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ADVANCEMENT IN DIGITAL SOLUTIONS ADDRESSING MEDICATION NONADHERENCE: AN INSIGHT INTO WHAT THE FUTURE HOLDS

Abstract

Medication adherence, referring to the extent to which patients take their medications as prescribed, is a key component to optimizing disease management and many patients fail to achieve that. This results in increased patient hospitalizations, mortality, cost and burden on healthcare systems. A number of factors contribute to barriers that lead to medication nonadherence but essential to preventing and solving this problem is adequate assessment and monitoring of patients' medication adherence. This paper is motivated by recent technology advancements and discusses digital solutions aimed at addressing medication adherence related issues with an emphasis on assessment and monitoring. In general, literature suggests that digital interventions can improve patients' medication adherence. Furthermore, digital solutions which integrate mobile applications, Internet of Things (IoT) and Artificial Intelligence algorithms are undergoing rapid growth and their application is being extended in the area of medication adherence. Many of these digital solutions are in early phases of development, deployment or implementation, requiring further research from clinical practice. However, evidence available thus far suggests that they have the capacity to address important existing barriers and potentially change the landscape of how medication adherence is assessed in the future.

Key words: Medication adherence and nonadherence, digital solution, internet of things, artificial intelligence.

Introduction

Using medications to address health related issues and treat diseases is the most common medical intervention.[1] Advances in the availability of medications as well as continuous breakthroughs in new treatment options have undoubtably resulted in significant improvements in patients' health outcomes. Therefore, it is critical that patients take

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medications as prescribed in order to reap the full benefits of their therapy. The extent to which patients take their medications as prescribed, is referred to as medication 'adherence'.[2] Another commonly used term to describe how patients take their medications is the term 'compliance'. Compliance is sometimes used interchangeably to the term 'adherence' with the key difference laying on 'adherence' implying patient agreement with prescribers' instructions.[3] Adherence to medication also implies that the patient complies with agreed medication regimen provided by their prescriber in relation to the timing, frequency as well as the dosage of therapy.[4,5,6]

The problem of medication nonadherence

The level of medication nonadherence is high. It is estimated that approximately 50% of patients with chronic conditions are nonadherent to their prescribed drug therapy.[2,7] This results in significant undesirable health outcomes and increased costs for both patients and the healthcare system. For example, both morbidity and mortality are increased as a result of poor adherence to medications accounting for approximately 125,000 deaths and 10% of all hospitalizations in the United States alone.[7] Pellegrin et al report that medication nonadherence is also one of the main medication-related reasons for hospital readmissions.[8]

Achieving medication adherence is complex and the process is affected by a number of challenging factors. Medication nonadherence can be intentional or unintentional. There are patient and health professional related barriers as well as health-system related and socioeconomic barriers. These barriers can affect how patients take their medications and therefore whether they are adherent to their therapy.[3] Additionally, there are barriers specifically related to medications and disease. These barriers are summarized in Table 1.

Table 1. Barriers to achieving medication adherence[2,3,9]

Related barriers	**Examples**
Patients	Lack of disease and treatment understanding, low health literacy, forgetfulness, age, living independently, health beliefs and attitudes, dexterity skills
Health professionals	Lack of time, communication issues, failing to deprescribe, complex prescribing, inadequate follow-up, poor relationship with patient, lack of medication counselling
Disease	Severity of disease, psychological problems, cognitive impairment, asymptomatic disease, major events such as stroke
Medications	Polypharmacy, adverse effects, toxicity, formulation, instruction for use
Health system	Fragmentation, limited coordination, overload, missed appointments, lack of insurance, patient's interaction with health system, low level of job satisfaction
Socioeconomic	Cost of medication, access, supply, transportation, lack of family & social support, embarrassment, stigma

Measuring and monitoring medication adherence

Evaluating whether the patient is adherent to prescribed drug therapy requires assessment, measurement and monitoring of medication adherence. Medication adherence can be evaluated directly or indirectly. Direct methods of assessing medication adherence involve direct observation of the patient or direct measurement of the drug or its metabolite in blood via laboratory procedures.[2,4] Whilst these methods are accurate and objective, they are nonetheless limited by being invasive and requiring direct contact with the patient. Furthermore, these methods can be time-consuming and expensive, especially given the direct involvement of health professionals. Considering that vast majority of medication usage takes place outside clinics in outpatient settings[10], direct observation methods of measuring medication adherence are further limited by lack of ongoing monitoring in outpatient settings such as at home. Additionally, when patients are directly observed by health professionals in relation to how they take their medications, the process may also be flawed by a phenomenon known as the ‘white-coat compliance’. When this occurs, patients perform better than in their usual environment of taking medications.[11]

Indirect methods of assessing medication adherence involve patient self-reports during which various questionnaires and scales are used to measure medication adherence.[2,12] These methods are usually inexpensive, practical and also predictive of clinical outcomes. [2,4,7] However, they are subject to recall bias and potential distortion/alteration by the reporting patient.[2] Additionally, these methods usually require the health professional to administer the questionnaire in order to measure adherence. Pill counting and assessment of pharmacy records are other key indirect methods of measuring medication adherence. These are both objective and easily performed methods however they too have their limitations. For example, in case of pill counting the process can be affected by the patient through pill dumping.[2] This can happen both intentionally or unintentionally. On the other hand, assessing prescription refills via pharmacy records is limited by the fact that pharmacist dispensing the medication is not equivalent to patient actually taking the medication. This means that patients may obtain medications from pharmacy but not actually take them as prescribed. Furthermore, some health-care systems may lack pharmacy documentation systems in which case assessment of pharmacy records is not possible. Additionally, most of the over-the-counter medications purchased in pharmacies are actually not documented in pharmacy records. Medication adherence can also be assessed indirectly through organizing patient diaries which can assist them in cases of poor recall.[2] However, diaries can also be altered by patients and would not be feasible to organize for patients with cognitive impairment.

Technology to the rescue

Technology-based solutions are becoming increasingly attractive in order to overcome the problem of medication nonadherence. For some time now, use of technology to assist with assessment of medication adherence has mainly been focused around *electronic medication monitoring* and *medication-taking alert* systems.[7] Electronic monitors of medication-taking rely on detection and recording of patient behaviors such as opening or activating medication containers or delivery systems. The accuracy of these systems is generally supported by the literature with studies reporting successful assessment and monitoring of medication adherence as well as clinical improvements.[7,13,14] These systems can be non-automated in which case they rely on direct text messages (e.g., SMS, emails), telephone call reminders. Systems can also be automated such as in the case of digital timers installed on medication containners or delivery systems. [7] Medication-taking alerts and reminder systems produce their reminders/alerts in a timely fashion and therefore record non-adherence of missing times accurately.[2,7,12] Text messages and telephone reminders are effective especially when they involve clinicians or other health professionals who design personal and interactive ways of prompting patients of their medication refills.[7,15] However, electronic monitoring systems based on non-automated text messaging and telephone calls may be limited by the time availability of the health professional or the person assessing medication adherence. Electronic medication monitoring and medication-taking alert systems are precise and information provided can be easily quantified.[2] However, they are expensive and require functional capability as well as technology knowledge by the patient.[2,12] Additionally, they can also be susceptible to technology failures.[12]

