production capacities are built.

The preceding analysis is also shown in fig. 3, where the required net energy import is presented.

In the case of greater electricity export, the required primary energy import is increased (natural gas or high-calorific coal) because part of it is used for production of the exported electricity in power plants with a certain degree of efficiency. This scenario will be developed in the other direction if electricity is imported. This is reflected in fig. 4 where the need for construction of new facilities for electricity production is presented. In the scenario where new coal TPP will not be built, beside new natural gas power plant, new renewable electricity production facilities (mostly hydro power plants, wind power plants, and photovoltaic solar systems) will be build. For the reason that the capacity factor of renewable electricity production facilities in the Macedonian conditions is small, the installed capacity in this case is higher are constructed.

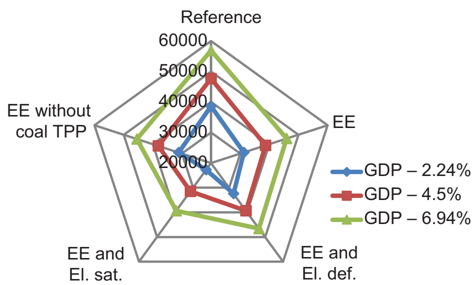

Figure 3. Cumulative net import of energy [Ktoe]

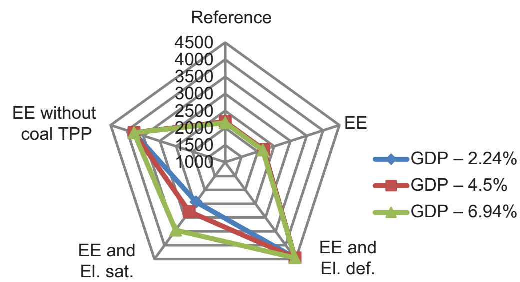

Figure 4. Total new capacity for electricity production [MW]

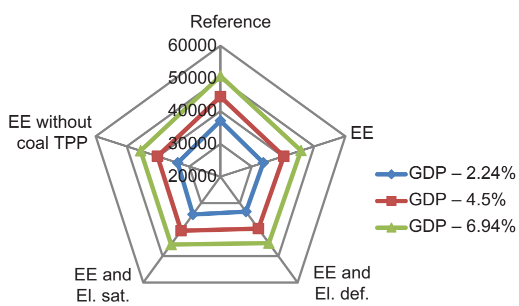

Figure 5. Cost of the system [2012 M€]

The total cost for realization of a particular scenario mainly depends on the energy consumption growth rate, which in turn is directly dependent on the projected GDP growth rate (fig. 5). The total cost of the system is reduced by the introduction of the measures for energy efficiency.

In addition to the above scenarios, an analysis is made of the introduction of a fee for CO_2 emissions. If the price of the CO_2 emissions reaches 40 €/t per ton, then it is not economically feasible to construct new coal fired thermal power plants.

Conclusions

From the calculations reported in the paper it is clear that predicted development of the energy system highly depend on the introduced assumptions, which cannot be predicted with a high level of reliability. A large number of uncertainties lead to an uncertainty of the planned energy development, especially in planning of the energy development of a small country. In addition to that, by the action of politicians and other interested parties, the very solid forecasts may be changed.

However, despite all the uncertainties, the energy development planning is useful for many reasons. Firstly, it indicates the main direction of movement and the possible variations. Also, it indicates the feasibility of the desired energy development. Moreover, the energy development planning quantifies the costs and technology choices that result from imposition of the policies and programs. It shows the possible long-term consequences of current policies, as well as the possible consequences of failure to implement certain policies and programs. Furthermore, the behavior of investors, politicians, and other stakeholders may be influenced to a certain extent in order to achieve desired objectives. Finally, by comparing different predictions, reasons for different results may be identified, and based on that analysis, which and whose interests are behind it may be concluded.

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