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Factors for Building New Nuclear Capacities in the Light of Energy Markets Liberalization in the European Union

G.I. Deyanova

St. Kl. Ohridski University of Sofia, Faculty of Physics, 1164 Sofia, Bulgaria

Abstract.

This work is an attempt to answer the question how the liberalization of energy and gas markets in European Union reflect on the construction of new nuclear capacities in Bulgaria. Among the investigated factors are historical hysteresis of Bulgarian nuclear energetics, liberalization processes in European Union, its climate change policies and long-term strategies as well as the internal and regional electricity markets profiles and trends.

1 In the Light of EU Policies for Market Liberalization

1.1 The processes of market liberalization

Since the 1990s in Bulgaria have started two processes: the market economy transition and opening the national markets to those of the European Union (EU). These processes go parallel with the liberalization of electricity and natural gas markets in EU, see [1]. As a consequence, the internal market restructuring has been synchronized with the liberalization policies and requirements for the EU Accession. The market changes are running on two levels: the State one and the Union one. At a "Union's level" existed the challenge to establish common synchronized market. At a "State's level" the opening of the energy markets includes a series of reforms (such as privatization, restructuring, deregulation *etc.*) of the electric power industry with the transition from vertically integrated regulated monopoly companies to a competitive market (with unregulated prices) [2].

The instruments for establishment of the market liberalization are Energy packages - a series of directives, regulations and measures, which EU member-states transpose into their national legislation [3].

The First energy package, released in 1996, imposed the member states to change their national legislation in order to phase in a market integration. In 2003, the Second energy package established the requirements for "third party access to the network (pipeline)" or transit conditions for the "third parties suppliers". In 2009, the Third Energy Package was adopted. It regulates the ownership "unbundling" (separation of the electricity transmission and distribution activities) and to enhance cross-border infrastructure for the common energy market and harmonize technical rules. As a consequence, the electricity exchanges over the whole EU were created and trading regions are in the process of consolidation. The electricity export tariffs between the member-state countries were repealed. However, as a result of uneven development of member-state countries and their competitive interests the liberalization processes were going more slowly than expected. In 2016, the Fourth, so-called "Clean Energy" package was released [4].

1.2 Climate and energy frameworks

Significant part of the EU policies are related to Climate and Energy Frameworks (CEFs) [7], which are applied synchronously with the Energy Packages. The CEFs include series of directives, decisions and regulations, concerning the climate changes mitigation, such as: the utilization of renewable sources of energy (RES), reduction of greenhouse emissions (GNG), introduction of combined cycle heat and power generating capacities (as a part of the energy efficiency measures). The CEF 2020 framework originates from the ratification of United Nations Framework Conventions for Climate Change (UNFCCC) and its annex – Kyoto protocol (1997). CEF 2030 is consistent with the Paris Agreement (2015) - another UNFCCC.

Among the CEF 2020 cumulative targets were: 20% of greenhouse emissions reduction (GNG), 20% improvement of energy efficiency and 20% renewable energy sources (RES) for electricity generation until 2020 (here and below in the text the percentages are related to 1990 referent year) as well as the building of new 10% system interconnections. As a main sequence of Kyoto agreement ratification in EU, the "Emission Trading Directive" was released, which placed a limit on overall emissions from over 11000 high-emitting energy installations as of 2013 in industrial and energy sectors, which covered 45% of total EU emissions. Emissions Trading Scheme (ETS-EU) was implemented and market for allowances was found in 2005 [8]. In the last few years the effects of these measures became more significant since the prices of allowances are getting higher and will continue to increase.

"RES directives" [9] have stimulated the introduction of power plants, which utilizes renewable energy sources, such as solar, wind and geothermal energy (as well as the small hydro plant). The Directives required priority dispatching of the "RES" electricity to the power grids. For the period (2004–2016) in the EU were installed 245 370 MW of RES generating capacities. Beyond 2020 horizon are planned additional RES capacities. However, the future preferences and funding mechanisms for new RES builds are under revision.

