Journal of Energy

VOLUME 65 Number 1–2 | 2016 Special Issue

journal homepage: http://journalofenergy.com/

Possible Role of NPP in Long Term Low Carbon Development Strategy – Case Study Croatia

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ABSTRACT

The term low – emission development strategies (LEDS) was developed on the UN Framework Convention on Climate Change (UNFCCC) in 2008. LEDS is used to describe a long-term national economic development plans or strategies that include low emissions and economic growth resistant to climate change.

The concept of Low Carbon Development Strategies (LCDS) has been introduced by the Conference of Parties to the UNFCCC as a common but differentiated approach to meet the overall emissions reduction objectives:

"*All countries shall prepare Low Emission Development Strategies …nationally-driven and represent[ing] the aims and objectives of individual Parties in accordance with national circumstances and capacities*" (Cancun Agreement).

Low Carbon Development Strategies (LCDS) in this way become an overarching framework to design and achieve Nationally Appropriate Mitigation Actions (NAMAs) reflecting the Common but Differentiated Responsibilities (CBDR) of all countries.

For Long-Term National Strategy and Action Plan for Low-Carbon Development the main objective of this programme is the development of a long-term national strategy and action plan for low-carbon development to enable country to fulfil its commitment to carbon obligations.

Low-carbon development strategy will become the fundamental for the development of the energy sector with low rate of carbon, but also for the entire economy. European Union is the leader in the effort to reduce emissions especially in the energy sector – sector with the highest rate of emission. With the goal of reducing emissions, necessary measures are accentuated for energy in the EU Countries, as well as in Croatia. The possibilities for realization of Croatian low-carbon development and particularly possible role and barriers for Nuclear power plants for Low carbon emissions development in the electricity sector until 2050 will be presented in this paper.

Keywords: *Low Carbon Development Strategies, Electricity Sector, Greenhouse Gasses, Energy Efficiency, Renewable Energy, Low Carbon Technologies, PLEXOS*

1 INTRODUCTION

In the aspects of financial and economic crisis, low carbon development, with the goal of predominant production from renewable sources, is becoming increasingly important. Positive changes in national and international policy making with the huge impact of low carbon development in long term strategic planning are also notable. The United Nations Framework Convention on Climate Change (UNFCCC), an agreement about the integration of policies and measures for the protection of the climate system from dangerous anthropogenic interference with

https://doi.org/10.37798/2016651-2123

the climate system, also includes national development plans and programs. [1] It was the first step toward limiting global warming and to face future climate change with it effects. [2] Main objective of UNFCCC is stabilisation of greenhouse gas concentration in atmosphere at levels which will stop dangerous effect on the climate. [3] UNFCCC parties have signed the Kyoto Protocol and agreed to set internationally binding emission reduction targets. The main objective of last COP21 in Paris was to achieve a legal binding agreement on climate and to keep global warming below 2°C above pre-industrial levels. Implementation of this agreement will start in 2020.

The term Low Emission Development Strategies (LEDS) was first used by UNFCCC in 2008. The primary task was to enable the improvement of national climate change, to develop policies in more directing, coherent and strategic manner and to bring international impetus for climate action. Parties agree to commit to a maximum global temperature rise of 2°C and to prepare a low-carbon development strategy. National climate strategies include plans for mitigation of climate change with a focus to specific circumstances and development objectives of each country. LEDS, as a strong climate document, manages national development and national strategies.

The concept of Low Carbon Development Strategies (LCDS) has been introduced by the Conference of Parties to the UNFCCC as a common but differentiated approach to meet the overall emissions reduction objectives:

> ***All countries shall prepare Low Emission Development Strategies …nationally-driven and represent[ing] the aims and objectives of individual Parties in accordance with national circumstances and capacities*" (Cancun Agreement).**

2 OBJECTIVES AND GUIDELINES OF LEDS

Based on the LEDS it is possible to highlight disadvantages and to prioritize activities for founding on the national level. [4] Thereby, LEDS can be integrated and build on existing strategies (National Sustainable Development Strategies (NSDS), National strategy on climate change, Technology Needs Assessment and Nationally Appropriate Mitigation Action (NAMA)). Legal form of LEDS is a strategic plan to help countries in promoting their development pathway towards a low-carbon sustainable development based on the socio-economic development priorities of the country. There is a long-term component that includes a strategic vision and short- and medium-term components to show precise action to be undertaken. [5] Elementary guidelines adopted in LEDS Global Partnership workshops are stated in [6].

Strategy development process includes: high level of political support, identification of important interested groups and stakeholders, strengthening of the institutional framework and establishment of cross-sectoral coordination body, collection and analysis of data, identification of greenhouse gas emission scenarios and projections, identification of climate change mitigation policies and measures, political support for document adoption, and climate change measures application and monitoring. [7] LEDS developing process and comprehensive explanation can be found in [4].

3 NATIONAL CLIMATE POLICY

In year 2010 at COP16, Cancun UNFCCC members officially agreed on the preparation of low-carbon development strategies (LEDS), which will be developed at the national level and take a special place in the national considerations. [8] The national development strategy is usually based on the individual plans of each sector which are described by specific objectives and development strategies. According to the [9] following elements are basis for development of national climate plan: goals and objectives, sectoral plans and investment plans. Over the past two decades both, developed and developing countries, have been active in the preparation of national plans for climate change and sustainable development strategy.

3.1 Low-emission development strategy in EU

Key elements of low-emission European policy framework for 2030 identified by European Commission can be found in [10]. Many strategies have already been launched in several countries, such as Great Britain, Germany, Sweden, Finland, France, Netherlands, Belgium and Ireland. Details can be found in [11].

3.2 Low-emission development strategy in Croatia

The main objective of Long-Term National Strategy and Action Plan for Low-Carbon Development is the development of a long-term national strategy and action plan for low-carbon development to enable country to fulfil its commitment to carbon obligations.

The Strategy is fundamental document in the field of climate change mitigation as well as a main economic, development and environmental strategy. [12] The objective of the Strategy is to achieve a competitive low carbon economy by 2050 in line with relevant guidelines such as [8] and [10].