Various electronic medication monitoring systems can record and time-stamp medication container openings (e.g., in bottles), drop dispensing, dose activation of the medication delivery devices used in chronic diseases such as Asthma and Chronic Obstructive Pulmonary Disease (COPD) and dose delivery of insulin. In asthma and COPD, use of inhalers is mainstay therapy which is associated with high level of medication non-adherence (i.e., non-adherence levels of up to 60.5% have been reported).[16] Recently there has been a surge in smart inhaler devices which aim to address adherence issues. These smart inhalers include technologies that can assist measurement of medication adherence by enabling tracking and recording of when the inhaler was used.[17] Smart inhalers can also be equipped with the capability of sending reminders to patients in regards to taking their medication.[17] Recent innovations in sensor technologies in eyedrop usage for conditions such as Glaucoma have resulted in the design of systems which through their sensor technology can in real-time provide information to clinicians in relation to eyedrop usage.[18] Significant digital health related advancements have also taken place in the area of Diabetes with the introduction of ‘smart’ insulin pens. These can be integrated smart pen systems which are based on refillable cartridge having built-in sensors with real-time wireless communication capability.[19] Smart pens can also have sensors attached to the actual pen. Typically, these smart pens have sensors and a memory that connects to the smartphone application therefore accurately displaying timing of dose administration as well as dose delivered by the device. The application is also capable of generating reminders in relation to the time of injection.[19] The abovementioned upgrades to the Asthma/COPD inhalers, eyedrops and insulin pens are capable of generating data streams of information which can be used to communicate and track medication usage, therefore providing information valuable for measuring medication adherence.

Medication adherence can also be assessed via tele-monitoring or tele-conferences involving patient interviewing and direct observation of medication administration. These methods rely on telephone or computer-assisted communication between patients and health professionals.[20] They allow remote monitoring of patients and can also reach patients living in less accessible areas in a timely manner.[20] Some success has been already demonstrated with telemedicine-based approaches in mental health.[20-22]

Current and future trends in digital solutions

Continuous technology advancements are likely to further advance digital solutions which are aimed at improving assessment and measurement of medication adherence. In this regard, there are a couple of key recent developments that could significantly affect how medication adherence measurement systems are designed and applied in the near future. These include rapidly increasing use of mobile applications, the Internet of Things (IoT) and Artificial Intelligence. Increased use of these technology advancements as well as research focus on these fields can also be seen in Figure 1, which summarizes the number of publiccations indexed in PubMed from 1948-2020 that appear when searched with their respective terms i.e.: ‘mobile applications’, ‘internet of things’ and ‘artificial intelligence’.

There is a significant rise and uptake of mobile devices and smartphones which are becoming increasingly convenient and are integrating new approaches that promote medication adherence.[20] Mobile-device based interventions to address medication adherence are also being received well by patients.[20] Disease specific mobile applications are being designed to address education and medication related issues.

As Huang et al report, of the 143 commercial applications identified with focus on medication management in diabetes, 50% of them included medication-taking reminders.[23] Other mobile applications are designed around enabling text-messaging. These applications facilitate communication between patients and health professionals as well as provide personal health support.[20,24-28] A recent systematic review of randomized controlled trials with meta-analysis identified nine randomized controlled trials with 1159 participants and concluded that mobile-application based interventions may result in positive medication adherence effects.[29] It is expected that by promoting and improving medication adherence, these approaches will also facilitate measurement of medication adherence. Another rapidly developing area of mobile device use in measuring and monitoring medication adherence is around applications designed to receive and communicate information from digital sensor technologies attached to medication delivery devices and containers.[17-19] It is expectable that as mobile technology advances further, in the near future we may see more complex medication adherence measurement systems which will combine patients' medication-taking behavior and alerts/reminders with location, technique of administration, disease specific parameters as well as medication-related outcomes – all communicating into single mobile-device applications.

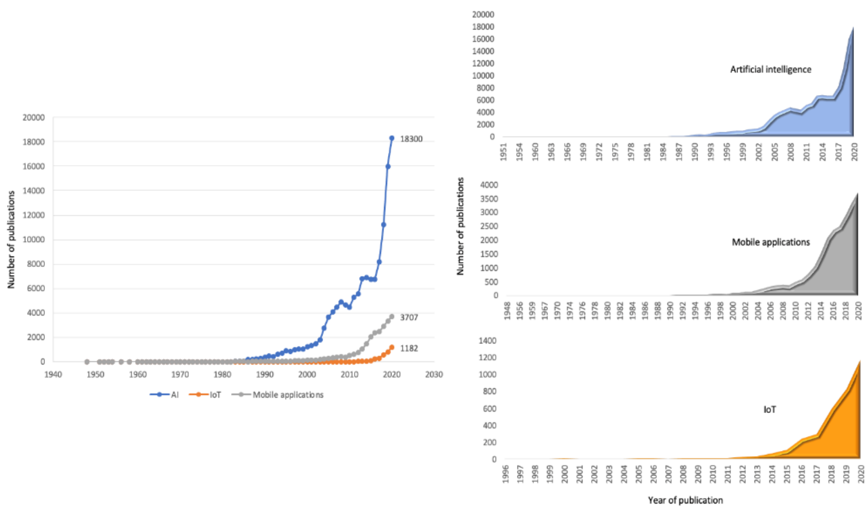

Fig. 1. An illustration of publications with search terms: mobile applications, internet of things and artificial intelligence

a. Internet of Things

The Internet of Things (IoT) has gained attention in healthcare in recent years as having the potential to significantly relieve existing healthcare pressures, especially considering strains caused by aging population and the rise in chronic diseases.[30] There are a number of IoT definitions all of each at its core imply the interaction of digital devices with each other with the aim of collecting and exchanging information.[30-32] Connectivity of devices in IoT is usually achieved via the internet.[33] In healthcare, IoT is currently focused on assisting patient remote monitoring at home, reduce hospital burden and unnecessary use of resources and empower people who live independently.[30] A number of IoT technologies have been developed with focus on various chronic conditions including Diabetes and Parkinson's Disease as well as assisted ambient living for the elderly. [30,34,35] For example, in diabetes, IoT systems have been developed which enable blood glucose monitoring.[34] After analyzing glucose levels, in cases when they are abnormal, the system makes a decision on whether to notify patients, family or health professionals.[30,34] Similarly, IoT based systems have been developed for detection of heart attacks through use of electrocardiogram (ECG) sensor which monitors heart activity.[36] IoT based systems have also proven to be successful during the COVID-19 pandemic. These systems enable remote digital monitoring of patients as well as assist in social distancing, therefore potentially mitigate against the risk of COVID-19 spread.[33,37] The IoT systems use technologies such as wearables, smartphone, bluetooth and vision-based sensors to effectively collect and exchange biometric information needed to monitor and make clinical decisions. Additionally, recent advancements in artificial intelligence (AI) have proven critical to further advance IoT based solutions. For example, a hybrid AI-based system has been developed which uses machine learning algorithm to assess facial features of pain. This information is then digitally combined by user with additional non-facial pain parameters to produce a pain severity score.[38-39] This digital solution has IoT connectively through its open Application Programming Interface (API) capability, allowing it to communicate and integrate with other data management systems.[38-39]

