energies

MDPI

Review

Energy Resources, Load Coverage of the Electricity System and Environmental Consequences of the Energy Sources Operation in the Slovak Republic—An Overview

Martin Lieskovský [1], Marek Trenčiansky [1], Andrea Majlingová [2,*] and Július Jankovský [3]

[1] Faculty of Forestry, Technical University in Zvolen, T. G. Masaryka 24, 96001 Zvolen, Slovakia; martin.lieskovsky@tuzvo.sk (M.L.); marek.trenciansky@tuzvo.sk (M.T.)

[2] Faculty of Wood Science and Technology, Technical University in Zvolen, T. G. Masaryka 24, 96001 Zvolen, Slovakia

[3] Apertis, s.r.o. (LLC), V. P. Tótha 17, 960 01 Zvolen, Slovakia; julius.jankovsky@apertis.eu

* Correspondence: majlingova@tuzvo.sk; Tel.: +421-45-520-6065

Received: 1 March 2019; Accepted: 30 April 2019; Published: 6 May 2019

Abstract: According to the current circumstances that are related to the effectiveness of the tightened European Union (EU) environmental legislation, which sets minimum requirements for the heat and power sources of energy that are part of the Slovak Electricity System (SES) source mix, an article was prepared to summarize the information regarding energy and environmental legislation, which is in force as in the EU as in Slovakia. This information was completed with a description on the current situation and requirements for the safety and reliability of the "new" mix of sources and technologies of electricity production within the SES in terms of energy and economic efficiency and environmental consequences.

Keywords: energy resource; energy security; energy sources; Slovakia

1. Introduction

The start of electricity usage reaches the end of the 19th century. First, electricity has begun to be used for lighting, and later as a source of power for mechanical drives. Further, its use has gradually spread to other sectors, too. Today, electricity has penetrated all areas of the economy and the social spheres. The production and consumption of electricity places demands on the reliability of the elements of the power system and the creation of capacity reserves at the same time. Energy needs to have enough primary energy resources and the availability of flexible technologies. Whereas, in the past, the regulatory reserves have been dimensioned and activated to compensate for the deviations in the consumption or for bridging the failures of production capacities. Resource reserves must now also be activated in balancing the variations in the change in the volume of electricity production to sources with unpredictable direct production in the direct conversion of solar and wind energy. Such production, due to the preferential connection with the power system, requires back-up with predictive sources in the full potential of its installed power.

The availability of electricity is taken for granted and the break-up of the system is not allowed in the European Union (EU). Electricity has become available to subscribers, of course, so almost nobody is interested in the technical nature of its production and distribution. The consequence of this interpretation is the misconception that it is necessary to pay "exorbitant" high bills for an ordinary socket and switch. The electricity bill in the family budget, even in the corporate budget, accounts for a fraction of the cost of mobile operator services, the Internet, licenses for software, hardware, car leasing, and other substantially less important items that would be "non-functional scrap" without electricity.

Overall, it is forgotten that electricity in the socket and switch is continuously available thanks to the reliable operation of the power grid, which is the most important, the most extensive, and most expensive infrastructure in each EU country, while the transmission system connections are subjected to the Union for the Co-ordination of Transmission of Electricity (UCTE) in the EU and North Africa, the rules of which must be strictly observed by national operators both dispatching and commercial dealers. The life of a civilized society without electricity is impossible. Of course, the consequences of a power failure are sometimes perceived during natural disasters quite differently to the ones that are directly affected by the failure. Power-supply engineers warn that reliable operation is not a matter of course. Since the beginning of the millennium, nine large disruptions of the power systems ("blackouts") had occurred in the world, and even the smallest had impact on more inhabitants, as it lives in the whole Slovakia. Overall, more than a billion inhabitants of the planet have been affected by the disruption of the power system since the beginning of this century. Five of the all disruptions have taken place in the EU in the last 18 years.

The largest electricity failure in the EU in this century occurred at the end of September 2003. It initiates a series of network failures in northern Italy, which were caused by the fall of a tree on the electric power transmission line in Switzerland during a storm. Within four seconds, the failure spread to Italy, Slovenia, and Croatia. The disruption of the electricity power system has affected 55 million people; fortunately it only lasted for a short time, one day. Life in Italy, except Sardinia, has stopped. Rail and air travel completely collapsed, cars were moving sharply across the streets while the traffic lights were not operating, and thousands of them stood without fuel at the edge of the road due to the non-operating filling stations. The mass media and the internet ceased to exist. The public did not know what had happened. Banks, ATMs, shops, restaurants, and offices were totally collapsing. The lives of people in hospitals saved electricity from backup sources. Fortunately, the disintegration of the electric system occurred at the end of summer at 2.00 pm at night. If the failure would occur in the winter, during a cold weather, the consequences would be catastrophic when the outside temperature can fall below the freezing point in the temperate climatic zone.

2. European and Slovak Legislation Governing the Energy Sector

In January 2007, the European Commission (EC) published the Communication "An Energy Policy for Europe" [1]. This Communication outlined the developments in the energy sector by 2010, as well as the 2020 targets. This Communication, while respecting the sovereignty and energy mix of the individual EU countries, integrated energy policy with climate change policy and clearly formulated the three basic pillars of EU energy policy that were: energy security; competitiveness; and, sustainability.

Subsequently, in March 2007, the European Council adopted the Energy Efficiency Action Plan 2007–2010 [2], which is an important element of climate change commitments: reducing greenhouse gas emissions by 20% by 2020 as compared to 1990; increasing the share of renewable energy to 20% by 2020; achieve a 10% share of renewable energy in transport by 2020; and, achieve 20% energy savings as compared to projections by 2020.

The Energy Efficiency Action Plan has become the basic document for the development of the legislative framework in the upcoming period. It was followed by the other strategic and legislative documents that covered the different areas of the Action Plan: Strategic Energy Technology Plan (2007) [3], Third Liberalization Package (2007) [4], Climate-Energy Package (2008) [5] and Energy Efficiency Plan (2006–2011) [6]. The Second Strategic Energy Review—An EU Energy Security and Solidarity Action Plan (2008) [7] focused on the least developed energy policy pillar—energy security, just in gas crisis time in January 2009. The European Economic Recovery Plan (2008) [8] included a proposal to support the development of energy infrastructure, with the support of specific projects in the area of gas infrastructure development in the Slovak Republic.

An important milestone in the development of energy policy was the adoption of the Treaty of Lisbon [9] in 2009. The Treaty on the functioning of the EU defined a new legal basis for EU energy policy measures and its Article. 194 defined the basic objectives and principles of EU energy policy. The main objectives of the European energy policy are to ensure the functioning of the energy market; ensuring security of energy supply in the EU; enhancing energy efficiency and energy savings and developing new technologies for electricity production and promoting the production of electricity from renewable energy sources, as well as supporting the interconnection of energy systems and networks. The sovereignty of the Member States in the composition of the energy mix as well as in ensuring their energy security are enshrined in the basic principles of European energy policy.

The 2020 energy principles and targets were based on the Europe 2020 Strategy [10] and they are further elaborated in the Energy 2020 strategy: A Strategy for a Competitive, Sustainable, and Secure Energy [11]. The key energy priorities included: to make effective use of energy resources in the EU, to complete a pan-European integrated energy market by 2015, to increase the rights of consumers and to achieve an increase in energy security, to maintain the EU's leading role in energy technology, and to strengthen the external dimension of the EU energy market.

The energy efficiency demands have been gradually becoming a centre of interest, as evidenced by the revision of the EU's energy efficiency policy in the form of the adoption of the Energy Efficiency Directive 2012/27/EU [12]. This Directive established a common framework for measures to promote energy efficiency in the EU in order to secure the EU's main energy efficiency target of a 20% reduction in energy consumption by 2020 under the Europe 2020 Strategy [10].

In the field of energy infrastructure, in November 2010, the Communication "Energy Infrastructure Priorities for 2020 and Beyond" [13] identified the key roles for the needs of infrastructure development in the oil, gas, and electricity sectors by 2020 and the basic long-term and short-term (by 2020) priorities in the field of European energy infrastructure that are needed to complete the interconnection of the internal market. These include the North-South Gas and Electricity Interconnections, the oil connections in Central Europe, and the Southern Gas Corridor, regarding the development of energy infrastructure in Central Eastern and South-Eastern Europe, with relevance to the Slovak Republic. These priority corridors of the European Energy Infrastructure were further elaborated in the "Energy Infrastructure Package" that was proposed in 2011 and adopted in 2013 by the European Parliament and Council (EP and C) no. 347/2013 on the Guidelines for Trans-European Energy Infrastructure (TEN-E) [14] and Regulation 1316/2013 [15] establishing the Connecting Europe Facility (CEF). The decision-making body adopted in July 2013 a European list of projects of common interest in the electricity, gas, and oil sectors.