At the end the Low-emission development strategy contains three scenarios [13]:

1. NUR – the referent scenario which represent the implementation of existing regulations;
2. NU1 – scenario of the gradual transition, reduction of the greenhouse gas emissions in Croatia to the binding level according to the European Union;
3. NU2 – scenario of the strong transition, 80% reduction of the greenhouse gasses emissions by 2050 compared to the 1990

3.3 Certain measures related to the energy sector

Technical measures that can be applied in the energy sectors are stated and discussed in [14]. The focus is on the following: energy efficiency of residential and non-residential buildings; energy audits in industry; metering and informative billing of energy consumption; construction of the cogeneration (CHP); labelling the energy efficiency of the appliance; eco-design of energy using products; RES; use of refuse-derived fuel to generate electricity and heat; carbon tax. [15]

3.4 Possible measures in electricity sector

List of possible measures in electricity sector consists of:

1. Increase energy efficiency in electricity production and consumption,
2. Renewable energy sources (wind, PV, geothermal, biomass & biogas),
3. **Croatian Nuclear Energy Program – CRONEP,**
4. Additional utilization of hydro potential and
5. Thermal power plants with CSS.

3.4.1 Croatian Nuclear Energy Programme (CRONEP)

The Energy Strategy of the Republic of Croatia is the first document that indicates necessity for Croatian nuclear energy program (CRONEP) and the need to build nuclear power plant in Croatia.

Energy Strategy of the Republic of Croatia [16] predicted that by 2030 two nuclear power plants, about 1,000 MW each, will be in operation.

Assuming this decision is confirmed, nuclear power plants could start with operation between year 2030 and 2035, and corresponding investment will be 3-5 billion € for each of them. The main constraints for this implementation are public acceptance public and the significant financial resources.

On the other hand, this option will significantly reduce greenhouse gasses emissions with annual production of electricity around 9,000 GWh by year 2030 and around 18,000 GWh by year 2035. with zero associated greenhouse gasses emissions.

This also means employment opportunity in Croatia: the construction will result in an average of about 1400 to 1800 jobs (with a peak around 2400 in the designated time) and 4000 of indirect employments. The operation of the power plant will generate directly about 500-700 permanent jobs. There will be also a huge number of additional jobs in the local community to supply goods and services.

Positive side effects can also be significant: the technological development of domestic industries, the advancement of science and education, economic benefits for the local community etc.

Certain disadvantages are also expected such as storage and disposal of nuclear waste (low, medium and high-radioactive).

4 CROATIAN POWER SYSTEM MODEL

For the purpose of this analysis Croatian power system is modelled in the „PLEXOS for Power Systems“. PLEXOS is product of the Australian company Energy Exemplar for simulations of the electricity market. For power system modelling specific data was collected on request for the purpose of research and from publicly available sources. The simulation model requires a large amount of input data: technical and economic parameters of power plants, power plants availability, system load; the key parameters for the power plants that are candidates for the expansion of the system. Parameters which are not available were estimated or assumed.

4.1 Basic assumptions

LEDS for Croatia was made for the period up to 2050. Following major assumptions are made:

- One of the assumptions is unavailability of the external market since 2020 because the determination of the Croatian CO_2 footprint in conditions of self-sufficient energy production. External market for period between 2015 and 2020 was modelled by using the hourly EEX prices from 2014. The ability to import and export is limited to model the restriction of cross-border transmission capacity.
- Power plants outages and new entries are also modelled.
- Predicted rise of installed renewable capacities is based on the key documents: Croatian Energy Strategy, National Renewable Energy Action Plan by 2020, and others.
- Possibility of CO_2 capture and storage technology in the scenario becomes available at the earliest by year 2035. Power plant Plomin C has the ability to upgrade the CCS technology (Retrofit) using a special restriction, but also after 2035.
- Wind power is possible from three areas, each has its own capacity factor which is obtained at the request for the Study. It is assumed that the intensity of the construction of wind power is equal in all three areas.
- For photovoltaic power generation three areas are also used which are presented with their capacity factors. It is assumed that the intensity of the construction of photovoltaic systems is equal in all three areas.
- Hourly electricity demand curve is based on the actual data. For each of scenarios (NUR, NU1 and NU2) separate curves were created based on the prediction of electricity consumption. It is

assumed that the growth of the peak load is in direct correlation with the growth of electricity load.

- System capacity margin is 15% without taking into account wind power and photovoltaic systems.
- It is assumed that the photovoltaic system and other renewable energy sources are connected to distribution network while other plants (and wind) are connected to transmission network. This is a reason for separate modelling of losses in electrical power transmission and distribution system.
- Hourly energy demand curve for heating (and steam) is based on the actual data. For each of scenarios separate curves were created based on the prediction of heating energy consumption by 2050. It is assumed that the growth of the peak load is in direct correlation with the growth of consumption of the heat energy.

4.2 Modelled objects

Croatian power system model in PLEXOS consists of Thermal Power Plants (gas, coal, oil), Cogenerations, NPP Krško, Hydro Power Plants, Pump-storage Power Plant Velebit, Wind Farms, Photovoltaic Power plant and other renewables (RES). Depending on the scenario there are different costs of emissions and different annual production limits of CO_2 emissions. Expansion candidates are modelled based on data from commercially available technologies. In addition to the cogeneration, heat boiler and heat storage tanks contribute in covering regional energy heat and steam demand. In this model secondary reserve are provided by thermal power plants (gas) and hydro power plants.

In the nuclear scenario, introduction of new nuclear power plant was forced.

5 RESULTS AND DISCUSSION

PLEXOS allows huge amount of output date and it is impossible to show all of them within framework of this work. Those shown are selected according to the importance represented by the LEDS RH.

5.1 Selected results from LEDS

Three different scenarios are compared based on the results shown in following figures. From Figure 1 it is obvious that total electricity load in 2050 is expected to be highest in scenario NU2 and lowest in scenario NU1. In scenario NU1 implementation of energy efficiency measures will result in decreased electricity demand during whole time period of interest. Further, in scenario NU2 implementation of energy efficiency measures will result in decreased electricity demand until 2040, but afterwards intensive electricity usage in transport sector is assumed that results in significant increase in electricity demand [12]. In accordance with the above data, installed capacity in scenario NU2 is larger, and in scenario NU1 slightly lower in comparison to NUR (Figures 2-4).

