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NUCLEAR POWER PLANT COMPETITIVENESS AND IMPACTS OF CO_2 PRICE IN CROATIA

Abstract: Long term power system planning faces growing number of concerns and uncertainties, which is especially true for nuclear power plants due to their high investment costs and financial risk. In order to analyze competitiveness of nuclear power plants and optimize energy mix, existing models are not sufficient anymore and planners need to think differently in order to face these challenges. Croatia will join EU ETS (European Emission Trading Scheme) with accession to EU (probably in 2012). Thus, for Croatian electrical system it is very important to analyze possible impacts of CO_2 emissions.

Analysis presented in this paper is done by electricity market simulation model PLEXOS which was used for modelling Croatian electrical system during development of the Croatian Energy Strategy in 2008.

Paper analyzes impacts of CO_2 price on competitiveness of nuclear power plant within Croatian power system between 2020 and 2025. Analyzes are focused on how nuclear power plant influences total emission from the power system regarding coal and gas prices, average electricity price regarding CO_2, coal and gas prices price. Results of this paper are showing that with emissions from Energy strategy development scenario with two new coal power plants (600 MW each) and two new gas power plants (400 MW each) until 2020, Croatia does not meet post-Kyoto target due to this emissions from power system. On the other side, introduction of nuclear power plants presented in this paper (1000 MW instead of one coal and one gas power plant) means nearly 6.5 MtCO_2 emissions less annually and gives possibility to achieve post-Kyoto target. Results are also showing how increase in CO_2 price is enhancing competitiveness of a nuclear power plant.

Key words: *power system planning, nuclear power plant, marginal costs, electricity market simulation, emission trading*

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1. INTRODUCTION

This paper presents results from modelling impact of nuclear power plant on Croatian power system between year 2020 and 2025 – namely on quantity of CO_2 emissions and on electricity price expected. Analysis has been built upon data used during preparation of Croatian Energy Strategy in 2008/09. Analysis presented in this paper was done by model PLEXOS (which was upgraded with new algorithm during modelling in order to include emission price). Questions analyzed in this paper were how nuclear power plant influences quantity of CO_2 emissions from Croatian power system, and how it influences electricity price in modelled period (2020–2025). Further, it is analyzed how emission price rise can influence economical competitiveness of different electricity generating technologies, and how to valorise emission trading impacts on power system.

First energy system modelling was performed by using economic theories and mathematical models. Today's electrical energy sector is characterized by new challenges such as deregulation, liberalization of energy markets, increased competition with growing demand for security of supply (together with ever growing percentage of imported energy resources) [[1],[2]]. Old centralized least-cost planning approach does not reflect how investment decisions are made in today's electricity markets, where generating companies are competing with each other, both in short run operations and long-run investments. Some of challenges concerning sustainability relevant for power system are satisfying minimal production from renewable energy sources, constraints on emissions or minimal energy efficiency goals. Other challenges in energy planning that need to be modelled are price insecurities of investments and energy resources and CO_2 emission price on emission market. All challenges mentioned above are calling for consideration of various options (like nuclear, coal, gas or renewable scenarios) in order to optimize energy mix and lead to satisfying development of power system. Power system modelling usually requires the representation of the underlying technical characteristics and constraints of the production assets.

2. MODEL PLEXOS

Used electricity market simulation model was PLEXOS. There are four basic simulation engines in PLEXOS: LT Plan (long-term planning module), PASA (for modelling scheduled maintenance and forced outages), MT Schedule (model medium to long term decisions, "decomposes" user-definable constraints to shorter term constraints suitable for detailed modelling in ST Schedule) and ST Schedule (short term modelling, can get to five-minute resolution). Each one of the engines can be used separately, but they can also be used sequentially. When problem is formulated, commercial MOSEK software is started for solving large mathematical optimization problems. After problem is solved, PLEXOS engine prepares data for interpretation in output users' interface.

3. CROATIAN ENERGY DEVELOPMENT STRATEGY AND EMISSION TARGETS

The Energy Development Strategy is the foundation document of the Energy Act that defines the energy policy and future plans for energy development for a ten-year period. The newest Energy Development Strategy of the Republic of Croatia [3] focuses on the period until 2020 to coincide with the period covered by all adopted EU energy strategies, and provides a general forecast until the year 2030, as a "glimpse into the future".

In all scenarios developed for Energy strategy energy efficiency measures were applied and it resulted in lower increase in electricity demand than in business-as-usual scenario: annual rate of 3.4% in the period 2006–2020. In the electricity production sector, a high demand for new capacity is projected, due to growing consumption and the age of current substations and power plants. The Croatian Energy Strategy set three basic energy objectives, respecting specific situation in Croatia and its national interests: security of energy supply, competitive energy system and sustainable energy sector development.

Challenges considering CO_2 emissions impacts on energy sector are coming out from integration into the EU ETS and burden-sharing agreement between EU member states.

New Energy Development Strategy considers EU objectives from new EU Energy and Climate Change Package: share of renewable energy in total primary energy for Croatia predicted by Strategy is 20% in 2020, emission reduction goal – 20% until 2020, energy efficiency goal is to lower final energy consumption by 9% from 2008 until 2016 (according to an average level between 2001–2005), and to increase the share of biofuels by 10% until 2020.

3.1. Development scenarios between 2020–2025

For Croatian power system situation in 2020, forecasted data from Energy strategy was used (meaning that economical crises that appeared afterwards and that will influence electricity consumption by than is not taken in account): based on the expected electricity consumption and on the forecasted load factor of 0.7, expected peak load in 2020 amounts to 4767 MW. Sufficient available reserves of installed capacity are needed in the power system in order to cover expected peak load. Necessary reserves in the system are determined on the basis of system features and the structure of production units in the system (taking in account large percentage of hydro generation which can provide less than one third of installed power during summer months). The outcome of analysis showed reserve margin of 30%, so the required capacity in the system amounts to 6200 MW.