The EC in the Roadmap to a Competitive Low Carbon Economy in 2050 (03/2011) [16] analysed the implications of a commitment to reduce greenhouse gas emissions by 80–95% by 1990 and indicated the extent of emission reductions in the key sectors for the years 2030 and 2050. Electricity will play a central role in the low-carbon economy. The Commission's analysis shows that, by 2050, it can contribute to almost complete elimination of CO_2 emissions and offers prospective partial replacement of fossil fuels in transport and heating. The EC calls on the other European institutions and the Member States to take this plan into account in the further development of European, national, and regional policies that are aimed at building a low carbon economy by 2050.

In the Energy Roadmap 2050 (12/2011) [16], in several scenarios, the EC is exploring ways of decarbonizing the energy system and ways of securing energy supply and competitiveness by 2050. The plan seeks to develop a long-term, technologically neutral European framework for energy policies, thereby achieving the necessary certainty and stability in investing in the energy system. The Roadmap does not replace the national, regional, and local efforts to modernize energy supply, it but seeks to develop a long-term, technologically neutral, European framework, in which these policies will be more effective.

The EC published the Communication "Renewable Energy: A Major Player in the European Energy Market" (06/2012) [17], which is aimed at ensuring the growth of sustainability beyond

2020. The Communication set out key priorities, such as increased coordination of support systems, strengthening the role of the Southern Mediterranean, the use of cooperative mechanisms, and progress in the field of energy technologies.

In March 2013, the EC issued the Green Paper: A 2030 Framework for Climate Change Policy and Energy Policies [18], and it launched a debate on the Energy and Climate Framework Policy Post-2020 at the same time. On 22 January 2014, the EC published the EC's Communication on an EU policy: 2030 Climate and Energy Framework [19], following the Green Paper from March 2013. In March 2014, EC accepted the commitment to adopt the 2030 Climate and Energy Framework policy by October 2014. The Slovak Republic still does not have a definitive position in this respect, although the coordination of positions takes place between the ministries concerned (Ministry of Finance SR, Ministry of Environment SR, and Ministry of Economy SR). During the negotiations on the future framework, the Ministry of Economy emphasized the need to preserve sovereignty in the field of energy mix, the non-binding character of the 2020 renewable energy sources (RES) and energy efficiency targets, the need to respect the national specifics, and the need to develop RES in a cost-effective way. It is a binding target for reducing greenhouse gas emissions by 2030, which was subjected to certain conditions.

The EC identified in the Communication "Progress towards Completing the Internal Energy Market" [20] (11/2012), the obstacles, and measures that are needed to meet the objective of completing the EU internal energy market (IEM) by 2014 and removing the isolation of Member States by the year 2015. The Communication also contained recommendations for the Slovak Republic concerning the elimination of the regulation of energy supply prices, the solution of round-the-clock issues, and the development of North-South connections in the gas and electricity sectors.

At the end of 2018, the EC concluded negotiations on all aspects of the new energy legislative framework "Clean Energy for All Europeans package" [21]. This is a significant step towards the creation of the Energy Union and delivering on the EU's Paris Agreement commitments. The package includes eight different legislative acts: "Energy Performance in Buildings Directive"; "Renewable Energy Directive"; "Energy Efficiency Directive"; "Governance Regulation"; "Electricity Directive"; "Electricity Regulation"; "Risk-Preparedness Regulation"; and, "Regulation for the Agency for the Cooperation of Energy Regulators (ACER)". This new policy framework brings regulatory certainty, through the introduction of the first national energy and climate plans. It will encourage essential investments to take place in the energy sector. It empowers European consumers to become fully active players in the energy transition and it fixes two new targets for the EU for 2030: a binding renewable energy target of at least 32% and an energy efficiency target of at least 32.5%—with a possible upward revision in 2023. For the electricity market, it confirms the 2030 interconnection target of 15%, following on from the 10% target for 2020. When these policies are fully implemented, they will lead to steeper emission reductions for the whole EU than anticipated—some 45% by 2030 relative to 1990 (as compared to the existing target of a 40% reduction).

That legislative framework also played an important part in the EC's preparations for its long-term strategy for a climate neutral Europe by 2050 ("Climate Neutral Economy by 2050" [22]), which was published in November 2018. The strategy shows how Europe can lead the way to climate neutrality by investing into realistic technological solutions, empowering citizens, and aligning action in key areas, such as industrial policy, finance, or research—while ensuring social fairness for a just transition. It is in line with the Paris Agreement objective to keep the global temperature increase to well below 2 °C and to pursue efforts to keep it to 1.5 °C. The purpose of this long-term strategy is not to set targets, but to create a vision and sense of direction, plan for it, and inspire as well as enable stakeholders, researchers, entrepreneurs, and citizens alike to develop new and innovative industries, businesses, and associated jobs. It investigates the portfolio of options that are available for Member States, business, and citizens, and how these can contribute to the modernisation of our economy and improve the quality of life of Europeans. The long-term strategy also seeks to ensure that this transition is socially fair and it enhances the competitiveness of EU economy and industry on global markets, securing high quality jobs and sustainable growth in Europe, while also helping to address other environmental challenges, such as air quality or biodiversity loss. The road to a climate neutral economy would require joint action in seven strategic areas: energy efficiency; deployment of renewables; clean, safe and connected mobility; competitive industry and circular economy, infrastructure, and interconnections; bio-economy and natural carbon sinks; and, carbon capture and storage to address remaining emissions.

The energy legislative framework in the Slovak Republic is based on several documents that can be divided into three groups in general. The first group consists of primary legislation. There are the acts that were adopted by the National Council of the Slovak Republic. The second group of documents (secondary legislation) consists of generally binding legal regulations (decrees) of the Ministry of Economy of the Slovak Republic, the Regulatory Office for Network Industries (URSO), or the Slovak Government. The last group of legislative documents is tertiary legislation, which includes the operating rules, technical conditions for access, and connection to the system and networks, dispatching orders and documents that are drawn up and published in accordance with the provisions of Act no. 251/2012 Coll. on Energy [23] and Act no. 250/2012 Coll. on Regulation in Network Industries [24].

The primary electricity legislation is represented by Act no. 251/2012 Coll. on Energy, Act no. 250/2012 Coll. on Regulation in Network Industries, and Act no. 476/2008 Coll. on Energy Efficiency.

The EU's third energy package was implemented in 2009 by issuing Act no. 250/2012 Coll. [25]. The Act provides greater independence and power for the regulatory authority to determine regulated prices as well as control activities in regulated entities. By implementing the EU's third liberalization package in the Slovak legislation, space for reducing the regulatory burden in the energy sector has been opened for the future. The Act in question regulates: the subject, scope, conditions, and method of regulation in network industries; the conditions for carrying out regulated activities and the rights and obligations of regulated entities; the rules for the functioning of the electricity and gas markets; establishment, status, and competence of the Regulatory Office for Network Industries (URSO) and the Regulatory Council; proceedings under this Act; and, administrative offenses for breach of obligations that are specified by this Act. The subject of regulation under this Act is the determination or approval of the method, procedures, and conditions for: connection and access to the transmission system, distribution system, transmission network and distribution network; electricity transmission and distribution in a defined area; gas transmission and gas distribution in a defined area; providing support services in the electricity and gas industries; providing transmission system operator and distribution system operator services, accessing and connecting new electricity and gas producers to the system or network, producing and distributing heat.

Act no. 251/2012 Coll. on Energy [23] is the basic legislative document of the Slovak energy sector. The Act regulates: the conditions for the functioning of the open energy market; the rights and obligations of individual electricity market participants and gas market participants; network and systems management issues, i.e., power dispatching and gas dispatching centres; issues of separation of regulated activities, i.e., unbundling; special forms of electricity production; network access conditions; rules for market behaviour of energy market participants; and, performance of state administration and supervision in the energy sector. From 1 July 2007, all customers, including households, have the option of choosing their energy supplier (electricity and gas) based on the open market.

Act no. 476/2008 Coll. on Energy Efficiency [25] sets out: the concept and action plans for energy use; evaluation of transmission, transport and distribution; energy consumption obligations in buildings; an obligation on the manufacturer to operate, reconstruct and build energy-efficient energy conversion equipment; for a manufacturer to carry out an energy audit to demonstrate the possibility of supplying usable heat; and, consumers of energy in industry and in agriculture the obligation to evaluate energy intensity of production by energy audits, conditions of operation of the monitoring system.