The CEF 2030 targets are set as follow: 32% RES share of gross final consumption, 32.5% energy efficiency and additional 15% system interconnections. Revised ETS-EU (2018) have reinforcing the Market Stability Reserve mechanism, in order to support the further 40% reduction of the CO_2 emissions.

In 2015, the "Framework strategy for a resilient Energy Union with a forward-looking Climate change policies" (2015) was announced [5]. Among the objectives of the strategy are: more energy independence, the increasing of the energy production in the EU and diversifying supplier countries and routes. These objectives include further development of RES generating capacities, sustainable production of fossil fuels and safe nuclear energy. A long-term strategy 2050 for "carbon neutral economy" was also released. The key aspects of the strategy are the development and usage of Carbon Capture and Storage/Utilization (CCS/CCU) technologies as well as the utilization of the large volume batteries and electric vehicles. The nuclear waste reprocessing and storage are also a part of the strategic EU projects.

Recently, the member-state countries have proposed their "National Integrated Plan for Climate and Energy" (NECP) [6] in accordance with the Fourth package. New trading rules and climate changes policies will be transposed in the national legislation of the member-states until 2021.

1.3 Nuclear energy in the EU

In 2017 there were operating 128 nuclear reactor units with total generating capacity of 119 421 MW. They have produced 788.7 TWh/y or 25.5% of the electricity in the Union [10].

In World Energy Outlook (2014) [11] is reported that around a half of the fleet in the EU member states is between 20-30 years old. Another 37% of nuclear capacities are between 30 and 40 years old and only 10% are between 10-20 years old. Without further lifetime extensions and new builds, the share of nuclear in generation capacities will drop from 25.5% today to 5% in 2040.

According to World Nuclear Association around 30 000 MW of nuclear capacities will be decommissioned until 2040, major part of them in United Kingdom (UK) and Germany. UK have planned new nuclear builds, which are going to replace the decommissioned units. France also intends to stop 15 aged reactors until 2030 and to build 6 new units of Gen 3+ design. In contrary, Germany is planning to phase out the major part of its nuclear fleet until the middle of 2020s.

New nuclear power plants have been planned or proposed also in Bulgaria, Czech Republic, Finland, Hungary, Lithuania, Poland, Romania, Slovakia and Slovenia. In Bulgaria, Czech Republic, Hungary and Slovakia operate exclusively Russian WWER reactors. The countries depend on deliveries of fuel assemblies from a Russian supplier and were fostered to test a fuel by Westinghouse (the Sweden branch). The nuclear fuel diversification have been done in last two decades in Temelin NPP (Czh), Zaporzhia NPP and South Ukraine NPP (Uk), and recently in Kozloduy NPP (Bg).

In 2014, the Commission approved new European consortium and its funding from European Union "to establish the security of supply of nuclear fuel for Russian-designed reactors in EU". Another project, known as European Supply of Safe Nuclear Fuel (ESSANUF) focuses on licensing alternative nuclear fuel suppliers for Russian-designed pressurized water reactors operating in EU.

It should be noted that the EU member states are prohibited in principle by Article 107 of EU Treaty (TFEU) from granting state aid that distorts competition and trade in the common liberalized market. The rule has reflected on the financing of new nuclear builds. However, the European Commission has the exclusive competence to determine the compatibility of the state aid under EU Treaty.