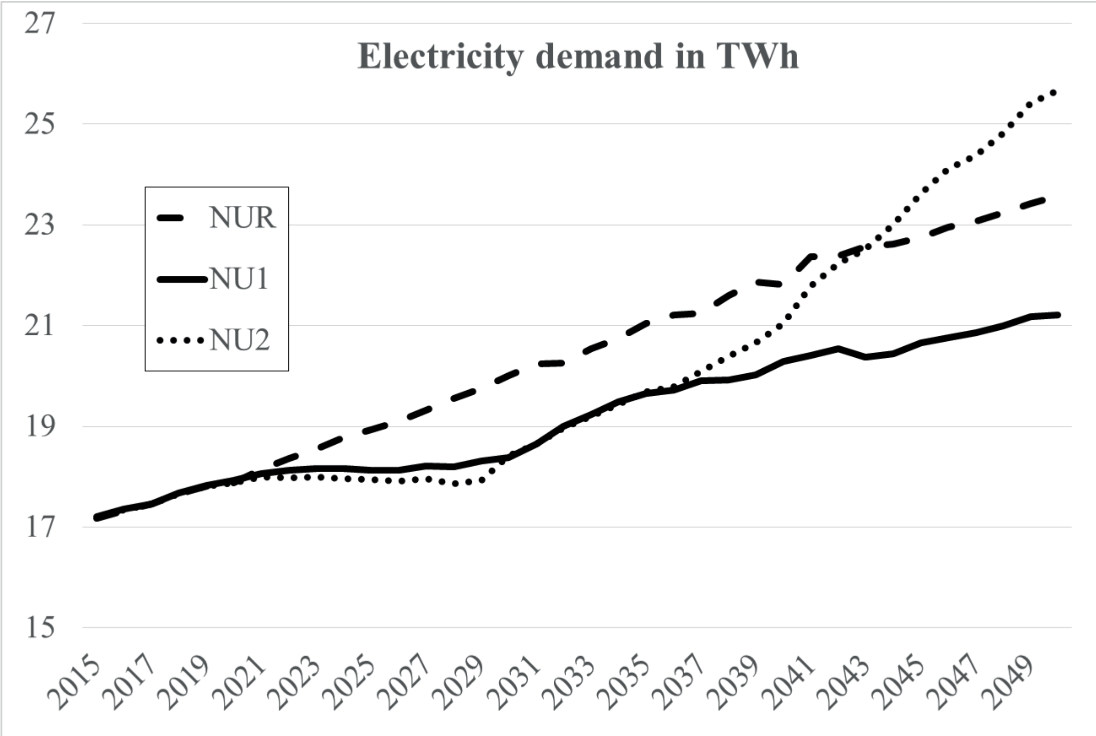

Figure 1 Total electricity demand comparison between scenarios

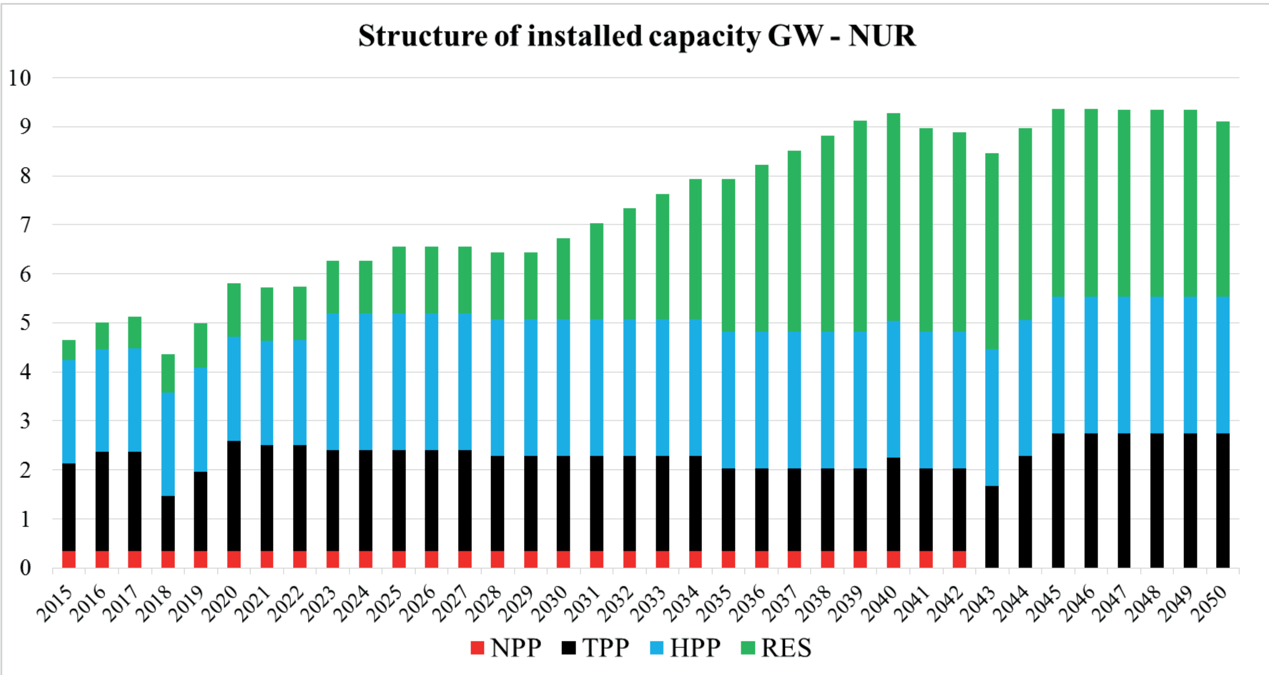

Figure 2 Structure of installed capacity for scenario NUR

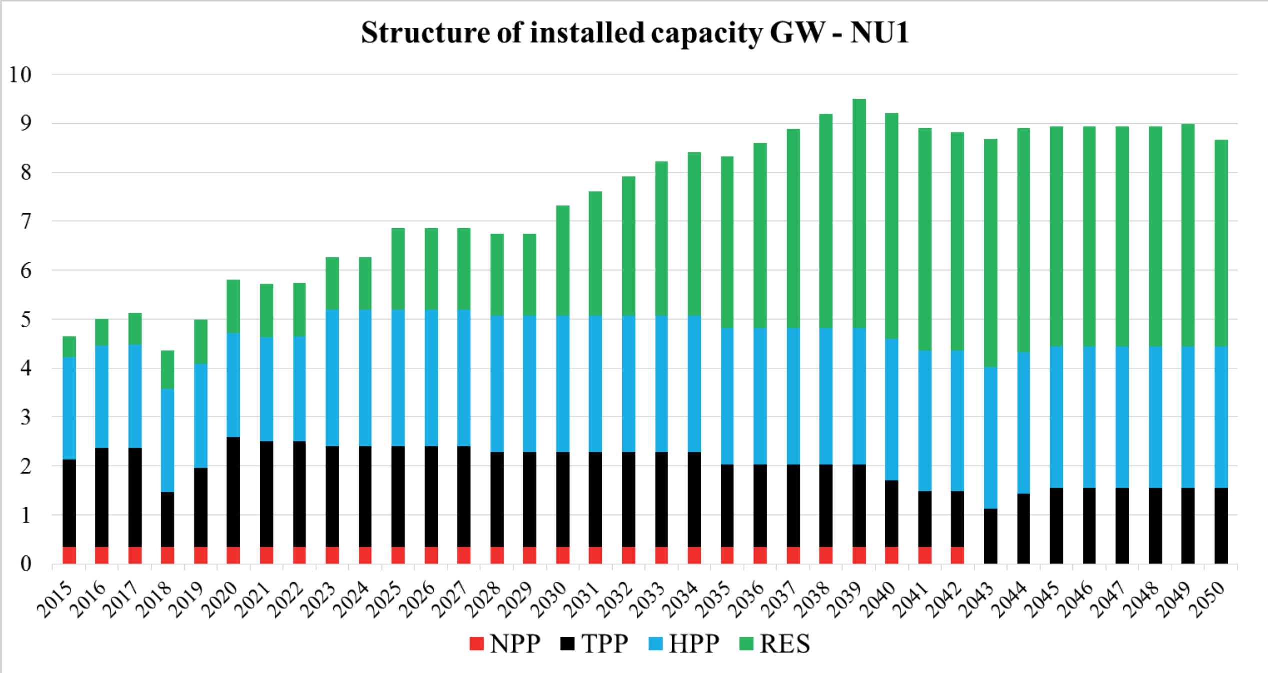

Figure 3 Structure of installed capacity for scenario NU1

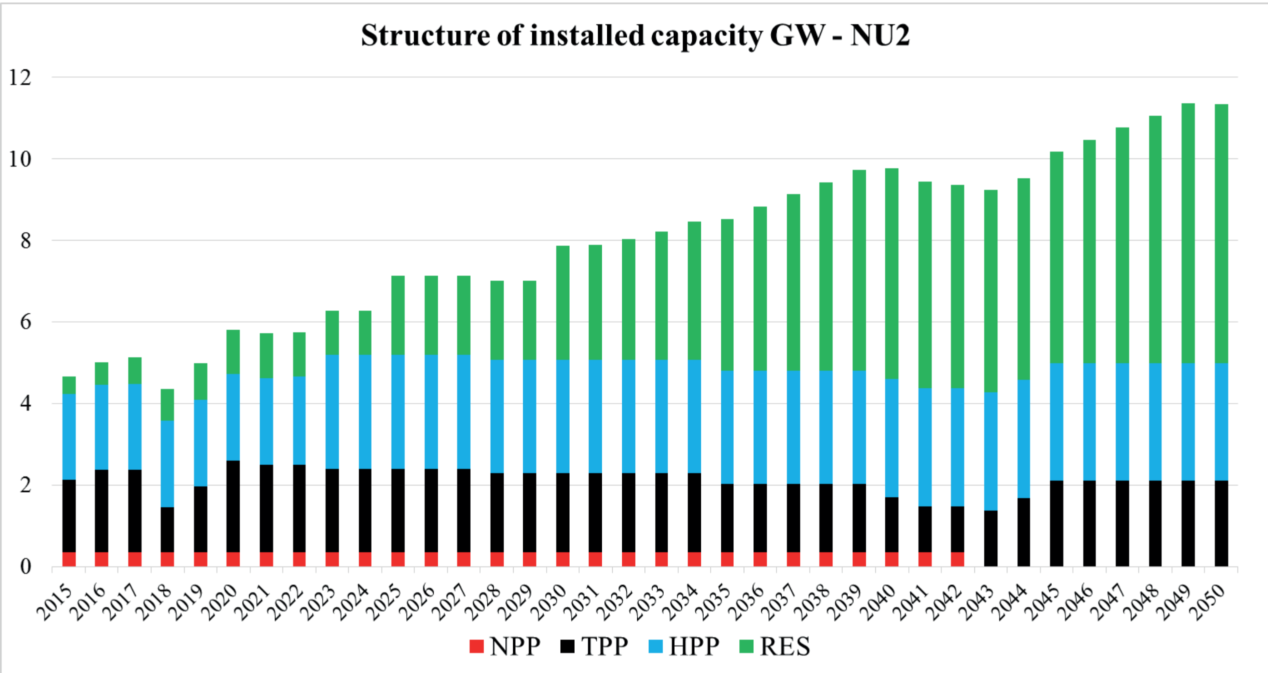

Figure 4 Structure of installed capacity for scenario NU2

From presented results it is obvious that there is no new NPP regardless of scenario of interest. Main reason for that is large increase in RES installed capacity that is partly due to current subsidies policy and partly due to increasing competitiveness of main RES technologies, wind and solar power. This large RES capacity is very volatile in nature and requires some kind of flexible power plants such as gas fired thermal power plants or pumped storage hydropower plants. Nowadays NPPs can't handle this volatile nature of RES and is therefore pushed out of future capacity schedule. But there are some strong reasons to take nuclear scenario into account as discussed in next paragraph.