Another important act from the energy point of view is the Act no. 309/2009 Coll. on the Promotion of Renewable Energy Sources and High Efficiency Cogeneration and on Amendments to Certain

Acts [26]. This Act specifies: the method of support and conditions for the promotion of electricity production from renewable energy sources, electricity by high-efficiency cogeneration, biomethane; rights and obligations of producers of electricity from renewable energy sources, electricity from cogeneration, electricity from high-efficiency cogeneration, biomethane; the rights and obligations of other electricity and gas market participants; and, the rights and obligations of the legal person or the natural person who places on the market fuels and other energy products used for transport purposes.

The secondary legislation is primarily represented by the Decree of the Office for Regulation of Network Industries no. 24/2013 Coll., laying down the rules for the functioning of the domestic market in electricity and the rules for the functioning of the domestic gas market [27] (including the Decree of the Office for Regulation of Network Industries no. 423/2013 Coll.).

This Decree lays down detailed rules for the functioning of the electricity and gas markets when the electricity market participant is connected to the system, the electricity market participant's access to the system, electricity transmission, cross-border electricity exchange, electricity distribution, electricity supply, including supply of regulation electricity and electricity supply to households, providing support services, providing system services, assuming responsibility for deviation, evaluating, clearing and settlement of electricity market participant's deviation and system deviations, and how to prevent system overloading and system overload solutions. It also discusses the procedure for changing the electricity supplier, the conditions, and the date of its implementation in detail.

Other important regulations are:

- Decree of the Ministry of Economy no. 599/2009 Coll. aimed at implementing the provisions mentioned in the Act on the Promotion of Renewable Energy Sources and High Efficiency Cogeneration. [28]
- Decree of the Office for Regulation of Network Industries no. 80/2015 Coll. amending the Decree of the Regulatory Office for Network Industries no. 490/2009 Coll. laying down details on the promotion of renewable energy sources, high efficiency cogeneration and biomethane. [29]
- Decree of the Office for Regulation of Network Industries no. 189/2014 Coll. amending the Decree of the Regulatory Office for Network Industries no. 221/2013 Coll. laying down the price regulation in the electricity industry. [30]

From January 2019 an amendment to the Act no. 309/2009 Coll. on the Promotion of Renewable Energy Sources and High-Efficiency Cogeneration and on Amendments to Certain Acts is in force [26]. In connection with this amendment, the Act No. 251/2012 Coll. on Energy was also amended. The biggest changes concern the payment for access to the distribution system (so-called G-component). This payment was introduced with effect from January 2014 by the Decree of the Office for Regulation of Network Industries focusing prices. In 2016, the Constitutional Court annulled the G-component and declared that part of the Decree imposing an obligation on the G-components to pay electricity producers to be unconstitutional. According to the Constitutional Court, the legal basis for the payment of the G-component can only be the agreement on access to the distribution system and the distribution of electricity. The amendment of this Act responds to this decision in several points. The first change is the modification of access to the distribution system definition. Access to the distribution system also means the supply of electricity to the system. The essential requirements of the agreement regarding access to the distribution system and electricity distribution are also changed. If the contract is concluded by the electricity producer, the transmission of electricity is not an essential requirement of the contract. Another change is the introduction of a definition of unauthorized supply. Unauthorized supply is the supply of electricity to the system without a contract on access to the distribution system and the distribution of electricity. If the producer delivers electricity without an access agreement, it will be an unauthorized delivery and the distribution company will be able to disconnect it. The last important change is the obligation for electricity producers to conclude a contract on access to the distribution system and electricity distribution system to with a system operator when they supply electricity to the system.

Act no. 250/2012 Coll. on the Regulation in Network Industries was also amended. The amendment introduces a statutory definition of tariffs for system operation and tariffs for system services. So far, these terms have only been governed by legal regulations. At the same time, there is a legal definition of one of the components of the tariff for operating the system, which is the tariff to produce electricity from renewable energy sources. There are also individual tariffs for operating the system for businesses with a consumption of at least 1GWh (energy-intensive businesses). The extended competences of the Office for Regulation of Network Industries to issue a price decision for RES and CHP electricity generation activities for the entire period of support by a supplement or surcharge, i.e., for a period of 15 years, are introduced. The amendment also ensures the effective implementation of the decisions of the Agency for the Cooperation of Energy Regulators (ACER). As a rule, ACER decisions have the character of methodologies and conditions. The amendment introduces an obligation for the Office for Regulation of Network Industries to publish these decisions on its website in order to ensure that electricity market participants and gas market participants are properly informed regarding their issue. It also provides for the possibility for the Office for Regulation of Network Industries to stop the price proceedings, if, by issuing a price decision, the total installed capacity of the new electricity generation facilities from RES and CHP would be exceeded. The Ministry of Economy of the SR for the relevant calendar year will publish the total installed capacity of new equipment.

3. Basic Information about the Slovak Electricity System

On the territory of Slovakia, the beginning of the electrification of the territory relates to the operation of the first hydroelectric power plants in the Central and Northern Slovakia at the end of the 19th century, which gradually merged into local systems. The first brown-coal-fired steam power plant, with 12.0 MW installed capacity, was put into operation in Handlova more than 100 years ago and became the primary source of the regional system in the area between Handlova and Prievidza. In 1949, a brown-coal-fired power station in Novaky with an installed capacity of 178 MW was commissioned. In 1963, a new 110 MW unit was put into operation in Novaky, connected to the Bystricany substation, and then connected to the already highly developed Czech electricity system through the 110-kV substation Liskovec in the north of Moravia. The operation of the first system power plant guaranteed the security of electricity supplies to Slovakia, which, until then, had been mainly supplied by electricity from a hydroelectric Vah river cascade which reliability was limited by the potential of the Vah's hydro energy. At present, the electrical system is an infrastructure property of high value with thousands of resources, tens of thousands of kilometres of superior and distribution air and cable lines, appliances, and safety features of the power grid. The electrical system facilities have made electricity continuously available throughout the country, and it serves the development of the economy and the population of the Slovak Republic.

It is important that a balance of production and consumption of electricity is always maintained in order to guarantee the safety and reliability of the electrical system operation. The frequency and voltage offset reflects the difference in electricity production and consumption, while the higher the power production and lower the power consumption, the frequency increases, and vice-versa. If the frequency (49.8–50.2 Hz) and voltage offset is exceeded, their life span would be reduced and their own protections would start to be disconnected from the system. According to the current load, the difference in MW production and consumption may cause local outages in the supply of electricity, which in the undesired process ends with the disruption of the system. Disturbances in the system spread at a speed that goes beyond the possibilities of human perception. Therefore, each regulatory area must have a system of protection and management of the electricity system that prevents the spread of faults and controls the production of resources and consumption of consumers in the nodes, while real controlling the operation of the power system of the Slovak Republic (SR) is provided by the "Slovenska elektrizacna prenosova sustava" (SEPS Inc., Zilina)/Slovak Electricity Transmission System.

4. Production, Distribution and Consumption of Electricity in Slovakia

A power system of 7721 MW was installed in 2017 and the system integrated the production of electricity from almost 2800 electricity production sources, according to the Yearbook 2017 of the SEPS [31]. Electricity consumption reached 31,066 GWh, of which the domestic production was accounted for 28,036 GWh. The electricity production balance reached 3 030 GWh, i.e., almost 10%. The annual power maximum of 4550 MW was reached on January 11, 2017, and the power minimum of 2380 MW on 21 May 2017, the regulatory range of the system was of 2170 MW. The share of production from fossil fuels, nuclear sources, and renewable energy sources (RES), as well as the import of electricity, has been stabilized for the long time, and optimal in terms of safety and reliability. Regulatory requirements increase due to the unpredictable change in the power of photovoltaic power plants, with an installed power potential of 540 MW. When compared to 2015, the installed capacity was reduced by more than 400 MW. Four units of coal power plants were decapitated, of which two 110 MW blocks belonged to the Coal Power Plant Novaky and two blocks of equal power belonged to the Coal Power Plant Vojany. The reason for the decapitation was the failure to comply with the prescribed environmental requirements of the EU and SR. The Ministry of Economy of the Slovak Republic did not allow further decapitation of system resources installed capacity in order to maintain energy security of Slovakia, unless they are put into operation the domestic sources, i.e., new blocks of the nuclear power plant in Mochovce.

Electricity that is produced in the Slovak Republic is loaded with low greenhouse gas emissions. In 2017, only 20% of electricity was produced from fossil fuels. The total load of electricity that was consumed by CO_2 emissions was 230 g/kWh, which is the seventh lowest position within the 28 EU countries.

Table 1 shows the share of resources for installed power and total electricity production, costs, and prices of electricity produced and imported. Table 1 provides a detailed overview of the major electricity producers (about 90% of electricity production in Slovakia) with the volume of emitted CO_2, NO_X, and SO_X.