1.4 Scenarios for energy development in the EU

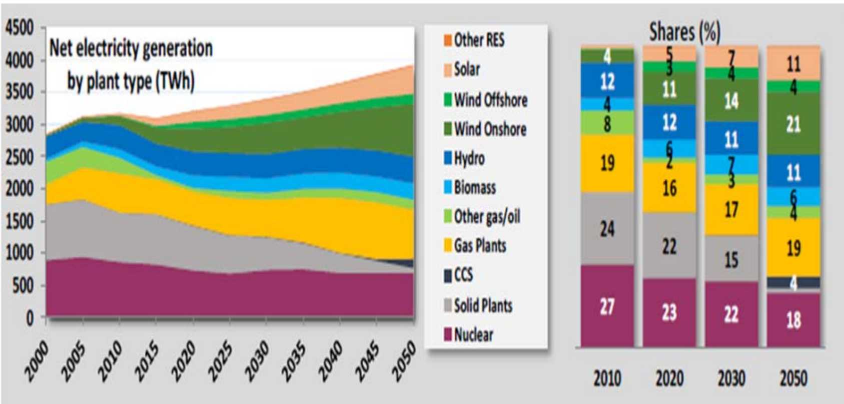

Figure 1. Power generation development by plant type and the dynamics of the generation capacities shares by decades (EU Reference Scenario. Energy, Transport and GNG emissions. Trends by 2050, version 2016)

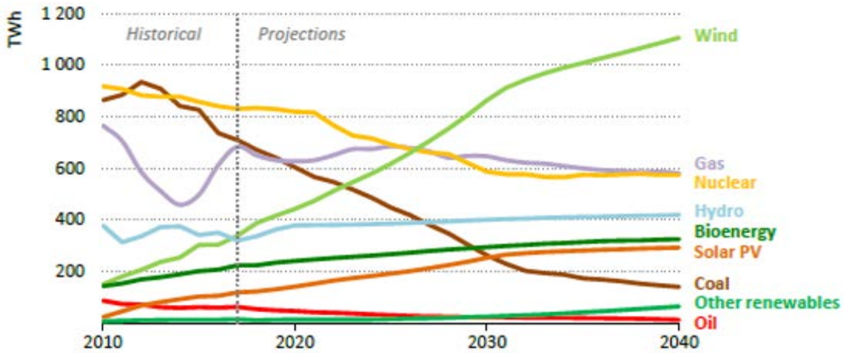

Figure 2. The dynamics of electricity generation by fuel type, proposed in the EU's New Policies Scenario (World Energy Outlook, 2018).

Figure 1 shows the EU Reference scenario (2016) of the European Commission, which is based on the current policies (CEF 2020) and projected market

	Year	2020	2025	2025	2030	2030	2030	2040	2040	2040
	Scenario	Expected Progress	Coal Before Gas	Gas Before Coal	Sustainable Transition	EUCO	Distributed Generation	Sustainable Transition	Sustainable Transition	Sustainable Transition
€/net GJ	Nuclear	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
	Lignite	1.1	1.1	1.1	1.1	2.3	1.1	1.1	1.1	1.1
	Hard coal	2.3	2.5	2.1	2.4	4.3	2.7	2.5	1.8	2.8
	Gas	6.1	7.4	7.0	5.0	6.9	8.8	5.5	8.4	9.8
	Light oil	15.5	18.7	15.5	15.3	20.5	21.8	17.1	15.3	24.4
	Heavy oil	12.7	15.3	12.7	12.5	14.6	17.9	14.0	12.6	20.0
	Oil shale	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
€/ton	CO_2 price	18.0	25.7	54.0	33.3	27.0	50.0	45.0	126.0	80.0
	Fuel Price Source	WEO 2016 New Policies	WEO2016 New Policies	WEO 2016 450	WEO 2016 New Policies Fuel Prices adjusted to create a "Low Oil Price Scenario"	Fuel Prices Provided by DG Energy	WEO 2016 New Policies with higher CO_2	WEO 2016 New Policies Fuel Prices adjusted to create a "Low Oil Price Scenario"	WEO 2016 450	WEO 2016 New Policies with higher CO_2

Figure 3. The projections of fuel prices and carbon emissions allowances prices until 2040, according to the existing scenarios of WEO (OCED), systematized in TYNDP (2018) of ENTSOg.

trends. The "New Policies Scenario" is the core "decarbonization" scenario of the Commission (2018), which is in line with CEF 2030. The key aspect of the scenario is the decreasing of all type base load capacities, see Figure 2. As a result, it is predicted that the nuclear generation will decrease gradually from 800 TWh nowadays to 600 TWh in 2040, while the wind, natural gas and hydro capacities tend to keep their growth. Furthermore, the "Sustainable development" scenario proposed that CO_2 reduction is possible by replacing of coal and lignite fuel with natural gas.