The IoT connectivity capabilities can also be harnessed in assessment and improvement of medication adherence. A number of solutions with IoT connectivity and valuable information needed to assess medication adherence have already been developed. These include systems such as smart-pill bottles, smart insulin delivery and inhaler systems.[4,17,19,40] One can envisage that there will be more medication adherence focused solutions leveraging from IoT infrastructure in the near future. In this regard, Hui et al., recently identified that clinicians are keen to see logs of medication use which would assist them with assessing medication adherence, therefore confirming their potential interest in the uptake of these solutions.[41]

b. Artificial Intelligence

Artificial Intelligence (AI) aims to mimic human intelligence and when applied in health it uses algorithms that approximate cognitive behaviours of clinicians. [42] In order to achieve its purposes, AI uses various techniques including ‘machine learning’ and its subset approach called ‘deep learning’.[43] Generally, these techniques require large amounts of data in order to uncover associations in data, with deep learning technique requiring even larger amounts of data.[43] This data is represented as neural networks in which neurons are interconnected similarly to human brain.[44] Through this process AI based systems can solve complex problems that otherwise require clinicians’ cognitive intelligence with key advantage laying on the capability of these systems to simultaneously observe and analyze limitless data inputs.[44] These unique capabilities coupled with the availability of big data has recently started a ‘revolution’ in development and implementation of many AI based health-related applications.[45] Thus far AI based technologies have been effectively deployed in various digital solutions aimed at disease prevention, prediction, diagnostics, and treatment. [46-48] Furthermore, AI based solutions have been also used in the fight against COVID-19 pandemic in both disease detection as well as tracking and prediction of infection trends.[49] AI has important applications in the area of therapeutics including medication adherence. Figure 2 illustrates a non-exhaustive list of current and potential roles of AI in this space.

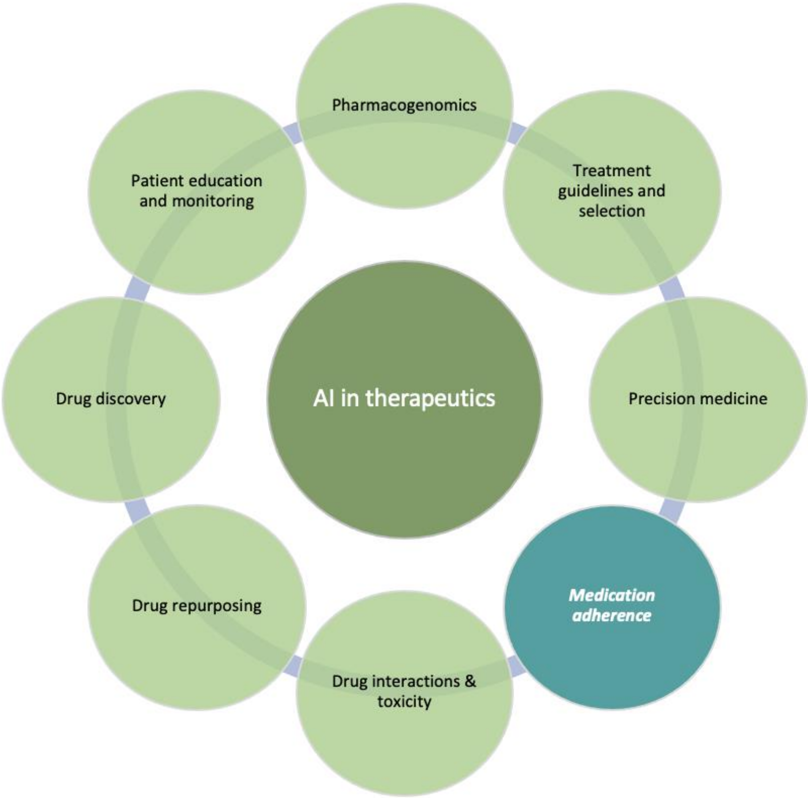

Fig. 2. Current and potential roles of Artificial Intelligence in therapeutics- a non-exhaustive list

Kim et al. show how their AI algorithm can predict tuberculosis medication adherence as well as monitoring.[50] AI-powered visualized medication information interfaces designed and integrated into smartphones have also been proposed to facilitate medication adherence for patients with various chronic conditions.[51] Up to 50% improvement in anticoagulant therapy adherence has been found in patients that were monitored using smartphones. These smartphones had AI-based platform that identified the patient and matched their medication with their actual administration.[52] Similarly, Litwin et al. demonstrated successful application of AI based platform that optimized adherence to antiviral therapy. This platform used smartphones, computer vision and machine learning to monitor adherence by analyzing medication ingestion.[53] A 78.3% accuracy in medication adherence detection was achieved with a user-activity based machine learning system that involved wearable sensors (wrist-band).[54] Zhao & Hoti, et al., recently proposed an AI-based system that automatically assesses self-administration of insulin pens (area under the curve = 0.967) and inhalers (area under the curve = 0.992).[55] This provides valuable information for assessing adherence as well. Their system could also evaluate the technique of administering these devices – another key component needed to assess medication adherence. This was achieved wirelessly without any contact with the patient using radio signal technology.[55]

Overall, multiple AI-based solutions to address medication adherence related issues are emerging rapidly. Their deployment to patients and clinical practice is generally via hybrid systems which also use smartphone and IoT based technologies. These developments can be prone to limitations such as cost, technology failures, cumbersomeness (e.g., wearables) and potential privacy issues. Legal liability of autonomous systems, morality and ethical dilemmas have been also discussed in relation to AI.[42] Nonetheless, the continuously evolving digital solutions are creating a 'smarter' environment which could take existing electronic medication monitoring and alert/reminder systems to another level by enabling timely and remote medication adherence assessment. This is in addition to their potential to facilitate communication with and between health professionals. Figure 3 illustrates such an environment where mobile devices, reminders/alerts, IoT and AI-enabled technologies can synchronize with each other during assessment and monitoring of medication adherence.

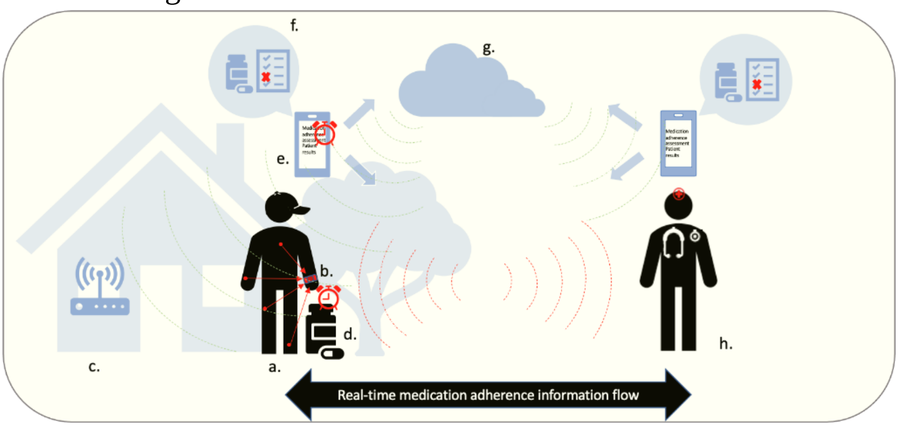

Fig. 3. An IoT environment in which digital solutions assist with real-time assessment and monitoring of medication adherence; a) patient being monitored; b) wearables receiving biometric signals and medication adherence related information from patient and communicating with other digital devices; d) smart medication fitted with digital sensors (e.g. reminders and alerts); e) mobile devices receiving and communicating information relevant to medication adherence; f) medication adherence related information communicated in real time; g) cloud-based systems storing and communicating information; h) health professional receiving and assessing medication adherence information and communicating with patients.