Table 1. Production and consumption of electricity in Slovakia in 2017 (Source: [31,32]).

Energy Sources	Installed Power (MW)	Installed Power (%)	Electricity Production 2017 (GWh)	Electricity Production 2017 (%)	Use (%)	Price (€/MWh)	Costs (K €)
Nuclear	1940.0	25,1	15,081.0	53.8	88.7	36.20	545,932
Water	2539.0	32.9	4667.0	16.6	21.0	45.71	213,329
Lignite	333.0	4.3	1734.0	6.2	59.4	97.44	168,968
Hard coal	221.0	2.9	1062.0	3.8	54.9	86.93	92,324
Natural gas	1106.0	14.3	2228.0	7.9	23.0	77.72	173,169
Oil	257.0	3.3	687.0	2.5	30.5	100.60	69,115
Mixed fuels	431.0	5.6	90.0	0.3	2.4	91.93	8274
Sun	530.0	6.9	609.0	2.2	13.1	385.73	234,912
Biomass	225.0	2.9	1113.6	4.0	56.5	97.59	108,681
Biogas	105.0	1.4	642.0	2.3	69.8	134.51	86,358
Wind	3.0	0.0	3.9	0.0	14.8	64.59	252
Others RES	12.0	0.2	76.5	0.3	72.8	113.11	8653
Other	19.0	0.2	42.0	0.1	25.2	26.93	1131
Production	7721.0	100.0	28,036.0	100.0	41.5	61.03	1,711,098
Import/Export	345.9	4.5	3030.0	9.8	100.0	36.20	109,686
Consumption	8066.9	104.5	31,066.0	100.0	44.0	58.61	1,820,784

Among the "other RES" belongs, e.g., geothermal energy or sewage sludge processing in Slovakia.

The price of electricity from photovoltaics is several times higher than from coal due to the high investment and costs and lower efficiency of utilization of this RES. For solar energy, the average use of installed power is only 13.1% and for coal 55–60%. Coal from Slovak mines is subsidized by the state, so the price is as high as the price of biomass.

The price of electricity and natural gas is rising, mainly due to the dramatic increase in the price of greenhouse gas emission allowances. Paradoxically, in Slovakia at the end of 2018, an Act was issued to stop the combined production of electricity and heat from biomass. Electricity that is produced in this way is considered to be particularly environmentally friendly in a civilized world, because, in addition to high energy efficiency, it slows down climate change, as it is neutral in terms of greenhouse gas production. Moreover, the prices of heat that is produced in the cogeneration process together with electricity would not increase for more than 400 thousand of the inhabitants of Slovakia, as the purchase of emission allowances does not affect this production.

Figure 1 introduces the end user price of electricity according to the energy sources.

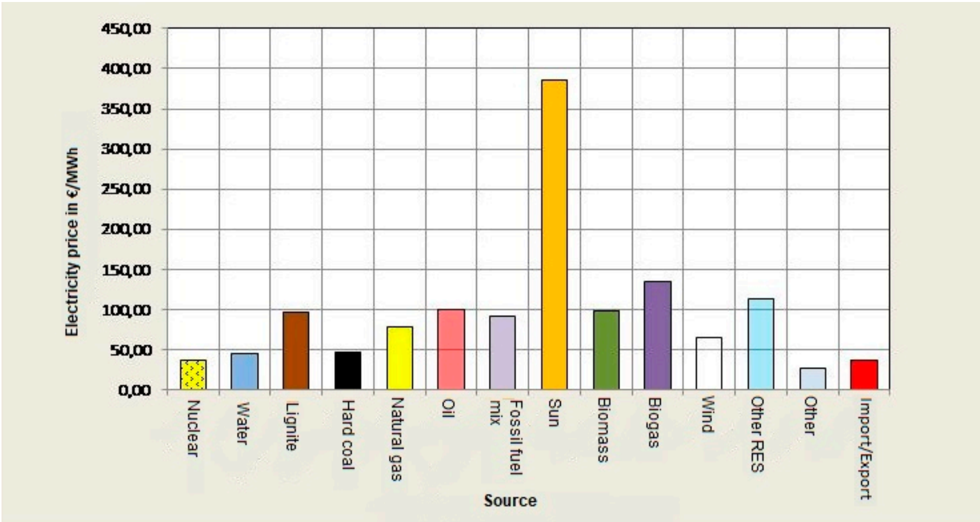

Figure 1. Comparison of commodities end user prices (Source: [31,32]).

Figure 2 shows the electricity production and consumption in Slovakia, as well as the electricity production and consumption balance.

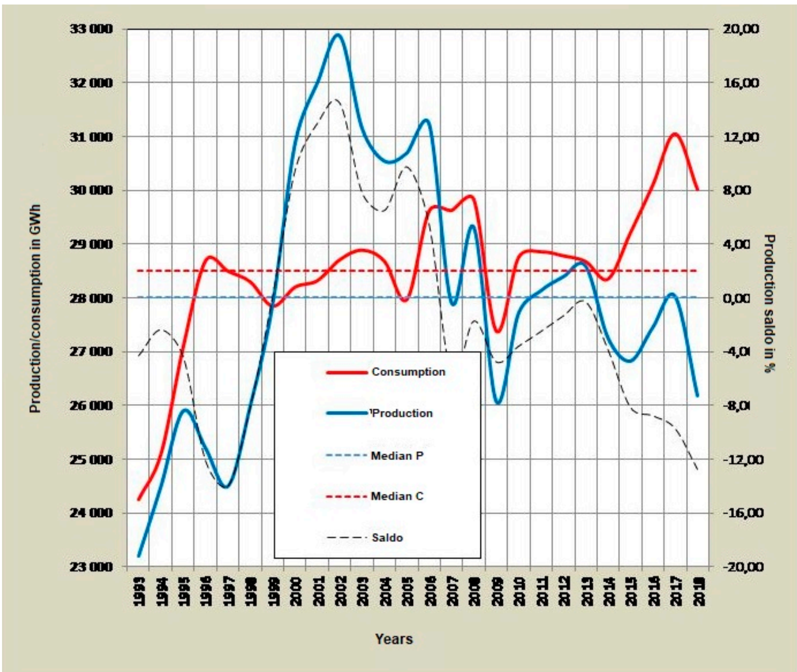

Figure 2. Production and consumption of electricity in Slovakia (Source: [31,32]).

Figure 2 shows the decrease in electricity production. The reason is the termination of the operation of the first block V-1 of nuclear power plant in Jaslovske Bohunice in January 2007 as well as its second block V-1 in January 2009. Each of these V-1 blocks generated 10% of all energy that is produced in Slovakia. The country is expected to become self-sufficient again after putting the third and fourth block of the nuclear power plant in Mochovce into operation (2019, 2020).

Figures 3–5 show the commodities end user prices for electricity, gas, and EUA's emission allowances.

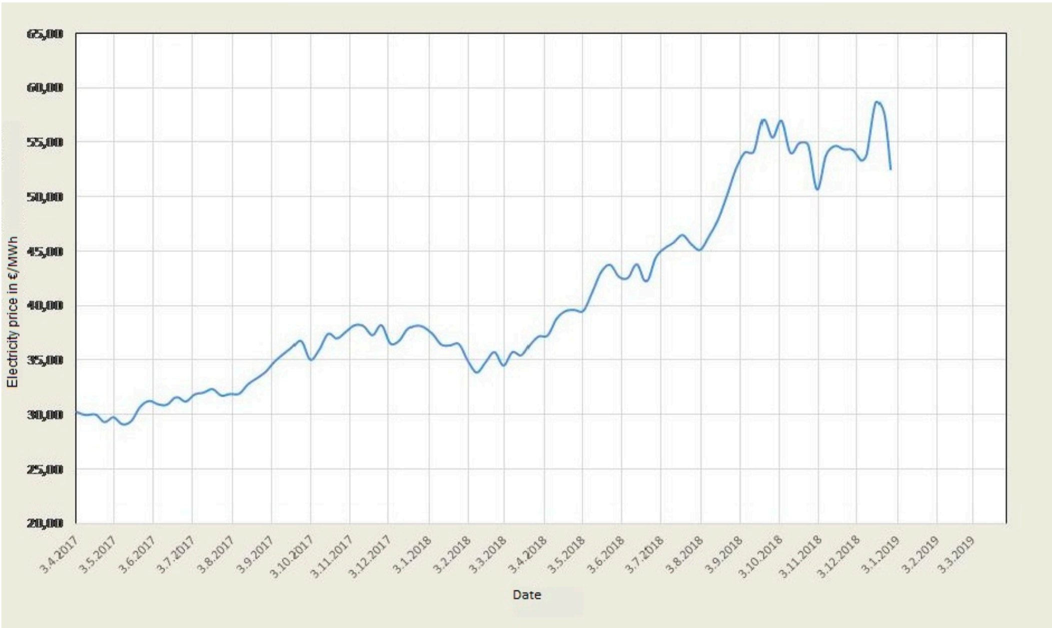

Figure 3. Electricity end user prices development on the stock market—the index PXE (Source: [33]).