Figure 3 presents the prognoses for fuel prices and emission allowances obtained in four different model calculations, summarized in the "Ten Years Development Plan" (TYNDP 2018) of the European Network of Transmission System Operators for gas (ENTSOg). The prices for nuclear fuel are the lowest ones in all the scenarios.

An important factor for the future development of power generating capacities is the world's wide tendency to use natural gas as fuel type of thermal plants, since the gas-fired plants produce less GNG emissions than the coal ones. Also, EU have diversified its natural gas suppliers: Russian Federation, USA, Algeria and Norway.

2 The Bulgarian Nuclear Energetics in a Nutshell

Bulgaria is the first country in South-East Europe, which managed to build nuclear power plant "Kozloduy" NPP (KNPP). Six WWER reactors were commissioned in the period 1970 - 1991 with total installed capacity of 3760 MWe. In the late 1980s, the "Belene" project for second nuclear power plant has been started and 80 % of its first unit was built until 1991 [13], [14]. Meanwhile, the economy transition in Bulgaria was started [15], [16].

The "Belene" project was halted as well as the uranium mining was stopped. The liquidation of uranium mining was a crucial decision (see [17]). It should be noted that despite the uranium mining has terminated, the proven reserves of uranium ore are about 20 000 tones (see the Balance of resources in Bulgaria (2011)).

During the negotiations process for membership in the EU on Chapter 14 "Energy" Bulgaria committed itself to shut down units 1-4 of KNPP. These reactor units (WWER-440, type V-230) of total 1760 MW installed capacities have been decommissioned in the end of 2002 and 2006, respectively. Since 2003 have started public debates on the possibility to restart the "Belene" Project. In 2006, the National Electricity Company (NEK EAD) has chosen Atomstroyexport (ASE), to build two WWER-1000, type V466, based on the evolutionary AES-92 design. Currently, both reactors are supplied to the nuclear island and will be part of future development of the project.

In 2009, GERB party came in power and the new Government refused the negotiated state share of 51% in the project and rejected the proposed investors. It was also announced that the construction will not continue unless it is funded by an appropriate investor to reduce Bulgarias dependence on Russian Federation. Then, in 2012, the "Belene" project was terminated and the procedure for "New builds at Kozloduy NPP" was started. The construction of the AP-1000 reactor was regarded until 2014. However, the negotiations were stopped.

Since 2018, the restart of the " Belene" Project is again under consideration. In May 2019, Bulgarian Government launched the procedure for a choice of strategic investor. Recently, the short-listed candidates were chosen: Rosatom (Rus), China National Nuclear Corporation (CNNC) and Korea Hydro and Atom Power Co (KHNP) [21].

Both projects "Belene" and "New Builds at KNPP" are at different stages in the licensing process."Belene" project is pending at the Technical Project Approval stage, as the major part of the analysis has been done [22]. "New Builds at KNPP" is at its pre-project phase, waiting for the site evaluation and Ordinance of Site Approval by Bulgarian Nuclear Regulatory Agency (BNRA).

3 Internal Market

3.1 Electricity production structure

Bulgaria has developed a well diversified structure of electricity production. The major indicators of the electricity production structure, which have taken from [23] are shown in Figure 4. The total installed capacity are 13 563 MW, while in the"Statistical factsheet 2017" of European Network of Transmission System Operators for electricity (ENTSOe) are given 12 073 MW generating capacities. From the data is seen the potential for additional electricity production of 8-10 TWh/y . The data, published by Transmission System operator

(TSO) the absolute maximum load of the power system for 2018 was about 7131 MW.