Conclusions

Medication nonadherence remains a challenging issue with important clinical implications, cost and high burden to patients and healthcare systems. More traditional methods of measuring medication adherence rely on direct patient observation which can be time-consuming and invasive whilst other methods are limited by potential recall bias and alterations associated with self-reporting. In the field of medication adherence, digital solutions are quickly emerging and continuously evolving. Many artificial intelligence-based solutions integrated into mobile applications and IoT are being developed which have the capacity to change the landscape of how medication adherence is assessed in the future and how non-adherence is detected. This may contribute to a timely detection of medication adherence which is done remotely and without the need for frequent patient visits to clinics. Many of these solutions are in early stages of development and clinical practice implementation. However, despite their limitations they are promising and could address some of the existing barriers in measurement of medication adherence. Further clinical-practice and implementation-based research is needed to provide more evidence of the effectiveness of these digital solutions in improving medication adherence.

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AVANCIMET NË ZGJIDHJET DIGJITALE QË ADRESOJNË JOADHERENCËN E BARNATIMIT: NJË VËSHTRIM PËR ROLIN NË TË ARDHMEN

Përmbledhje

Adherenca e barnatimit, që i referohet shkallës së përdorimit të barnave nga pacientët në përputhje me udhëzimet e përshkruesit, është një komponentë kyç për optimizmin e menaxhimit të sëmundjeve dhe shumë pacientë dështojnë për ta arritur atë. Kjo rezulton në rritje të hospitalizimeve të pacientëve, mortalitetit, kostos dhe barrës në sistemet shëndetësore. Ekzistojnë një numër faktorësh që kontribuojnë në barrierat që rezultojnë në joadherencë ndaj barnave, por esenciale për të parandaluar dhe zgjidhur këtë problem është vlerësimi dhe monitorimit adekuat i adherencës së pacientëve ndaj barnatimit. Ky artikull është i motivuar nga avancimet e fundit të teknologjisë dhe diskuton për zgjidhjet digjitale që për qëllim kanë adresimin e çështjeve që ndërlidhen me adherencën e barnatimit me theks në vlerësimin dhe monitorimin. Në përgjithësi, literatura sugjeron se intervenimet digjitale mund ta përmirësojnë adherencën e pacientëve ndaj barnave. Zgjidhjet digjitale që integrojnë aplikacione mobile, IoT (Internet of Things) dhe algoritma të inteligjencës artificiale janë duke kaluar nëpër një fazë të zhvillimit të shpejtë dhe aplikimi i këtyre teknologjive është duke u zgjeruar edhe në fushën e adherencës ndaj barnatimit. Shumë prej këtyre zgjidhjeve digjitale janë ende në fazë të hershme të zhvillimit, shpërndarjes apo implementimit, dhe ato kërkojnë ende hulumtim nga praktika klinike. Megjithatë, deri më tani evidenca sugjeron se zgjidhjet digjitale kanë kapacitet që të adresojnë barriera të rëndësishme ekzistuese dhe potencialisht ta ndryshojnë peizazhin e asaj se si bëhet vlerësimi i adherencës së barnatimit në të ardhmen.

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CHEMICAL COMPOSITION OF THE ESSENTIAL OILS OBTAIND FROM NEEDLES AND TWIGS OF ABIES ALBA AND ABIES BORISI-REGIS GROWING IN KOSOVA

Abstract

The principal aim of this study was to determine the chemical composition of the essential oils obtained from needles and twigs of silver fir (*Abies alba* Mill.) and Bulgarian fir (*Abies borisii-regis* Mattf.) growing in Sharr Mountain, Kosova. GC-MS and GC-FID were used for qualitative and quantitative analysis of volatile secondary metabolites in the plant material. In both species monoterpenes were the principal constituents of essential oils. Principal constituents in respective organs, needles and twigs, of *A. alba* were Limonene, followed by β-Pinene, Bornyl acetate, α-Pinene, Camphene, γ-Eudesmol, β-Caryophyllene etc.; while in needles and twigs of *A.borisii-regis* the principal constituents were Limonene, followed by β-Pinene, α-Pinene, Bornyl acetate, Camphene, β-Caryophyllene, γ-Eudesmol, etc. In order to assess if the variability of essential oil composition can be used to reflect chemotaxonomic differences between the species, and to assess the variability between the plant organs, Principal Component Analysis algorithms were used.

Keywords: Silver fir, Bulgarian fir, essential oils, variability

Introduction

Silver fir or European fir (*Abies alba* Mill., Pinaceae) is large coniferous tree species that occurs mainly in many mountainous regions of eastern, western, southern and central Europe [1]. The silver gray trunk is smooth, with 200–260 cm diameter at breast height [2]. The tree grows up to 60 m tall, making it among the tallest tree species of the genus *Abies* in Europe [3]. Needle-like leaves are dark green and

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glossy above with two silver green waxy lines beneath, with stomata in 5–8 ranks. Buds are red-brown and slightly pubescent [3].

Abies borisii-regis Mattf. (Pinaceae), known as Bulgarian fir, Kings Boris fir, or Macedonian fir, is native species to the mountains of Balkan Peninsula. The species grows in humid bio-climates at altitudes of 700–1.800 m, in Bulgaria, North Macedonia, Serbia, Kosova and Northern Greece [4, 5]. In Kosova, it grows only in Sharr National Park, near Restelica villages [6]. Regarding the taxonomical identity, some scientists consider *A. borisii-regis* as a hybrid between *Abies cephalonica* and *Abies alba*, naming it *Abies* × *borisii-regis* Mattf. [7-9]. In Greece, this species, together with *A. cephalonica*, is protected *in situ* in various areas [10]. *A. borisii-regis* is an evergreen tree up to 45 to 60 m tall, and trunk 1.5 to 2 m diameter at breast height. The leaves are needle-shaped, 18-35 mm long; 2-3 mm broad and 0.5 mm thick, dark green color at the top and with two blue-white colored bands of stomata the lower surface. The tip of the leaf is usually acute, occasionally with rounded or notched apex. *A. borisii-regis* is very similar to *A. alba*; the principal distinction is that *A. alba* has no stomata on the upper leaf surface and generally has an emarginated leaf apex; occasionally (especially on sun foliage) bears stomata on the distal, upper surface of the leaf, and does not have an emarginated leaf apex [11]. The cones are very similar to those in *A. alba*, but often longer, between 10 and 21 cm long and 3-4 cm broad [11, 12].

Generally fir woods are used in many industry branches. From the crude material, pharmaceutically important turpentine oil can be obtained. In addition, due to their color, fragrance and other suitable properties most of firs have been widely used as the ornamental plants. The essential oils obtained from the leaves of *A. alba* were also used in the past to heal bruises as well as for treating coughs and colds [3, 10]. The fir essential oils, apart from their cosmetic purpose, have been traditionally used for the treatment of infections, respiratory and rheumatic disorders [13-15]. Literature data revealed that the extracts from different parts of *A. alba* are rich in antioxidative polyphenols and demonstrate cardioprotective, antioxidant, free radical scavenging activity, protective effect against atherogenesis, anticarcinogenic effect [16-19]. Furthermore, essential oils obtained from the *A. alba* needles demonstrate antibacterial effect against different bacterial strains and radical scavenging activity [20-24]. The composition of essential oils obtained from needles and twigs of *A. alba* of various provenances has been studied from different groups of scientists [21, 25-32]. In addition, data concerning the composition of oils from *A. alba* cones and seeds are available [24, 33]. On the other hand, concerning the composition of volatile metabolites obtained from *A. borisii-regis*, literature search delivered only few publications [30, 34].