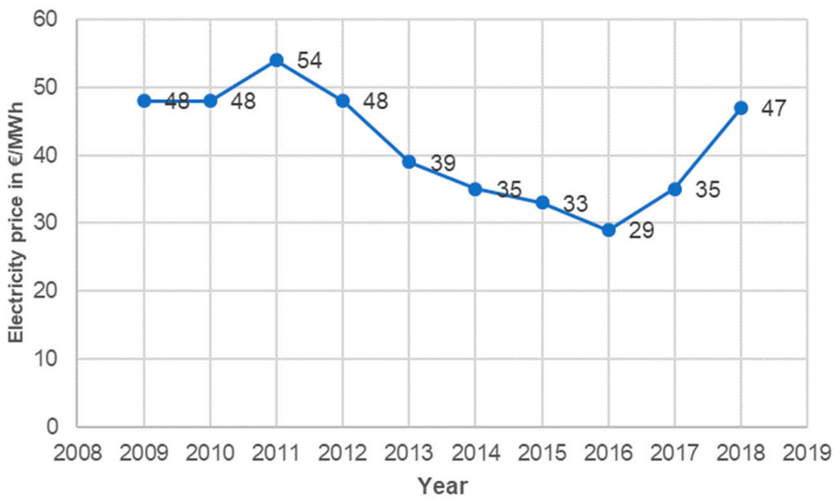

Figure 4. Stock market year-on-year increase of average electricity end user prices (€/year) in period 2009–2018 (Source: [33]).

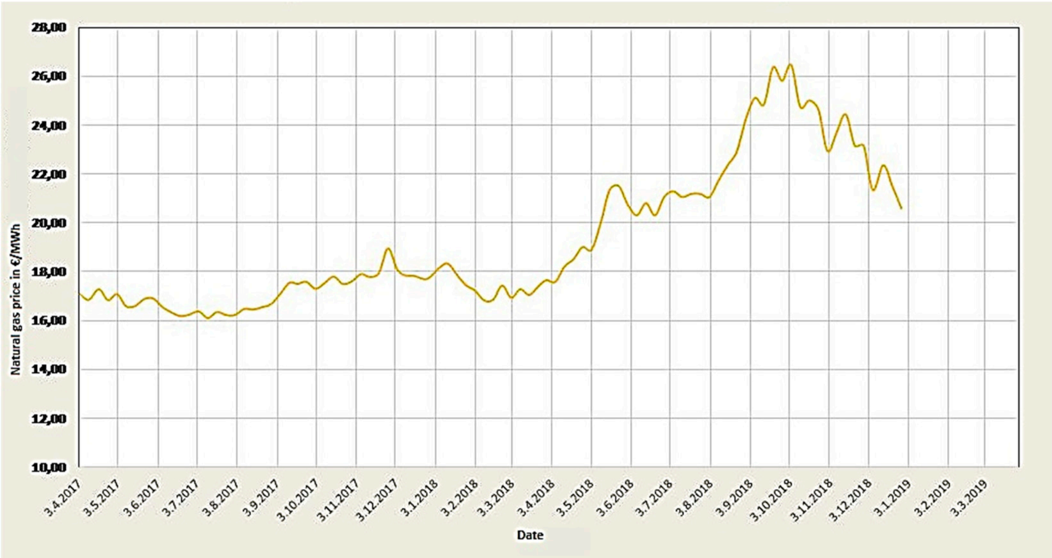

Figure 5. Gas end user prices on the stock market—the index PXE (Source: [33]).

Figure 3 shows the development of the electricity price on the stock market—the PXE index in the period April 2017–January 2019.

The stock market average electricity end user prices for period 2009–2018 are introduced in Figure 4.

Recently, the price of electricity had been significantly rising, being mainly driven by the course of electricity prices in neighbouring countries, as well as gas price developments and the price of greenhouse gas emission allowances (Figures 5 and 6).

Figure 6. End user prices of emission allowances for greenhouse gases (Source: [34]).

Figure 7 shows the course of the spot price of electricity in Slovakia in 2018 according to the Energetika.cz web portal [19].

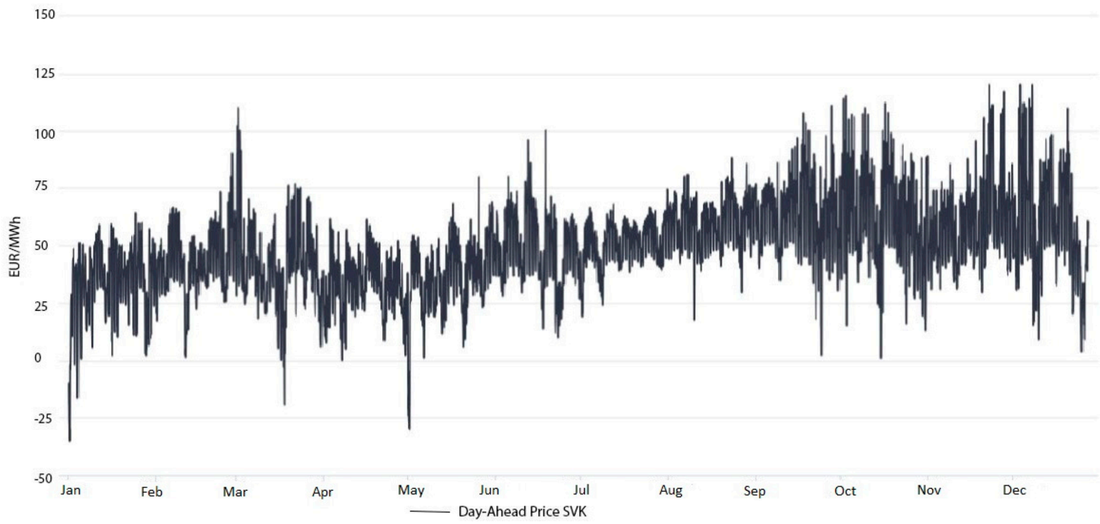

Figure 7. Electricity spot prices in 2018 (Source: [33]).

The rising price trend in 2018 was due to the extraordinary rise in commodity prices on stock markets. The prices that are introduced in Figure 7 reflect the year-on-year increase of prices in the production of electricity by 27%, gas by 24%, and emission allowances increase by more than 200%.

Figure 8 introduces the utilization of the Slovak electrical system and its coverage by the energy sources on 7.12.2018.

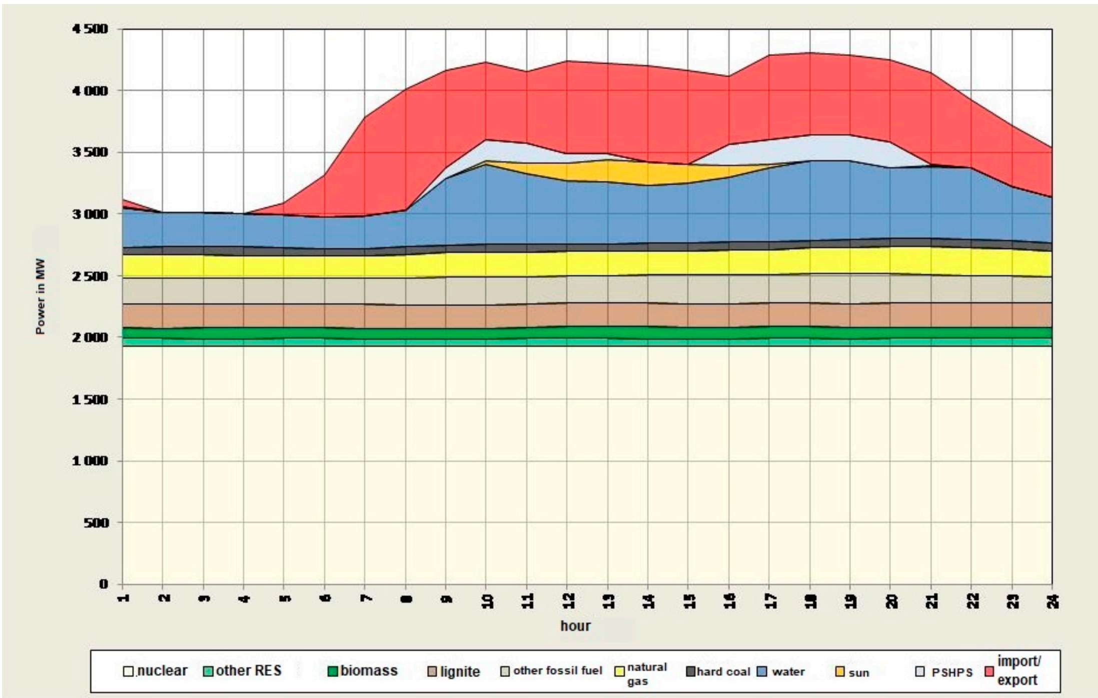

Figure 8. Slovak electrical system utilization and its coverage by the energy sources on 7.12.2018 (Source: [35]). PSHPS—Pumped-storage hydropower stations.