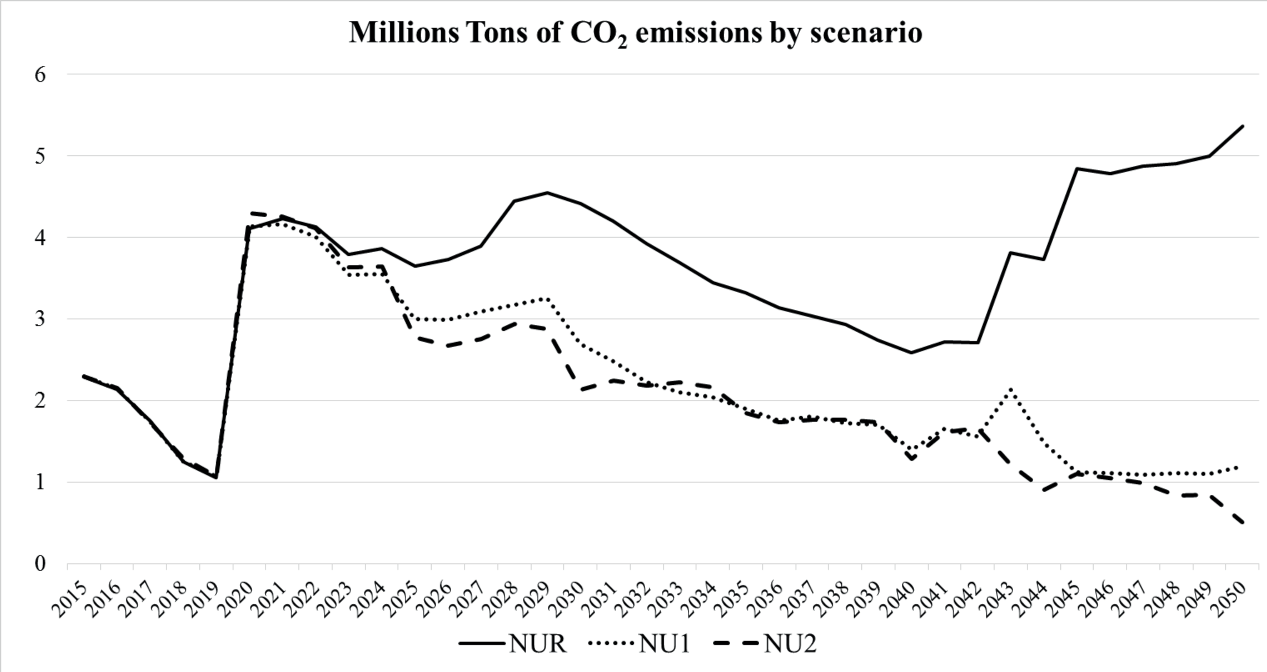

Figure 5 Greenhouse gasses emissions by scenario

Figure 5 shows total yearly CO_2 emissions generated in Croatian power system for each scenario. There are three main sources of CO_2 emissions: Gas (CO_2 emissions generated in gas fired thermal power plants), Coal (CO_2 emissions generated in coal fired thermal power plants) and Heating (CO_2 emissions generated for the heating purposes).

It is evident that measures taken in both scenarios, NU1 and NU2, significantly reduce CO_2 emissions in comparison to referent scenario NUR. By year 2050., it is expected that greenhouse gasses emissions will be more than 5 times lower in NU1 and NU2 compared to NUR levels. CO_2 emissions are high in NUR scenario during whole horizon due to relatively low emission prices (10 €/ton). Emission spike in NUR around 2040 (Figure 5) is because Krško NPP must be decommissioned in 2042 when its production is replaced with some greenhouse gasses production power plant.

5.2 Nuclear scenario

Why nuclear scenario?

- NPP is already a part of Croatian power system - Hrvatska Elektroprivreda - HEP (Croatian Power Utility) is co-owner of 696 MWe NPP Krško in Slovenia (NEK);
- The Energy Strategy Green Book indicates that energy system development scenarios with nuclear power plants provide the regional competitiveness in electricity generation, contribute to the security of energy supply, and that the nuclear power is the only one, along with the renewable energy sources, which contributes to reducing the CO_2 emissions in the atmosphere;
- National Energy Strategy is approved by the Croatian Parliament on October 16th, 2009;
- The Strategy decided in favour of launching the Croatian Nuclear Energy Program (CRONEP), consistent with the IAEA methodology (Milestones in the Development of a National Infrastructure for Nuclear Power) – entering into PHASE 1.

In the nuclear scenario one nuclear power plant with installed capacity of 1000 MW is forced to operation in year 2035.