In this work, we report the chemical composition of the essential oils obtained from needles and twigs of *A. alba* and *A. borisii-regis* collected in southern parts of Kosova, aiming to elucidate the chemical variability of essential oils among the two species and among the plant organs in the same species. At the best of our knowledge, there are no published studies that address the variability of essential oils in needles and twigs of *A. alba* and *A. borisii-regis* of Kosova provenance.

Material and Methods

Plant materials

In order to analyze the composition of essential oils, plant material consisting on needles and twigs of *Abies alba* Mill. and *Abies borissi-regis* Mattf. were collected from June to September 2014. Plant materials of the *A. alba* was collected in the Bredhik, near Restelica village (Dragash Municipality) and Gotovushë (Shtërpcë Municipality), whereas plant material of the *A. borisii-regis* was collected only in the Bredhik, near Restelica village. Plant material was dried in shade and in room temperature, and stored in the dark and dry place. Needles (young and mature leaves) and twigs (on year old twigs without leaves), was crushed and hydro-distilled for 3 hours in the Clevenger apparatus. Pale yellow essential oil obtained after distillation was stored in cold and dark place (temperature -18^{o}C) until the analysis.

Qualitative analysis of essential oils

Separation and identification of the essential oils constituents was performed using Gas Chromatography-Mass Spectrometry (GS-MS) analysis (Gas-Chromatograph Agilent 7890A) hyphenated with Mass-Spectrometer (Agilent 5795). Applied Ionization energy was 70eV. Separation was achieved in the chromatographic column HP-5MS (30 m × 0.25 mm, coated, 0.25 μm film thickness). Analytical conditions were: Helium was used as a carrier gas, 1.0 ml/min, isocratic flow, injection temperature, 280°C, injection volume 1.0 μL and the split ratio 1:50. Initial oven temperature of Gas-Chromatograph was kept 60°C for 5 minutes and subsequently temperature was increased from 60°C to 200°C at a rate of 5°C/min.

Quantitative analysis of essential oils

Separation and quantitative determination of the essential oils constituents was performed using Gas-Chromatography-Flame Ionization Detector (GC-FID - Agilent Technologies 7890A). Separation was achieved in the column HP-5 MS (30 m × 0.25 mm, coated, 0.25 μm film thickness). Helium was used as a carrier gas with the initial flow of 0.6 mL/min and subsequently at a constant pressure of 50.0 psi. The initial temperature in GC oven was 60°C, temperature was subsequently increased to 160°C at a rate of 10°/min and 280°C at a rate of 20°/min. FID operated at 250°C with an air flow of 350 mL/min and a hydrogen flow of 35 mL /min. The injection volume was 1.0 μL.

Identification of Essential-Oil Components

Identification of the each components of the essential oil was made by comparing their Kovats retention indices with those in literature. Calculation of the Kovats index was made based on linear interpolation of the retention time of the homologous series of n-alkanes (C9-C20) under the same operating conditions [35]. In addition, the identification of the constituents was confirmed by comparing their mass spectra with those listed in the NIST 08.L and WILEY MS 9th databases and with those from the literature [35].

Statistical Analysis

Principle Component Analysis (PCA) was used to evaluate whether the identified essential oils components can be useful for reflecting the population diversity and chemical variability among the investigated populations and plant organs of *A. alba* and *A. borisii-regis*. The essential oil components with contents higher than 2% of the total oil composition in at least one sample were subjected to PCA and HCA, using the statistical analysis software XLSTAT Version 2014.2.03.

Results and discussion

In total seventy-six components were separated, which are listed in order of their elution from an HP-5MS column (Table 1). Monoterpenes were the most abundant constituents in needles of *A. alba* (56.2-57.3%), while their percentage in twigs were 68.6%-74.1%. Monoterpenes were followed by oxygenated monoterpenes (needles: 16.6%-20.6%; twigs: 4.1%-13.2%), sesquiterpenes (needles: 9.8%-15.8%, twigs: 6.5%-13.2%); percentage of oxygenated sesquiterpenes were 6.7%- 9.4% in needles and: 5.5%- 9.0% in twigs (Table 1). Similar results were obtained for *A. borisii-regis.* Monoterpenes were dominant constituents (needles: 65.1%; twigs 82.8%), followed by oxygenated monoterpenes (needles: 22.4%; twigs 6.7%), sesquiterpenes (needles: 5.7%; twigs: 5.8%), and oxygenated sesquiterpenes (needles: 3.9%; twigs: 2.9%).

In both species and both organs, Limonene was the most abundant compound. In *A. alba* needles its concentration was 30.5-31.2% and in twigs, 36.1-38.7%; while in *A. borisii-regis* the average percentage in needles was 34.9%, whereas in twigs 42.4% (Table 1). The other prominent constituents in respective organs, needles and twigs, in *A. alba* were: β-Pinene, 11.4-15.0% and 17.2-17.7%; Bornyl acetate, 12.9-17.9% and 0.84-9.2%; α-Pinene, 4.7-4.9% and 11.2-17.2%; Camphene, 5.9-7.4% and 0.5-2.7%; γ-Eudesmol, 3.0-6.2% and 0.7-4.6%; and β-Caryophyllene, 3.0-4.5% and 1.8-2.7%. On the other hand, similar results concerning the percentages of most abundant constituents were obtained for *A. borisii-regis*. As mentioned above, the principal constituents in needles and twigs were: Limonene; followed by β-Pinene, 14.7% and 18.6%; α-Pinene, 5.4% and 19.9%; Bornyl acetate, 2.2% and 18.9%; Camphene, 1.6%-8.48%; and β-Caryophyllene, 1.4% and 1.6%.

Hence, the order of abundance of the most prominent constituents found in needles and twigs of *A. alba* was: Limonene > β-Pinene > Bornyl acetate > α-Pinene > Camphene > γ-Eudesmol > β-Caryophyllene; whereas in *A. borisii-regis*, the order of abundance was: Limonene> β-Pinene> α-Pinene> Bornyl acetate> Camphene> β-Caryophyllene> γ-Eudesmol.

In accordance with our study, literature data addressing the composition of volatile secondary metabolites obtained from the different organs of *A. alba* revealed that monoterpenes were the most prominent constituents. In samples of *A. alba* twigs from Corsica, Limonene, β-Phellandrene, α-Pinene, Camphene and β-Pinene were found to be the major components [25, 32]. In *A. alba* originating from Poland the major component of the seed essential oil was Limonene, while α-Pinene was the principal component of the cone scale oil [24, 33]. The principal components of commercially available oils obtained from the Korean *A. alba* were Bornyl acetate > Camphene > 3-Carene > Tricyclene > Limonene > α-Pinene [21]. In *A. alba* samples (leaves) from different locations of

Albania, α-Pinene, Camphene, ß-Pinene, Limonene and Bornyl acetate were the most prominent constituents; whereas in cortical oleoresin, the major components were α-Pinene, ß-Pinene, Limonene, ß-Caryophyllene and Germacrene D [26]. Similar results were reported for Romanian samples. Main compounds identified in volatile oil sample of leaves of *A. alba* were: α-Pinene (30.2%), β-Pinene (31.1%); Camphene (15.2%), Limonene (10.1%), Bornyl acetate (4.1%), Tricyclene (1.65%) [31]. In commercial essential oil obtained from leaves and branches of *A. alba* originating from Montenegro the main constituents were β-Pinene (32.8%), α-Pinene (17.3%), Camphene (16.7%), Bornyl acetate (9.0%), Limonene (6.1%) and β-Phellandrene (4.9%) [29]; whereas in *A. alba* samples originating from west Serbia the most prominent constituents were: β-Pinene (19.8%), Camphene (15.3%), α-Fenchyl acetate (14.2%), Limonene (11%) and α-Pinene (10.9%) [30].