It can be seen from Figure 7 that, during the selected day, the least dynamic variation in electricity (power) produced was recorded by the nuclear power plants, sources of electricity from biomass and other RES, lignite and hard coal, other fossil fuels, and natural gas. On the other hand, significantly dynamically variable electricity production (power) is evident in the case of hydropower plants, pumped-storage hydropower stations (PSHPS), solar power stations, and import/export. It is also clear from the figure that, during daylight, when the power of solar power plants increases, hydropower plants and PSHPS simultaneously control this power.

5. Heat Supply from Power Plants of Slovenske Elektrarne, Inc.

Slovenské elektrarne (SE, Inc.)/Slovak Power Plants is the third largest heat supplier in Slovakia. In 2017, SE produced 898 GWh and sold 705 GWh of heat. The largest system of central heat supply (CHS) within the SE is the system in the Jaslovske Bohunice nuclear power plant. The heat that is produced by this system supplies the towns Trnava, Hlohovec, Leopoldov and Jaslovske Bohunice. In addition to the supply of non-residential premises, institutions, public buildings, and medical and school facilities, the heat is supplied for heating and water to 22,730 dwellings, including 364 family houses in the village Jaslovske Bohunice. The second largest CHS system belongs to the Novaky heating power plant and it supplies about 11,494 flats in the towns of Prievidza, Novaky, and Zemianske Kostolany with heat for heating and water heating, including 46 family houses in Zemianske Kostolany.

The highest electricity production used for heating during the year occurs during the heating season (November—March), see Figure 9.

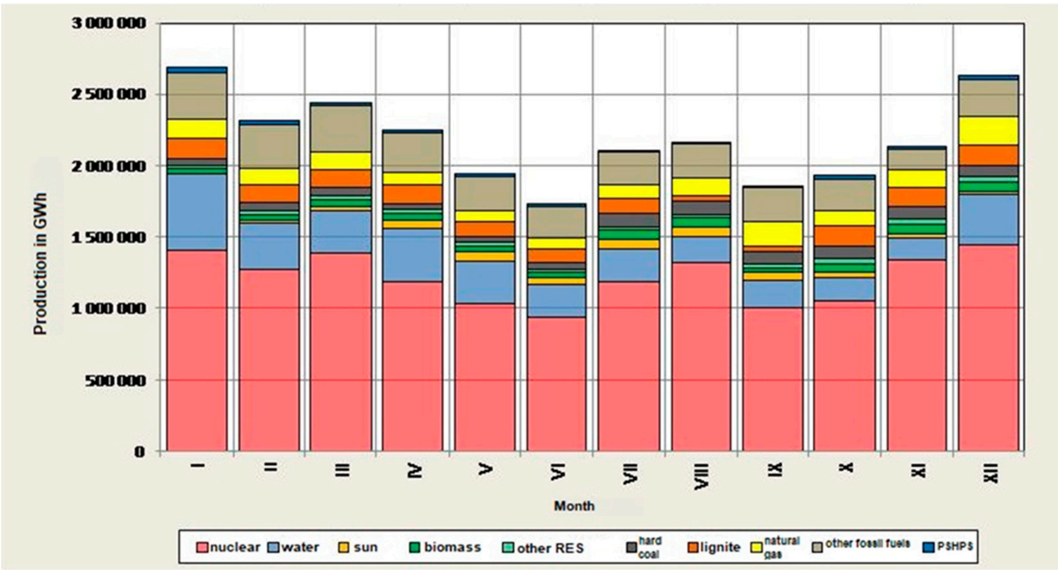

Figure 9. Electricity production for heating at sources in Slovakia in 2018 (Source: [35]).

6. Environmental Consequences of Electricity Production

Coal mining has traditionally been an important industry in the Slovak Republic. Hard coal is mostly used in the steel industry. Lignite is mostly used for power and heat generation at the Novaky power plant. In 2016, the power plant accounted for 6.4% of the total power generation in the country. The remaining extractable lignite reserves in the Slovak Republic would be sufficient to supply the Novaky power plant for at least for another 20 years. [36]

However, in recent decades, coal has moved from the largest energy source in the country's energy production, total primary energy supply (TPES), and electricity generation to only account for around 10–20% of the energy mixes. Starting the operation of nuclear power and the growth in bioenergy use has reduced the relevance of coal for the Slovak Republic's energy security, and some uneconomical coal mines are now closed down. The remaining coal mines depend on subsidies for domestic coal use in power generation. [36]

According to [36], two-thirds of coal supply is imported, mainly from the neighbouring countries and the Russian Federation. Russia accounted for 29% of total imports, followed by the Czech Republic (25%) and Poland (20%). Most of the imported coal is hard coal, but lignite also accounted for 11% of the total coal imports in 2017. Coal imports declined by 31% from 2007 to 2017, which is in line with the decline in coal demand. Domestic lignite production accounts for 30% of the total coal supply when measured in weight, and 14% when measured in energy content. Lignite production decreased by 13% in the past decade and several coal mines are now closed.

The challenge is that domestic lignite is uncompetitive in power generation. However, its perceived security of supply benefits means that the government has adopted a compensation system for its use in electricity generation. Electricity from domestic lignite also benefits from a priority dispatch to the network, just as renewable energy. The subsidy costs electricity users around 100 million EUR a year, or around 14,000 EUR per employee in coal mining and related services. [37]

The government considers that an abrupt termination of coal mining in the Upper Nitra would radically increase unemployment in the area. It prefers to find solutions that gradually phase out coal mining and the subsidy to minimise the impact on employment. Subsidies are also granted to mine closures. From 2002 to 2015, a total subsidy of 6.7 million EUR was given to the mining company Bana Dolina a.s., to cover the exceptional costs to end the mining activities and to cover the severance payments to workers. The closure of the Cigel mine is expected to cost around six million EUR in state aid. [37]

According to [37], practically all domestic coal is used for power generation, and therefore it is part of the electricity security equation and its future should be considered in this context. The International Energy Agency notes that, to the extent that domestic lignite is currently needed for the security of supply, this concern will be alleviated as soon as the first 470 MW nuclear unit comes on line, which is planned for completion in 2018.

There is a long-standing unacceptable situation from point of view of the environmental protection and health and safety of the population in Slovakia, because the territory of Slovakia is mostly affected by the emissions arising from the cheapest electricity production in neighbouring countries, not as much from the Slovak electricity production sources and coal mining. The problem of coal-fired power production is not the technologies used to produce the electricity that must meet the strict emission limits that are set by the EU and Slovak legislation. The problem is the method of coal mining and the preparation of fuel, in general. In neighbouring countries, the environmentally unacceptable surface mining of coal is the main source of environment pollution.

It is evident that "responsible persons", not only activists, are aware of the effects and consequences of dust scatter, so the fuel dumps have to be covered by the Best Available Techniques reference documents (BREF) for the best available techniques (BAT) and the ash storage under a constant water level, but hundreds of square kilometres of surface mines remain without the corresponding technical solution.

Surface mines in Poland, Germany, and the Czech Republic pose a threat to the environment, especially since hundreds of square kilometres of deposit areas are exposed to moving air, which directly carries free dust particles into the breathable layer. The micro particles of dust from the area of thousands of square kilometres of surface mines in Germany, Poland, and the Czech Republic are issued by the movement of air directly into the layers of breathable air to air pollutants, such as particulate pollutants causing smog situation, not only in their countries of origin, but also in Slovakia.

Coal mining needs to be disrupted and relocated, because it is 10 times more overburdened than the coal itself. When mining 34 million tons of coal per year, 340 million tons of overburden is moved, while using the dunes and open conveyor belts. When processing and transporting, the moving air generates very dangerous solid pollutants that are emitted from the overburden layer in millions of tons. This dust type can reach the share even more than 1%.