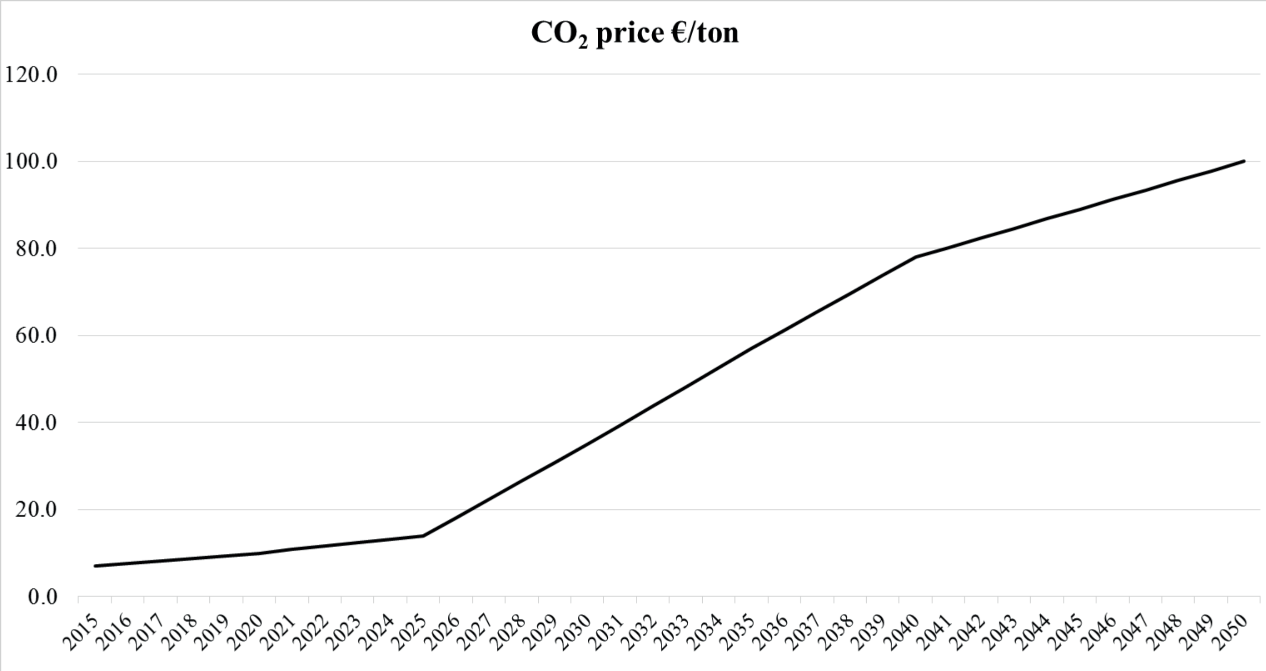

Figure 6 Increase of CO_2 price until 2050

One of the main barrier for new nuclear power plants is expected very slow growth of electricity demand (mainly because of very strong energy efficiency policy and high financial support to implementation of energy efficiency measures. Future electricity demand is assumed to be same as in NU2 scenario.

Further, expected high increase in CO_2 price until 2050 is highly in favour of nuclear technology (Figure 6).

Figure 7 shows total installed capacity in Nuclear scenario. It is obvious that introduction of new NPP resulted in decreased installed capacity of other base type power plants – thermal power plants. Installed capacity of RES and HPP are approximately the same as in NU2.

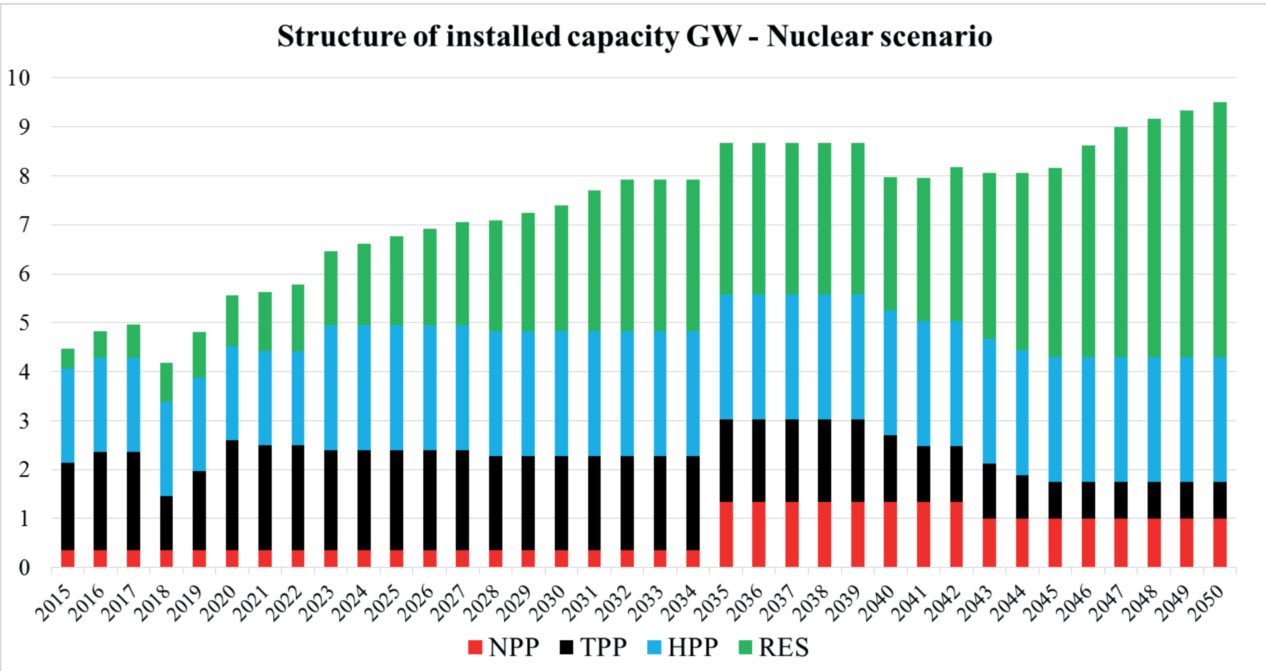

Figure 7 Structure of installed capacity for Nuclear scenario

Figure 8 shows CO_2 emissions in nuclear scenario compared to emissions in other scenarios.