In general, experimental results of our study are in accordance with the published literature data obtained from samples *A. alba* of European, particularly Balkan origin. Comparing with Albanian samples, essential oils obtained from needles the most prominent constituents are same. Similar results are obtained from Romanian samples, as well. The samples of Montenegro provenance qualitatively differ only in one constituent (β-Phelladrene), which has been not detected in our samples; whereas in *A. alba* samples originating from west Serbia α-Fenchyl acetate has been reported to be present in relatively high amount comparing to our samples where it could not be detected.

Comparison of our results with data addressing the composition of essential oils of *A. borisii-regis* samples originating from different locations delivered similar results. In *A. borisii-regis* samples grown in natural forests, in Katara and Trikala, west Greece, monoterpenes were the most prominent constituents and Limonene (22.5%), β-Pinene (11.4%), Camphene (10.2%), α-Pinene (8.2%), α-Fenchyl acetate (5.4%) were principal compounds [30]; while in samples grown in natural population, in Mt. Athamanika, Greece: Limonene (46.45%), Caryophyllene oxide (7.05%), α-Pinene (3.30%), β-Pinene (2.57%) and Junipene (2.55%) were the principal compounds [34]. Concerning the percentages of the most abundant constituents, found in *A. borisii-regis* of Kosova provenance, experimental data are in agreement with data originating from Greece samples. Exception is Junipene, which was present in low amount and α-Fenchyl acetate which is not detected in Kosova samples.

Table 1: Composition (%) of the needles and twigs oils of *Abies alba* and *Abies-borisii-regis* from different locations from Kosova.

		Abies alba				*Abies borisii-regis*	
		Needles		Twigs		Needles	Twigs
KI[a]	Compounds[b]	Goto-vushë	Reste-licë	Goto-vushë	Reste-licë	Reste-licë	Reste-licë
926	Tricyclene	0.7	0.94	0.27	tr	0.93	0.18
940	α-Pinene	4.72	4.98	11.28	17.2	5.41	19.94
948	Camphene	5.97	7.35	2.74	0.57	8.45	1.63
979	β-Pinene	15.02	11.39	17.71	17.2	14.85	18.49
990	Myrcene	0.18	0.15	0.29	0.26	0.20	0.16
1024	p-Cymene	-	tr	tr	tr	tr	tr
1031	Limonene	30.51	31.19	36.13	38.67	34.93	42.37
1033	1, 8-Cineole	tr	tr	tr	-	tr	-
1064	Unknown 1	0.18	0.25	0.21	tr	0.35	0.13
1088	α-Terpinolene	0.15	tr	tr	-	0.17	-
1095	6-Camphenol	-	-	tr	-	tr	-
1098	Linalool	tr	0.11	0.18	0.15	0.12	0.24
1125	α-Campholenal	0.14	0.13	0.61	0.65	0.13	1.1
1139	trans-pinocarveol	tr	tr	0.22	0.27	tr	0.57
1146	Camphor	tr	tr	0.23	0.20	tr	0.28
1153	neo-3-Thujanol	1.15	1.95	0.63	0.37	1.69	0.37
1164	Pinocarvone	tr	tr	tr	tr	tr	tr
1165	Borneol	0.62	0.7	0.82	0.35	1.12	0.3
1177	Terpinen-4-ol	tr	tr	-	0.28	tr	0.48
1185	Crypton	tr	tr	0.65	0.36	tr	0.53
1188	α-Terpineol	tr	tr	0.19	0.17	-	0.31
1195	Myrtenol	tr	tr	tr	0.13	-	0.11
1214	iso-Dihydro-carveol	-	-	tr	-	-	-
1230	cis-p-Mentha-1(7) 8-dien-2-ol	tr	tr	tr	tr	tr	tr
1243	Bornyl acetate	17.9	12.85	9.17	0.84	18.87	2.2
1336	Presilfiperfol-7-ene	0.22	0.43	0.12	-	0.52	tr
1338	δ-Elemene	tr	0.13	-	0.25	-	0.11
1346	trans-Piperitol acetate	0.31	0.44	0.19	0.18	0.11	0.15
1352	β-Terpinyl acetate	tr	tr	-	-	-	-
1352	α-Longipinene	tr	tr	tr	0.13	-	tr
1375	α-Yalangene	tr	0.12	tr	-	-	-
1376	α -Copaene	tr	0.26	-	0.24	0.13	0.11
1391	β-Elemene	-	tr	-	0.15	0.11	tr
1407	Longifolene	tr	0.16	-	-	-	-
1416	Junipene	0.24	0.33	0.14	0.14	tr	0.11

		Abies alba				*Abies borisii-regis*	
		Needles		Twigs		Needles	Twigs
KI[a]	Compounds[b]	Goto-vushë	Reste-licë	Goto-vushë	Reste-licë	Reste-licë	Reste-licë
1418	β-Caryophyllene	3.03	4.49	1.82	2.69	1.61	1.35
1431	cis-Thujopsene	0.77	1.39	0.40	0.36	0.25	0.22
1454	α-Caryophyllene	1.63	2.09	1.02	1.27	0.82	0.65
1467	Ethyl cinnamate	-	tr	-	tr	-	-
1477	γ-Gurjunene	0.13	0.21	tr	tr	tr	-
1479	γ-Muurolene	tr	0.16	tr	tr	0.11	0.04
1481	Germacrene D	0.16	0.38	0.22	1.51	0.15	0.62
1483	α-Amorphene	0.30	0.24	0.15	-	tr	tr
1490	β-Selinene	0.06	0.15	0.79	2.86	0.28	0.69
1492	δ-Selinene	0.41	0.42	0.15	-	tr	-
1492	cis-β-Guaiene	0.39	1.01	-	0.29	0.29	0.20
1498	α-Selinene	0.91	0.51	0.70	0.31	0.28	0.21
1506	Unknown 3	0.57	0.99	0.29	0.18	0.34	0.14
1513	γ-Cadinene	0.11	0.26	tr	0.41	tr	0.16
1515	Cubebol	0.32	0.37	0.21	0.11	0.19	tr
1524	Unknown 4	0.41	1.28	0.24	1.07	0.33	0.50
1523	δ-Cadinene	0.99	2.69	0.65	2.15	0.8	0.91
1534	trans-Cadina-1, 4-diene	-	tr	-	tr	-	tr
1538	α-Cadinene	-	0.11	-	tr	-	-
1545	α-Calacorene	tr	0.15	tr	0.15	-	tr
1566	Dodecanoic acid	tr	tr	tr	tr	tr	tr
1570	Unknown 5	-	-	-	tr	-	-
1578	Unknown 6	-	tr	tr	0.25	-	0.12
1583	Caryophyllene oxide	0.89	0.83	0.97	1.86	0.41	1.16
1600	Guaiol	0.52	0.39	0.55	1.05	0.22	0.59
1617	Unknown 7	tr	0.12	tr	tr	tr	tr
1630	γ-Eudesmol	6.23	2.98	4.62	0.69	1.99	0.74
1640	epi-α-Cadinol	0.11	0.26	tr	tr	0.13	tr
1636	cis-Cadin-4-en-7-ol OST	0.39	0.45	0.32	0.22	0.29	0.16
1646	Cubenol	0.24	0.98	0.18	0.26	0.42	0.16
1646	Allo-Aromadendrene epoxide	0.19	0.30	tr	0.19	0.30	-
1659	Unknown 8	0.38	tr	0.19	-	-	-
1661	Unknown 9	0.12	0.81	0.25	0.67	0.49	0.52
1663	7-epi-α-Eudesmol	0.85	0.36	0.66	-	0.15	0.05
1680	Kusinol	-	0.11	-	-	-	-