Power generation type	Installed capacity, GW	Share, %	Annual power availiability factor, %	Annual electricity production, TWh	Share, %
Nuclear	2.080	15.33	87.1	15.865	33.47
Thermal - condensing	5.262	38.79	40.6	18.694	39.44
Thermal - heating	0.733	5.4	44.2	2.84	5.99
Thermal-industry	0.511	3.77	47.4	2.121	4.48
Hydro-large	2.218	16.35	16.7	4.369	9.22
Hydro-storage	0.765	5.64			
Hydro-run of river	0.207	1.53	43.6	0.791	1.67
Wind	0.701	5.17	21.7	1.33	2.81
Solar	1.04	7.67	13.8	1.254	2.65
Biomass	0.047	0.35	32.9	0.135	0.29
Total	13.565	100	39.9	47.404	100

Figure 4. The structure of electricity production in Bulgaria (2014), TSO data

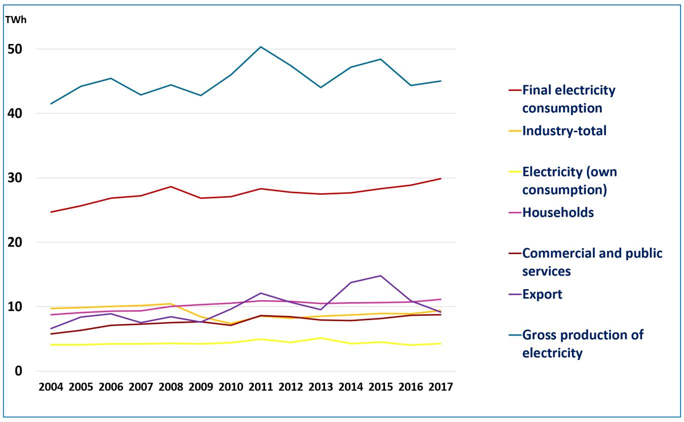

Figure 5. The dynamics of production and deliveries of electricity in Bulgaria (2004-2017)

In Figure 5 are shown data from National Statistical Institute -„General Energy balance of Bulgaria 2017 (Energy - 4.1) & Electricity 2018 (Energy-1.4). For the period (2004-2017) the gross electricity production varies between 40 and 50 TWh/y in the years of large export volumes. The net electricity consumption slightly increased from 25 to 30 TWh/y. The transmission losses are about 4-5TWh/y. The internal market is divided into three almost equal segments: the industry (32%), households (36%) and commercial and public services (31%). The electricity export is characterized by high volatility. Its lowest value is equal to 5 TWh/y for 2004, while the highest exported volume is almost 15 TWh/y for 2015.

The largest base load capacities, which generate almost 80% of the annual electricity production are KNPP and thermal condensing plants. The nuclear power plant is state-owned, part of Bulgarian Energy Holding EAD (BEH). Since 2007, in "Kozloduy" NPP only the 5^{th} and 6^{th} reactor units (WWER-1000, type V-320) are operational. Recently, both reactor units have obtained 10-years operating license until 2027 and 2029 respectively.According to the Proposal for integrated "National Energy and Climate Plan for the period 2020-2030" is expected that both reactors will operate until the end of 2040s.

The thermal plants, which use local lignite coals are: the state-owned "Maritza-Iztok-2" (1620 MW), "Contour Global" (908 MW) and "AES Galabovo"(670 MW). For the last two decades the plants were upgraded in order to met the ecological requirements for the carbon emissions reduction. However, due to excess of generating capacities and increasing carbon allowances price the plants are used in 30-40% of their annual availability, as it is shown on Figure 4. "Contour Global" and "AES Galabovo" are taken on the concession until 2024 and 2026 respectively. Both plants have long term power purchase agreements (PPAs) with the National Electricity Company (NEK EAD). According to PPAs are defined preferential prices of electricity. However, the future of lignite-fired plants is an open question. It is expected that they will operate until 2030 due to economic and ecological reasons. Most probably some of these plants will change its fuel type from lignite coals to natural gas.

It should be noted that the lignite coals are local resources with a great importance for the energy independence of the country. According to Euracoal data the proven lignite reserves in Bulgaria are about 1.6 Gt. The quantities are sufficient to secure power generation for the next 50-60 years.

The other larger fossil fuel plants are Varna TPP (1260 MW), Bobovdol (570 MW), followed by the combined heat and power gas plants (CHP generation). According to the TSO's "10 year's plan (2018-2027)", in the next decade Varna TPP is going to switch the fuel type from hard coal to natural gas. Also, new 814 MWe of natural gas-fired generating capacities are certified [6] as a high efficient combined generation of heat and power (CHP) in line with Energy Efficiency policies [24].