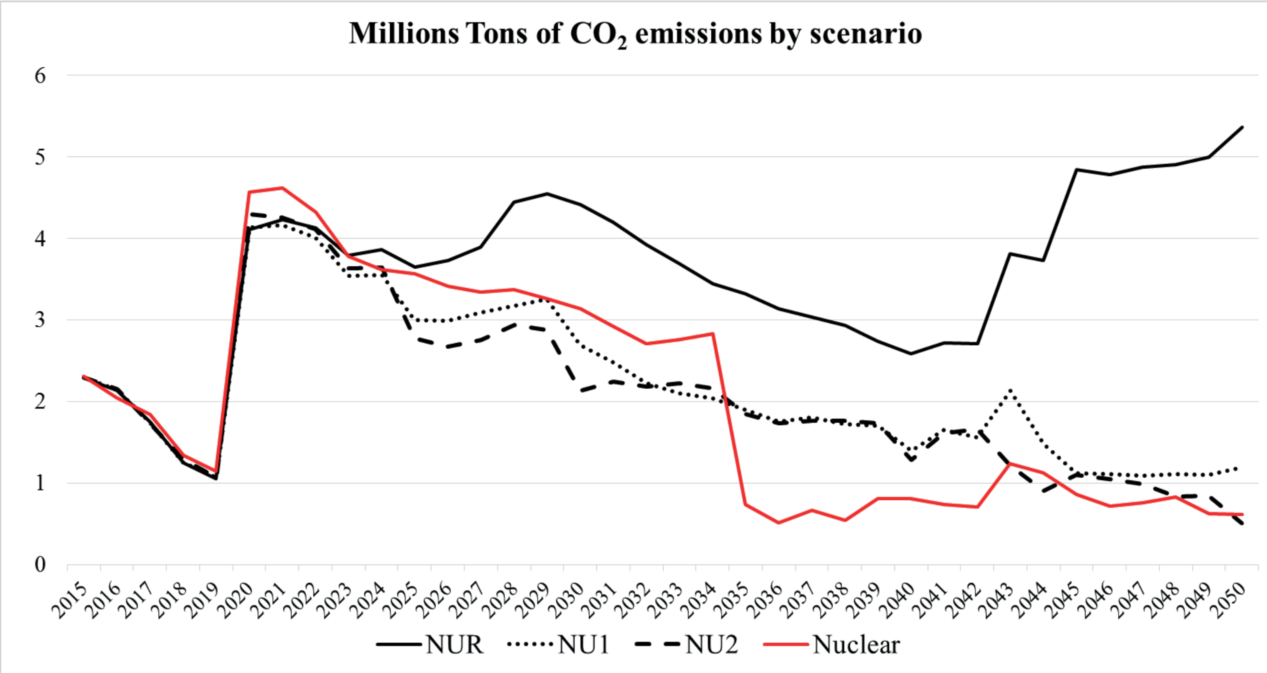

Figure 8 Greenhouse gasses emissions in Nuclear scenario

It is evident that Nuclear scenario provides approximately same CO_2 emissions decrease as scenarios NU1 and NU2 with significant drop in year 2035 when NPP is built.

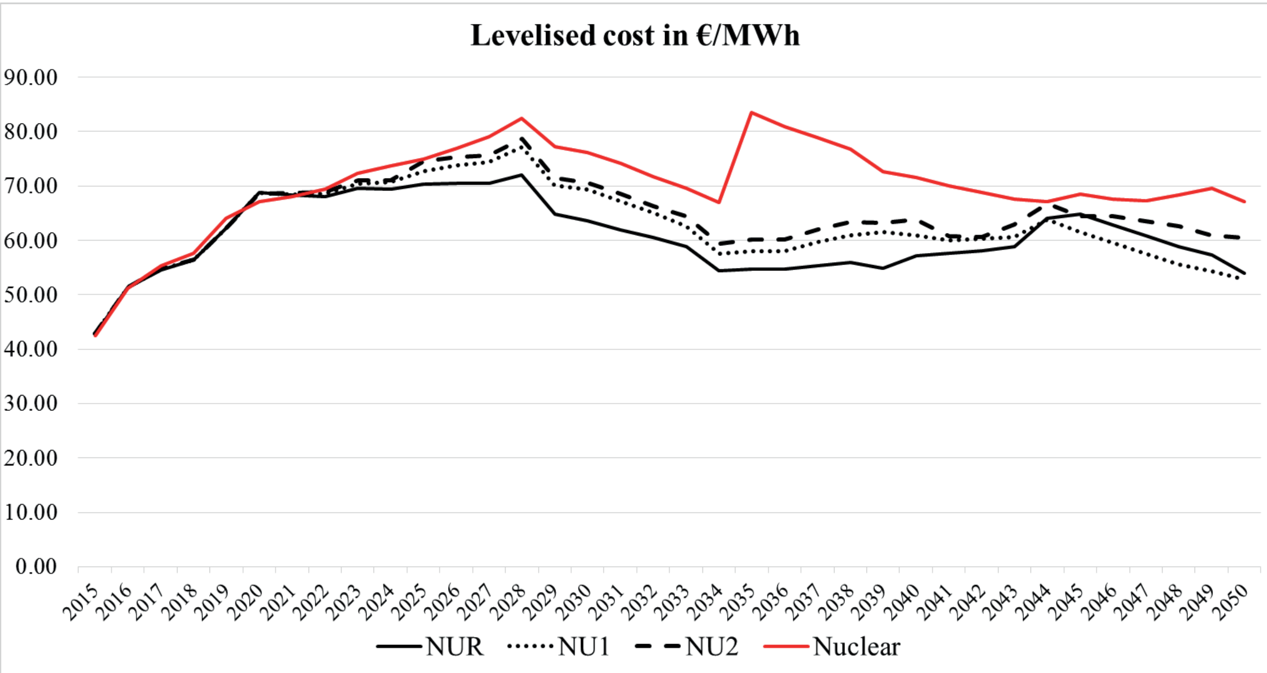

Figure 9 Levelized Energy Cost for each scenario

Now question can arise: Why Nuclear scenario isn't optimal one? Answer is given by Figure 9 where levelized cost between all scenarios are compared. Now it is evident that NUR scenario is the cheapest one and that at the same time Nuclear scenario is by far the most expensive one.