		Abies alba				*Abies borisii-regis*	
		Needles		Twigs		Needles	Twigs
KI[a]	Compounds[b]	Goto-vushë	Reste-licë	Goto-vushë	Reste-licë	Reste-licë	Reste-licë
1688	Eudesma-4(15), 7-dien-1-β-ol	-	tr	-	tr	-	-
1688	Unknown 10	-	-	-	-	tr	-
1701	Caryophyllene acetate	-	-	-	0.83	-	-
1717	E-Nerolidol acetate	-	-	1.39	0.15	tr	-
1845	2E, 6E-Farnesyl acetate	-	-	-	0.16	-	-
2156	Unknown 11	-	-	0.98	0.59	-	-
	Yield (% w per dry weight)	1.0-1.3	0.7-1.0	0.4-0.6	0.4-0.6	1.0-1.3	0.7-1.0
	Total identified	99.22	99.27	99.68	99.96	98.84	99.86
	Monoterpenes %	57.33	56.15	68.55	73.98	65.05	82.81
	Oxygenated monoterpenes%	20.63	16.6	13.17	4.11	22.35	6.74
	Sesquiterpenes %	9.81	15.83	6.49	13.2	5.68	5.81
	Oxygenated sesquiterpenes %	9.41	6.68	8.96	5.52	3.94	2.92
	Unidentified and non terpenoid compounds	1.8	3.69	2.33	3.04	1.65	1.51

[a]Kovats indices calculated against a mixture of C9- C28n alkanes on the HP-5MS column. [b]Compounds are listed in order of elution from a HP-5MS column. tr = trace < 0.1%. "-" =compound not detected.

Statistical analysis

Relevant statistical techniques have been carried out in order to assess if the composition of identified essential oils constituents can be used to reflect differences between the species from the chemotaxonomic point of view, and the variability between the plant organs of species, *A. alba* and *A. borisii-regis*. Principal component analyses (PCA) data, based on the percentages of the principal constituents of essential oils obtained from needles and twigs of both species, clearly shows that there are two main groups, respectively on the left of figure 1 are grouped the samples obtained from needles, whereas on the right part samples obtained from twigs. But there were not significant differences between two species, neither their locations.

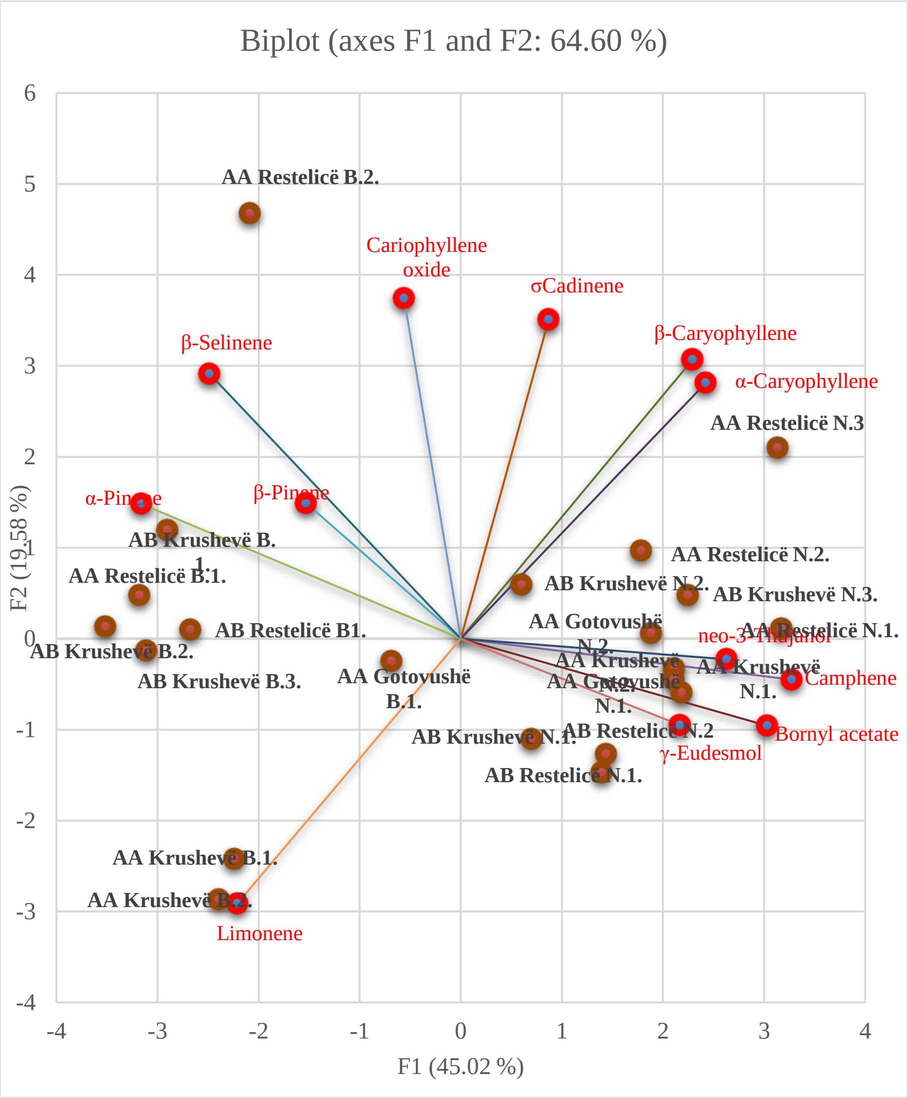

Figure 1: Principal component analysis of the essential oil constituents obtained from needles and twigs of *Abies alba* and *Abies borisii-regis* (AA - *Abies alba*, AB - *Abies borisii-regis*, N - needles, T - twigs, Got- Gotovushë, Res- Restelicë)

Conclusion

Chemical variability of essential oil constituents obtained from needles and twigs of two species, *A. alba* and *A. borisii-regis* growing in natural forests of Kosova has been reported in this study. Experimental data obtained were in agreement with the data obtained from the same species of different provenance in Balkan region. Therefore, monoterpenes were the principal constituents; Limonene, β-Pinene, Bornyl acetate, α-Pinene, Camphene, γ-Eudesmol, and β-Caryophyllene were the most prominent volatile compounds. The percentages of volatile constituents were higher in twigs comparing to needles, regardless of the species studied. PCA did not show significant differences between species neither their locations. On the other hand the algorithms employed confirmed the differences of constituents in different organs of trees.