The natural gas consumption is about 3,3 bcm, of which 30% is used by Energy sector. Bulgaria is a natural gas importer and depends on the sole supplier - the Russian Federation. Currently, the country is involved in the project "South gas corridor" for a natural gas supply from Caspian region.

Since 2003 were installed additional 1705 MW solar and wind generating capacities in accordance with the existing RES policies and their corresponding funding schemes [9].

Recently, Bulgaria have started a waste import and burning in Bobov Dol TPP as well as in some of the thermal heating plants [25].

3.2 Market model

Bulgarian electricity market consists of regulated and liberalized parts. The traded volumes and market participants are shown in Figure 6. According to Bulgarian legislation the whole trade is realized on the electricity exchange. The

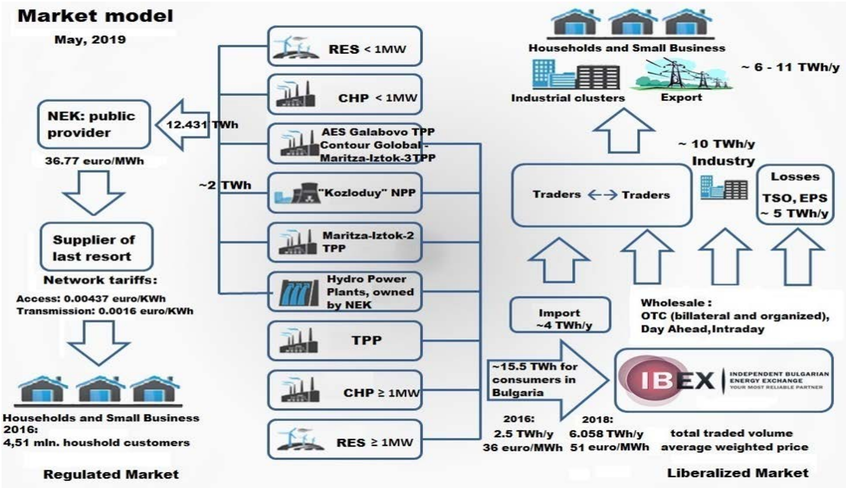

Figure 6. The established electricity market structure and traded volumes. Original picture is taken by Independent Bulgarian Electricity Exchange (IBEX) and modified for the purposes of this study

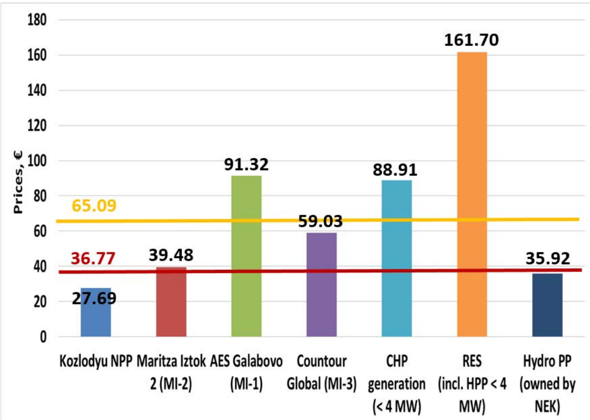

Figure 7. The electricity prices of different generating capacities, approved by EWRC. At these prices part of the power plants sell to NEK EAD the needed volumes of electricity for the regulated part of the market. With yellow line is shown the weighted mean "buy" price of the electricity, at which NEK (public provider) buys from the producers (PPs). In red is the price at which NEK sells to the suppliers.

liberalized market consists of multiple wholesale segments: "intraday","day-ahead", "OTC" *etc.*

The plants, which participate in the regulated market have to sell the needed volumes of electricity to NEK EAD at prices, calculated by the Energy and

Water Regulatory Commission (EWRC), see Figure 7. The regulated prices are formed on the basis of recognized expenditures as well as the required internal rate of return for each enterprise (also approved by EWRC).