Appendix A (Table A1) presents a list of selected sources of electricity production of the Slovak power system. The installed power, production, own electricity consumption, and emissions in 2017 are updated by expert estimation for 2018. For non-emission electricity producers, a negative emission value is shown in the table, which represents the saved CO_2 emissions. The biggest savings are in the nuclear power plants (about 14 million tons of CO_2) and hydropower plants (4.2 million tons of CO_2). Electricity production in Slovakia is associated with the annual CO_2 emission of 8.2 million tons of CO_2, representing 324 kg/MWh. The utilization of the electricity in Germany and in the Czech Republic is estimated to be more than 700 kg/MWh in 2018. Electricity utilization in Poland is estimated to be about 1000 kg/MWh. With such utilizations, the development of electro mobility in power production would cause an increase in greenhouse gas production.

7. Conclusions

Energy security is being tackled under the influence of energy in social life and in the economy, particularly in the liberalization of energy markets, in diversification and in resource efficiency, and in procedures that multiply competition in energy markets. More broadly, there are national and international measures to ensure stable energy supplies at affordable and stabilized prices, but also to guarantee the protection of critical energy infrastructure and to demonstrate state readiness to effectively respond to potential crisis. Since energy is one of the factors that determine the inputs into production and thus production costs, rising energy prices are multiplying pressures on producers, reducing profit. Therefore, it is necessary to secure energy resources in a liberalized market at acceptable prices in the interests of economic development.

From this point of view, the aim of this article was to summarize the information on EU and Slovak energy and environmental legislation, describe the current energy sources that are used for electricity production, current state of electricity production, consumption, and end user prices development. This information was also supplemented with information on heat production from energy sources and environmental consequences of lignite completed with information on the environmental consequences of electricity production using lignite (surface mining) as an energy source.

The data and charts used in the article come from publicly available sources.

Author Contributions: Conceptualization, J.J.; methodology, A.M., M.L. and M.T.; formal analysis, J.J., M.T.; resources, J.J., M.T.; data curation, A.M., M.L.; writing—original draft preparation, A.M.; writing—review and editing, A.M.; project administration, M.L..; funding acquisition, M.L.

Funding: This research was funded by the KEGA Grant Agency under the project KEGA 013TU Z-4/2017.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Appendix A

Table A1. List of selected sources of electricity production within the Slovak electrical system. (Source: [31,32]).

Source	Installed Power (MW)	Electricity Supply (MWh)	Own Consumption (%)	Emissions CO_2 (t)	Emissions NO_x (t)	Emissions SO_x (t)
Diesel generator station Levice	32.000	0		0	0	0
Diesel generator station Moldava	32.000	0		0	0	0
Diesel generator station Sucany	32.000	0		0	0	0
Diesel generator station PPC Trakovice	10.000	93	19.33	104	0	0
Diesel generator stations	**106.000**	**93**	**19.33**	**104**	**0**	**0**
Nuclear power plant Bohunice	1000.000	7,059,256	6.88	−7,294,478	x	x
Nuclear power plant Mochovce	940.000	7,000,331	6.67	−6,752,350	x	x
Nuclear power plants	1940.000	14,059,588	6.77	−14,046,828	x	x
Hydroelectric power plant Orava	21.750	26,893	1.02	−24,454	x	x
Hydroelectric power plant Tvrdosin	6.100	11,205	4.37	−10,545	x	x
Hydroelectric power plant Cierny Vah	735.160	234,765	1.32	−214,125	x	x
Hydroel. power plant Liptovska Mara	198.000	103,967	1.89	−95,377	x	x
Hydroelectric power plant Krpelany	24.750	55,475	1.94	−50,913	x	x
Hydroelectric power plant Sucany	38.400	78,117	1.06	−71,060	x	x
Hydroelectric power plant Lipovec	38.400	70,422	1.35	−64,245	x	x
Hydroelectric power plant Zilina	72.000	142,641	0.63	−129,195	x	x
Hydroelectric power plant Hricov	31.500	53,442	0.31	−48,246	x	x
Hydroelectric power plant Miksova	93.600	154,285	0.53	−139,598	x	x
Hydroelectric power plant P. Bystrica	55.200	93,793	0.91	−85,185	x	x
Hydroelectric power plant Nosice	67.500	143,161	0.26	−129,180	x	x

Table A1. *Cont.*

Source	Installed Power (MW)	Electricity Supply (MWh)	Own Consumption (%)	Emissions CO_2 (t)	Emissions NO_x (t)	Emissions SO_x (t)
Hydroelectric power plant Ladce	18.900	78,650	1.07	−71,549	x	x
Hydroelectric power plant Ilava	15.000	73,292	1.26	−66,808	x	x
Hydroel. power plant Dubnica/Vahom	16.500	72,605	1.11	−66,076	x	x
Hydroelectric power plant Trencin	16.100	69,433	0.29	−62,669	x	x
Hydroelectric power plant Kostolna	25.500	96,867	1.26	−88,297	x	x
Hydroel. power plant N. M./Vahom	25.500	98,271	0.47	−88,862	x	x
Hydroel. power plant Horna Streda	25.500	97,937	1.42	−89,414	x	x
Hydroelectric power plant Madunice	43.200	127,370	0.95	−115,730	x	x
Hydroelectric power plant Kralova	45.060	96,182	0.21	−86,747	x	x
Hydroelectric power plant Ruzin I.	60.000	55,038	2.36	−50,732	x	x
Hydroel. power plant V. Kozmalovce	5.320	9834	4.17	−9236	x	x
Hydroelectric power plant Domasa	12.400	9211	1.66	−8429	x	x
Hydroelectric power plant Dobsina I.	24,000	27,688	1.96	−25,418	x	x
Hydroelectric power plant Gabcikovo	720.000	1,430,006	1.02	−1,300,331	x	x
Hydroelectric power plant Cunovo	24.280	109,706	2.33	−101,094	x	x
Small hydroel. power plants < 5.0 MW	79.380	968,044	3.92	−906,786	x	x
Hydroelectric power plants	**2539.000**	**4,588,301**	**1.69**	**−4,200,300**	x	x
Solar power plants	**530.000**	**609,000**	**0.00**	**−548,100**		
Waste incinerator OLO Bratislava	6.300	35,350	23.71	−125,102	163	642
Waste incinerator Kosit Kosice	6.000	33,096	25.79	−120,409	157	618
Municipal waste	**12.300**	**68,446**	**24.73**	**−245,511**	**321**	**1260**
CHP source, Bioenergy, s.r.o. Bardejov	8.200	69,067	0.00	−111,889	162	0
CHP source, Bioenergy, Topolcany	8.200	69,410	0.00	−99,488	148	0
CHP source, Bukocel a.s. Hencovce	18.000	59,915	14.19	−228.513	341	0
CHP source, Energy Edge ZC, Zarnovica	11.000	97,257	15.00	−106.792	273	0
CHP source, Martinska teplarenska	9.000	12,227	15.16	−45,779	68	0
CHP source, Mondi SCP	137.600	500,979	15.00	−2,340,213	3058	0
CHP source, Zvolenska teplarenska	5.000	36,515	3.92	−90,642	188	0
CHP source, Chemes Humenne	24.000	50	15.99	−180	0	0
CHP source, DALKIA Ziar nad Hronom	15.000	21,138	34.91	−85,963	144	0
Another biomass	**236.000**	**866,559**	**13.09**	**−3,109,459**	**4384**	**0**
Biofuel	**105.000**	**603,500**	**6.00**	**−1,059,300**	**324**	**0**
CHP source, Bukocel a.s. Hencovce	1.600	1394	14.19	2753	8	3
CHP source, Martinska teplarenska	33.000	37,284	15.16	21,739	208	342
CHP source, Zvolenska teplarenska	35.000	39,373	3.92	91,613	239	664
CHP source, Zilinska teplarenska	49.768	96,485	9.18	243,765	683	268
Brown-coal fired Elektrarne Novaky	266.000	1,479,820	10.85	1,656,771	1546	2568
Lignite	**385.368**	**1,654,356**	**10.71**	**2,016,641**	**2684**	**3845**
CHP source, CMEPS, Slovnaft	89.000	288,922	21.83	764,693	1124	442
CHP source, Chemes Humenne	24.000	743	15.99	2357	4	2
Heavy fuel oil	**113.000**	**289,664**	**21.81**	**767,051**	**1125**	**443**
CHP source, Chemes Humenne	24.000	11,858	15.99	45,204	71	269
CHP source, Teplaren Kosice, a.s.	65.000	152,510	8.33	416,555	656	2482
CHP source, Teplaren USS Kosice	67.000	340,956	16.00	1,034,027	1627	6160
CHP source, DALKIA Ziar nad Hronom	10.000	6605	34.91	32,496	51	194
Brown-coal-fired Elektrarne Vojany SE	220.000	376,998	11.65	537,655	155	3562
Hard coal	**386.000**	**888,927**	**13.13**	**2,065,937**	**2560**	**12,667**
CHP source, Chemes Humenne	24.000	3477	15.99	5362	14	0
CHP source, Teplaren Kosice, a.s.	56.000	94,832	8.33	192,979	408	9
CHP source, Teplaren USS Kosice	45.000	23,517	16.00	54,403	112	2
CHP source, Mondi SCP, a.s.	3.336	52	15.00	119	0	0
CHP source, DALKIA Ziar nad Hronom	4.400	5294	34.91	10,537	28	1
CHP source, BAT - Teplaren Vychod	24.500	77,525	9.12	259,321	516	11
CHP source, BAT - Teplaren Zapad	25.000	39,358	8.08	125,971	251	5
CHP source, GT Teplaren Radvan	5.200	16,198	0.89	30,490	64	1
CHP source, GT1	6.300	46,944	1.18	92,311	190	4
CHP source, KGJ TEDOM	2.606	10,045	8.74	21,390	44	1
CHP source, PPC Investment Bratislava	217.960	1354	1.90	2683	6	0
CHP source, PPC Energy Bratislava GT	58.000	260	5.27	533	1	0
CHP source, PPC Levice	87.000	329,590	4.07	649,854	1362	29
CHP source, PPC Povazska Bystrica	57.966	258,131	6.00	249,213	494	11
CHP source, Energochem SVIT	11.970	58,461	3.22	63,804	127	3
CHP source, Zilinska teplarenska	49.768	172	9.18	392	1	0
CHP source, CGU, totally 108 sources	85.000	350,800	4.41	326,336	658	14
Dante Power Plant	50.000	1581	0.00	901	4	0
Natural gas	**814.006**	**1,317,593**	**5.60**	**2,086,599**	**4281**	**92**
CHP source, Teplaren USS Kosice	85.000	426,355	16.00	1,293,017	2035	7703
Metallurgic gases	**85.000**	**426,355**	**16.00**	**1,293,017**	**2035**	**7703**
Energy sources of the ES SR	**7245.674**	**25,339,286**	**6.81**	**8,229,349**	**12,688**	**24,751**