Scheduled generation capacities in 2020 are described in PLEXOS with technical and economical characteristics. Transmission capacities were modelled only for 400 kV lines and nodes, with two forecasted 'bypasses' planned until year 2020.

Electricity consumption is modelled according to hourly values and according to load share on different nodes. Scenarios presented in this chapter don't assume electricity import or export, as one of the simulation goals was to examine self sustainability of installed capacity and produced electricity. Retirement plan for existing power plants is showing that 1130 MW of installed capacities will be retired until year 2020, and additional 260 MW until 2030.

3.2. Comparation of scenario without NPP (Blue) and with NPP (White)

Two cases were modelled for each scenario, regarding CO_2 price. It means all together four cases were modelled and analyzed:

Case 1: Blue scenario with 0 €/tCO_2
Case 2: Blue scenario with 40 €/tCO_2

Fig. 1. Generation of power plants in Blue scenario – annual and monthly values of generation during 2020–2025

Case 3: White scenario with 0 €/tCO2
Case 4: White scenario with 40 €/tCO2

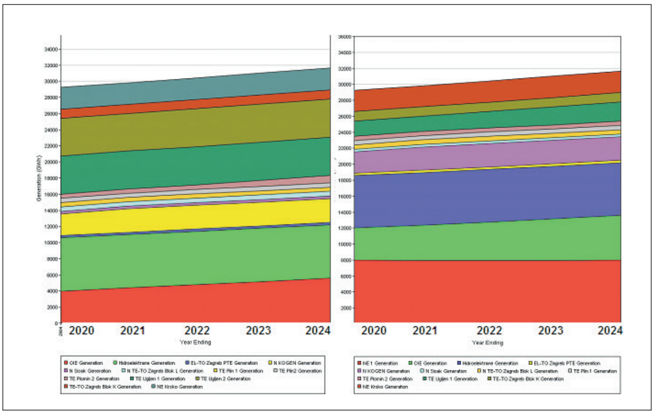

Fig. 2. Annual generation of power plants within Blue and White scenarios during 2020–2025

In the figure 2 above, for Blue scenario (on the left) red bar represents renewable and green represents hydro. Red bar in White scenario (right side) at the bottom represents new nuclear capacity which generates most of the energy in the system along with renewable (green bar) and hydro (blue bar).

The difference in emissions for two scenarios: emissions in Blue scenario start from 10.9 $MtCO_2$ in 2020 and grow up to 11.5 $MtCO_2$ in 2024. Emissions in White scenario are much lower – from 4.6 $MtCO_2$ in 2020 until 5.2 $MtCO_2$ in 2024. It means that nuclear scenario means approximately 6.5 $MtCO_2$ emissions which represents nearly 22% of Croatian Kyoto target.

3.3. Impacts of emission trading on competitiveness of nuclear power plants

Investment decisions in new plants are usually based on the LRMC – which includes fuel costs, variable costs, fixed costs and costs of capital. Since total investment costs in recent nuclear projects proved to be higher than expected, this sensitivity was analyzed within the model by adding additional variable – Nuclear HIGH, with significantly higher investment costs than variable Nuclear. Also, due to very fast development in technology and capacity installed, a case with economically more favourable wind power plant is considered (variable Wind LOW), with lower investment costs and lower fixed costs. It is clear how LRMC of fossil fuel-based power plants rises with CO_2 rise, while it remains the same for nuclear and renewable. This creates additional opportunities for nuclear technology as its competitiveness becomes higher. Even with higher investment costs for nuclear, investment in this technology becomes more attractive than in coal with CO_2 price of 10 €/tCO_2.

4. CONCLUSION

Over the next several years the economics of power generation will change in a manner that makes sources with high greenhouse gas emissions less competitive relative to those with lower greenhouse gas emissions. This change in the competitiveness of resources will result from interactions among a variety of factors (including policy actions, regulations, legislative initiatives, technological innovation) not due to any single factor.

These CO_2 price projections is for use in Integrated Resource Planning (IRP) and other electricity resource planning analyses. Projections of prices associated with carbon dioxide emissions reflect a reasonable range of expectations regarding the likelihood and the magnitude of costs for greenhouse gas emissions.

The projections represent a range of possible future costs, recommended price range, that are useful for testing range-sensitivity of various investment possibilities in resource planning in the electricity sector. The projection does not represent a prediction of specific future price trajectories; there will be variability and volatility in prices following supply and demand dynamics, as there is with other cost drivers. Intentions were to and anticipate that the CO_2 price projections presented here will be useful for planning in the face of uncertainty.

In order to fully understand impacts of CO_2 emissions on power system, new improved models are needed. Model PLEXOS is an electricity market simulator which is able to include emission price in power system modelling.

Results of this paper are showing that with emissions from Energy strategy development scenario with two new coal (600 MW each) and two new gas power plants (400 MW each) until 2020, Croatian power system is not meeting Kyoto target for 2012 (and post-Kyoto target will be even stricter due to accession to EU). On the other side, introduction of nuclear power plant in the scenario (1 000 MW instead of one coal and one gas power plant) means nearly 6 $MtCO_2$ emissions less annually and gives possibility to achieve Kyoto target (for which Croatia was already missing by 2.6 $MtCO_2$ in 2007). Results are also showing how increase in CO_2 price is enhancing competitiveness of a nuclear power plant by increasing long term marginal costs of power plants that use fossil-based fuels. Even with higher investment costs, nuclear option is more competitive than any other with CO_2 price higher than 10 €/tCO_2.

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