KNPP is the major producer and participant in both - the regulated and liberalized part of the electricity market. The plant holds a significant market strength

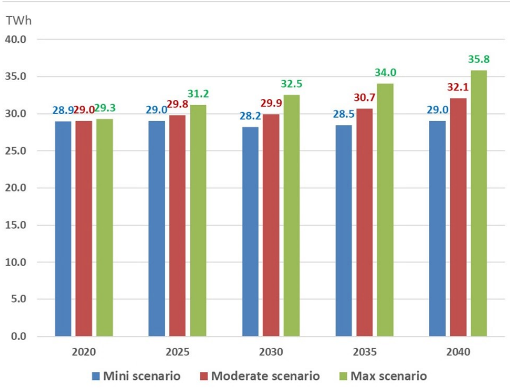

Figure 8. The forecast of BAS and TSO for the internal market consumption until 2040

and its "sell" price forms the "spot price" on the liberalized Bulgarian electricity exchange. It should be noted that the prices on the electricity exchange tend to be synchronized with the forward contract's prices at the neighbor's exchanges.

The long-term forecast of Bulgarian Academy of Science (BAS) is shown in Figure 8 [26]. According to the analysis the net electricity consumption will vary between 28.3 - 29.2 TWh in 2020 and will increase slowly up to 31.3 - 33.2 TWh in 2040.

3.3 South-East European market

South-East Europe region (SEE) is situated between Russian Federation and Central Europe and close to the Caspian Region and the Middle East. This strategic location gives opportunities for diversification of the type and source of energy suppliers. SEE region includes three groups of countries: EU member-states (Bulgaria, Croatia, Greece, Romania and Slovenia), West-Balkans Six countries (WB6: Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia and Serbia) and Turkey. The countries are characterized with uneven economic development, lack of energy resources as well as the different energy legislation. Bulgaria is a major electricity exporter in SEE region for the last three decades.

For the period 2000-2017 the installed capacities have increased from 94.6 to 161.04 GW, mainly in Turkey and Greece. The fossil fuel plants dominate: gas – 34.71 GW, lignite coals – 31.67 GW, hard coals – 11.42 GW. They are followed by hydro plants – 51.39 GW, wind capacities – 13.17 GW, solar –

8.42 GW. There are only 3.99 GW of nuclear capacities, which have generated around 36 TWh/y of electricity. In 2016 the total electricity production in the region is 538.9 TWh, while the total consumption is about 543.5 TWh (International Energy Agency (2019)). The highest electricity demand is observed in Turkey [27]. It has about 6–7% growth rate per year. However, for the rest part of the region [28] is expected the average consumption growth rate of 1.47% for the period 2014–2030 and the electricity production is going to increase from 230 TWh (in 2020) to 270 TWh (in 2050), depending on the scenarios, see [29]. In the “TYNDP ENTSOe,g Scenario Report 2018” are proposed 3 possible scenarios for the annual electricity demand in SEE region until 2040 (only the data for Kosovo are missing). Depending on the scenario, the demand varies between 701.56, 707.87 or 833.03 TWh/y in 2040.

Currently, three nuclear power plants are operational in SEE: Krushko NPP (PWR-Westinghouse, 696 MW, Slovenia), Cherna Voda (CANDU 6 PHWR, 2×650 MW, Romania) and KNPP.

There are several competitive projects in SEE region. New nuclear generation capacity of 1100 to 1600 MW at Krushko NPP is under consideration. Romania has planned to complete 3&4 reactor units at Cherna Voda NPP (2×720 CANDU 6 reactors). The turkish “Akkuyu NPP” project is underway. This is the biggest nuclear project in the region – 4×1200 MW reactor units of WWER-1200 type. It is expected that the plant will be commissioned until the middle of the 2020s. Turkey has been proposed two other projects: Sinop NPP and Igneada NPP or in total 10–12 GW nuclear capacities.

The internal market transformation as well as the liberalization processes are associated with geopolitical and regulation risks. As a result the direction of the development of the region after year 2030 remains uncertain.

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