References

1. An Energy Policy for Europe. Available online: http://www.europarl.europa.eu/meetdocs/2004_2009/documents/com/com_com(2007)0001_/com_com(2007)0001_en.pdf (accessed on 14 January 2019).
2. Energy Efficiency Action Plan 2007–2010. 2007. Available online: https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0109:FIN:EN:PDF (accessed on 13 January 2019).
3. Strategic Energy Technology Plan. 2007. Available online: https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan (accessed on 23 January 2019).
4. Third Liberalization Package. 2007. Available online: http://www.europarl.europa.eu/ftu/pdf/en/FTU_2.1.9.pdf (accessed on 23 January 2019).
5. Climate-Energy Package. 2008. Available online: https://ec.europa.eu/clima/policies/strategies/2020_en (accessed on 6 April 2019).
6. Energy Efficiency Plan 2011. Available online: https://ec.europa.eu/clima/sites/clima/files/strategies/2050/docs/efficiency_plan_en.pdf (accessed on 11 January 2019).
7. Second Strategic Energy Review—An EU Energy Security and Solidarity Action Plan. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0781&from=DE (accessed on 11 January 2019).
8. European Economic Recovery Plan. 2008. Available online: https://ec.europa.eu/inea/sites/inea/files/download/publications/eerp_v11.pdf (accessed on 13 January 2019).
9. Treaty of Lisbon. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:12007L/TXT&from=EN (accessed on 11 January 2019).
10. Europe 2020 Strategy. Available online: http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf (accessed on 13 January 2019).
11. Energy 2020 A Strategy for a Competitive, Sustainable and Secure Energy. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:en0024&from=EN (accessed on 12 January 2019).
12. Energy Efficiency Directive 2012/27/EU. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&rid=3 (accessed on 11 January 2019).
13. Communication "Energy Infrastructure. Priorities for 2020 and Beyond". Available online: https://ec.europa.eu/energy/sites/ener/files/documents/2011_energy_infrastructure_en.pdf (accessed on 12 January 2019).
14. Regulation EU No. 347/2013 on Guidelines for Trans-European Energy Infrastructure. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32013R0347&from=en (accessed on 11 January 2019).
15. Regulation EU No. 1316/2013 Establishing the Connecting Europe Facility. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32013R1316&from=EN (accessed on 11 January 2019).
16. Roadmap to a Competitive Low Carbon Economy in 2050. Available online: https://ec.europa.eu/clima/sites/clima/files/strategies/2050/docs/roadmap_fact_sheet_en.pdf (accessed on 11 January 2019).
17. Emisie.sk. Available online: http://emisie.icz.sk/ (accessed on 19 January 2019).
18. A 2030 Framework for Climate and Energy Policies. Available online: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0169&rid=8 (accessed on 13 January 2019).
19. 2030 Climate and Energy Framework. Available online: https://www.iddri.org/sites/default/files/import/publications/cs-iddri-eu-2030-framework_energy-security.pdf (accessed on 12 January 2019).
20. Communication "Progress towards Completing the Internal Energy Market". Available online: http://data.consilium.europa.eu/doc/document/ST-16037-2014-INIT/en/pdf (accessed on 12 January 2019).
21. Clean Energy for All Europeans. Available online: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans (accessed on 6 April 2019).
22. 2050 Long-Term Strategy. Available online: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-long-term-strategy (accessed on 6 April 2019).
23. Act No. 251/2012 Coll. on Energy and on Amendments to Certain Acts. Available online: http://www.zakonypreludi.sk/zz/2012-251 (accessed on 7 February 2019).
24. Act No. 250/2012 Coll. Regulation on Network Industries. Available online: http://www.zakonypreludi.sk/zz/2012-250 (accessed on 7 February 2019).
25. Act No. 476/2008 Coll. on Energy Efficiency. Available online: https://www.zakonypreludi.sk/zz/2008-476 (accessed on 6 April 2019).

26. Act No. 309/2009 Coll. on the Promotion of Renewable Energy Sources and High Efficiency Cogeneration and on Amendments to Certain Acts. Available online: http://www.zakonypreludi.sk/zz/2009-309 (accessed on 7 February 2019).
27. Decree of the Office for Regulation of Network Industries no. 24/2013 Coll., Laying down the Rules for the Functioning of the Internal Market in Electricity and the Rules for the Functioning of the Internal Gas Market. Available online: http://www.zakonypreludi.sk/zz/2013-24 (accessed on 7 February 2019).
28. Decree of the Ministry of Economy No. 599/2009 Coll. Aimed at Implementing the Provisions Mentioned in the Act on the Promotion of Renewable Energy Sources and High Efficiency Cogeneration. Available online: https://www.zakonypreludi.sk/zz/2009-599 (accessed on 6 April 2019).
29. Decree of the Office for Regulation of Network Industries no. 80/2015 Coll. Amending the Decree of the Regulatory Office for Network Industries No. 490/2009 Coll. Laying down Details on the Promotion of Renewable Energy Sources, High Efficiency Cogeneration and Biomethane. Available online: https://www.zakonypreludi.sk/zz/2015-80 (accessed on 6 April 2019).
30. Decree of the Office for Regulation of Network Industries no. 189/2014 Coll. Amending the Decree of the Regulatory Office for Network Industries No. 221/2013 Coll. Laying down the Price Regulation in the Electricity Industry. Available online: https://www.zakonypreludi.sk/zz/2014-189 (accessed on 6 April 2019).
31. Yearbook 2017 of the SED. Available online: https://www.sepsas.sk/Dokumenty/RocenkySed/ROCENKA_SED_2017.pdf (accessed on 21 January 2019).
32. URSO. Available online: http://www.urso.gov.sk/?language=en (accessed on 21 January 2019).
33. KBP Praha. Available online: http://www.kbp.cz/ (accessed on 23 January 2019).
34. KBB Bratislava. Available online: http://www.sk.kbb.sk/ (accessed on 23 January 2019).
35. Oenergetice.cz. Available online: https://oenergetice.cz/ (accessed on 20 January 2019).
36. Energy Policies of IEA Countries. Available online: https://www.connaissancedesenergies.org/sites/default/files/pdf-actualites/energy_policies_of_iea_countries_slovak_republic_2018_review.pdf (accessed on 29 April 2019).
37. Energy Policy of the Slovak Republic. Available online: http://www.economy.gov.sk/uploads/files/47NgRIPQ.pdf (accessed on 28 April 2019).