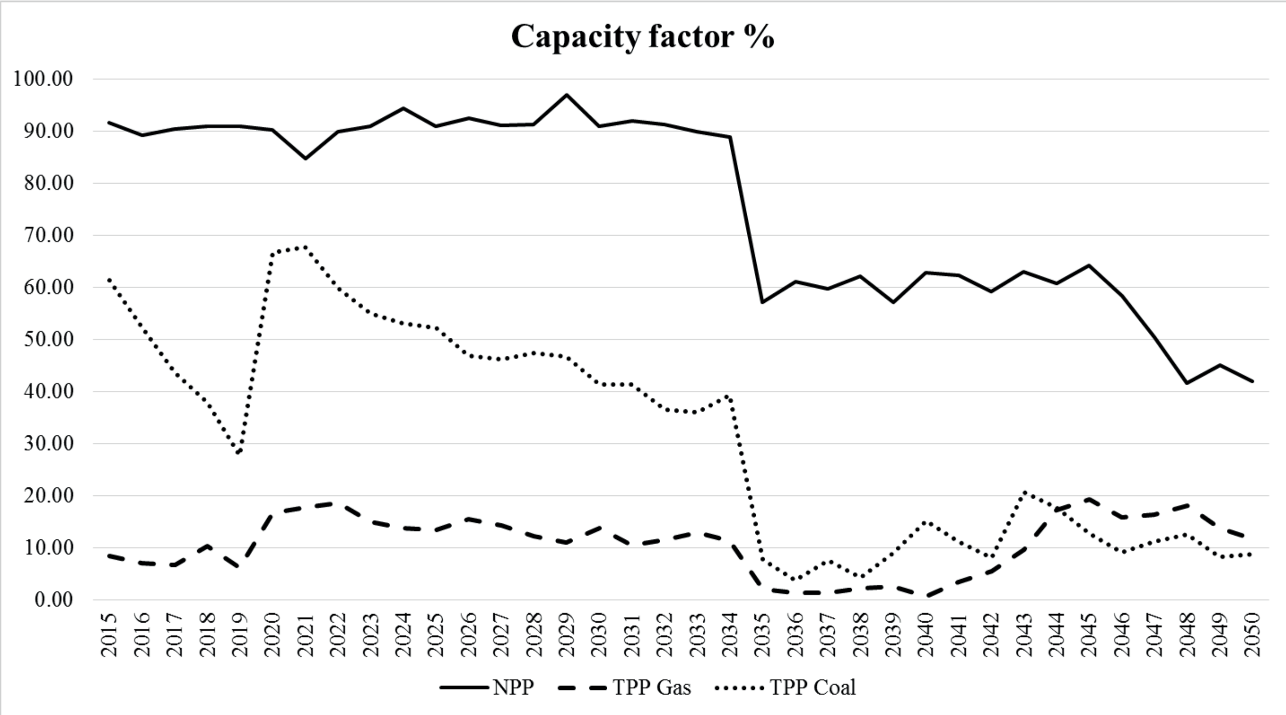

Figure 10 Capacity factors of power plant technologies

Another reason why Nuclear scenario is sub optimal is shown in Figure 10. By the year 2035. capacity factor of nuclear power plants was around stable level of 90%, as is usual for NPP. With addition of new 1000 MW of nuclear capacity, capacity factor decreased to approximately 60%. Meanwhile, it is obvious that coal power plants (usually treated as base units) become peak units after year 2035. with capacity factor between 10 and 20%. This situation is not economically nor technically sustainable from perspective of both NPPs and coal fired thermal power plants. Even gas fired power thermal power plants suffer greatly for first few years after NPP commission, but their capacity factor recovers to expected levels after that period.

6 CONCLUSION

Croatian LEDS is based on analysis of three scenarios: NUR – business as usual scenario; NU1 – huge energy efficiency measures implementations and consequently lowered electricity demand and NU2 – large scale electricity usage implementation, especially in transport sector and consequently increased electricity demand. This paper focuses on power system effects regarding LEDS. Long term planning horizon from 2015 to 2050 was analysed using model in PLEXOS. Based on assumptions and performed analysis it can be concluded that CO_2 in 2050 emission are expected to be significantly lower in NU1 and NU2 in comparison to NUR scenario.

In all three final scenarios: NUR – business as usual scenario; NU1 – huge energy efficiency measures implementations and consequently lowered electricity demand and NU2 – large scale electricity usage implementation, especially in transport sector, nuclear power plants were expansion candidates but have not become part of optimal solution. From that reason Nuclear scenario was created. In this case nuclear power plant entry was forced and results are compared with other scenarios.

Comparison shows that situation of these two cases shows that even nuclear case indicates some benefits, but also certain disadvantages. Analysis has shown that Nuclear scenario is viable and that it can provide about the same greenhouse gases decrease as scenarios NU1 and NU2. Further, main barrier for nuclear power plant is low growth of demand because of strong energy efficiency policy. Therefore, NPP would operate with low capacity factor of around 60% and would also negatively affect other thermal power plants which is not economically nor technically sustainable. Comparison based on levelized cost levels also indicates that Nuclear scenario is more expensive than scenarios analysed in Croatian LEDS.

7 BIBLIOGRAPHY

[1] OECC, The NAMA Guidebook (Manual for practitioners working mitigation actions), Japan, 2015.

[2] International climate agreements: http://www.consilium.europa.eu/hr/policies/climate-change/international-agreements-climate-action/, 22. April 2015.

[3] Croatian Ministry of Envirnomental Protection, Physical Planning and Construction: „Okvir za izradu strategije niskougljičnog razvoja Republike Hrvatske – Sažetak“, Croatia, 2013.

[4] Clapp, C. et al: „Low-Emission Development Strategies (LEDS): Technical, Institutional and Policy Lessons“, OECD, November, 2010.

[5] Low Carbon Growth Plans: Advancing Good Practice, Project catalyst, August 2009.

[6] Levin, K. et al: „Recommendations for Effective Low Emissions Development Strategies“, 02. April, 2012.

[7] Grgasović,V. et al: „Tranzicija prema niskougljičnom razvoju Republike Hrvatske“,Croatian Ministry of Envirnomental Protection, Physical Planning and Construction, Croatia, 2013

[8] United Nations Framework Convention on Climate Change: http://unfccc.int/meetings/cancun_nov_2010/meeting/6266.php, Cancun climate Change Conference, November, 2010.

[9] The NAMA Giudebook. 2nd. Edition, OECC, Japan, 2015.

[10] European Commission: „2030 climate and energy goals for a competitive, secure and low-carbon EU economy“, Bruxelles, 22. January 2014.

[11] European Commission: „A Roadmap for moving to a competitive low carbon economy in 2050.“, Bruxelles, 8. March 2011.

[12] Croatian Ministry of Envirnomental Protection, Physical Planning and Construction: „Strategija niskougljičnog razvoja Hrvatske“, http://www.mzoip.hr/hr/klima/strategije-planovi-i- programixxxx.html, 18. May 2015

[13] Croatian Ministry of Envirnomental Protection, Physical Planning and Construction: „ Stručne podloge za izradu strategije niskougljičnog razvoja Republike Hrvatske za razdoblje do 2030. s pogledom na 2050. godinu, Zelena knjiga“. Zagreb, Croatia, 2015.

[14] Jelavić,V: „Mogućnosti smanjenja emisije iz energetike i industrije“: http://mzoip.hr/doc/dr_vladimir_jelavic_mogucnosti_smanjenja_emisije_iz_energetike_i_industrije.pdf, 8. March 2016.

[15] Croatian Environment Agency. „Izvješće o provedbi politike i mjera za smanjenje emisija i povećanje odliva stakleničkih plinova“. Zagreb, Croatia, 2015.

[16] Croatian Parliament, Croatian Energy Strategy (NN 130/09), http://narodne-novine.nn.hr/clanci/sluzbeni/2009_10_130_3192.html, October, 2009.