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Behxhet Mustafa, Dashnor Nebija, Avni Hajdari

PËRBËRJA KIMIKE E VAJËRAVE ESENCIALE TË PËRFTUARA NGA GJETHET DHE DEGËT E BREDHIT ABIES ALBA DHE ATIJ ABIES BORISI-REGIS QË RRITEN NË KOSOVË

Përmbledhje

Qëllimi kryesor i këtij studimi ishte përcaktimi i përbërjes kimike të vajrave esenciale të ekstraktuara nga gjethet dhe degët e bredhit (*Abies alba* Mill.) dhe bredhit bullgar (A*bies borisii-regis* Mattf.), të cilat rriten në Malin e Sharrit, në Kosovë. Për analizën cilësore dhe sasiore të metabolitëve sekondarë të avullueshëm janë përdorur GC-MS (Gas-Kromatograf me detektor të spektrit të masës) dhe GC-FID (Gas-Kromatograf me detektor jonizues me flakë). Te të dy llojet, monoterpenet ishin përbërësit kryesorë të vajrave esenciale. Përbërësit kryesorë në gjethet dhe degët e *A. alba* ishin *Limoneni, β-Pineni, Bornil acetati, α-Pineni, γ-Eudesmoli, β-Kariofileni* etj.; ndërsa në gjethet dhe degët e llojit *A. borisii-regis*, përbërësit kryesorë ishin *Limoneni*, β-*Pineni, α-Pineni*, *Bornil acetati, Kamfeni, β-Kariofileni*, *Eudesmoli* etj. Në mënyrë që të vlerësohet nëse ndryshueshmëria e përbërjes kimike të vajrave esenciale mund të përdoret për të pasqyruar dallimet kimo-taksonomike ndërmjet specieve dhe për ta vlerësuar ndryshueshmërinë e përbërjes kimike të vajrave esenciale mes organeve të bimëve të analizuara, është përdorur analiza e komponentëve parësorë (*Principal Component Analysis*).

KDU 616.9(05)

Zeqir Veselaj*

STUDENT'S PERCEPTIONS ABOUT ENVIRONMENTAL IMPACTS OF THE COVID-19 LOCKDOWN IN KOSOVA DURING THE PERIOD MARCH-MAY 2020

Abstract

The COVID-19 pandemic caused humanity's most severe global isolation in the history of viral diseases. Like all areas of life, the pandemic and lockdown disrupted the education system, including the teaching process at the Faculty of Education. The initial monitoring data has also shown positive and negative impacts of the lockdown thoroughout the world. This research analyzed students' observations on the environmental impacts of the first lockdown in Kosova during the period March-May 2020. It used a quantitative approach by distributing an online questionnaire as a research instrument. The research sample consisted of 339 students of Bachelor teacher education programs of the Faculty of Education, from urban and rural areas.

About half of the students evaluated Kosova's environmental situation and its problems in comparaison with other countries of the region. The findings provide evidence that main environmental problems are waste generation and air pollution, while a huge discrepancy between local and global level is noticed for climate change as problem. Surprisingly, one-third of the students believe that the pandemic originated from the war between the world’s economic powers. Nonetheless, study findings also report improvements in the environmental parameters such as: ambient air quality, the level of outdoor noise and fuel consumption reduction. Moreover, increased consumption of resources with environmental impact is observed in water, hygiene products~~,~~ and food~~s~~. More than half of the students rated operations of the public safety institutions, health institutions, and public utility companies with excellent performance. Lower percentage of students rated with highest grade the central and local government institutions while the behavior of citizens is rated with lower satisfaction. A majority of students, expect post-pandemic improvement of the situation in three pillars of sustainable development: economy, social situation, and environment.

Keywords: COVID-19, environment, lockdown, pandemics, perceptions

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Introduction

The COVID-19 pandemic is shown to be the most severe health emergency of the 21st century and the greatest challenge for humankind since World War II. With a single search in Google machine, you will get about 4.8 billion results. Prior to COVID-19, the world experienced several epidemics, including epidemic of SARS in 2002 that caused 800 deaths out of about 8,000 cases, H1N1 pandemic in 2009 with 18,500 deaths, MERS epidemic in 2012 with 800 deaths out of 2,500 cases, and Ebola outbreak in 2014 with 28,616 cases and 11,310 deaths [1]. A new class of coronavirus, known as SARS-CoV-2 is responsible for the current pandemics. The first coronavirus, the avian infectious bronchitis virus, was isolated by Fred Beaudette in 1937 [2]. Scientists are now aware of dozens of strains, seven of which infect humans [3]. Among the four that cause common colds, two of them evolved from rodents and the other two from bats. Three viruses that cause severe disease: SARS-CoV (the cause of SARS), MERS-CoV, and SARS-CoV-2 originated from bats. Scientists think there is usually an intermediary- an animal infected by the bats that carry the virus into humans. With SARS, the intermediary is thought to be civet cats sold in live-animal markets in China [4].

The outbreak of the new coronavirus (COVID-19) started in the city of Wuhan in China [5]. SARS-CoV-2 can attack human cells at multiple points, with the lungs and throat being the main targets. Of the viruses that attack humans, coronaviruses are the most severe. At 125 nanometers in diameter, they are also relatively large RNA viruses, with 30,000 genetic bases. They represent the largest genomes of RNA viruses [3]. Although the known human coronaviruses can infect many cell types, they all mainly attack respiratory organs. Different from four viruses that cause common colds and easily attack the upper respiratory tract, MERS-CoV and SARS-CoV are more successful at infecting cells in the lungs. SARS-CoV-2, unfortunately, can do both very efficiently.

The virus's ability to infect and actively reproduce in the upper respiratory tract was something of a surprise, given that its close genetic relative, SARS-CoV lacks that ability. SARS-CoV-2 can shed viral particles from the throat into saliva even before symptoms start, and these can then pass easily from person to person [6]. These infections emerged in December 2019, in Wuhan (China), and WHO named the disease Covid-19 (Corona Virus disease 2019) [7]. Three months later, WHO categorized COVID-19 as a pandemic, and reiterated that countries should do everything possible to stop the outbrea [8]

From the very beginning of civilization, humans gradually transformed nature for their benefit. As an inevitable consequence, environmental pollution and degradation reached alarming levels today. Environmental concerns of the modern era include air pollution, water scarcity and pollution, climate change, ozone layer depletion, global warming, depletion of groundwater level, loss of biodiversity, waste etc. [9,10].

Due to the unusual outbreak of COVID-19, almost all affected countries decided on a partial or total lockdown, see Table 1. All countries worldwide have banned the free movement of citizens outside their homes to avoid transmission. The various religious, cultural, social, scientific, political and sport mass gathering events are canceled. Various types of industries shut down while all types of travel are canceled during the lockdown.

Table 1. Number of cases globally and in Kosova until May 31, 2020, since the outbreak started

	First case	**Nr. of infections**	**Nr. of deaths**
Global level [11]	Dec. 31, 2019	5,817,385	362,705
Kosova [12]	Mar. 13. 2020	1,083	30

Due to partial or total non-functioning of industry, transport and other pollution streams, significant changes in the environment are noticed during the lockdown. As industries, companies and transport activities have stopped their operations, it has brought a sharp drop in greenhouse gas (GHGs) emissions. Compared with the same period of 2019, levels of air pollution in New York have reduced by nearly 50% because of measures taken to control the virus spread [13]. The European Environmental Agency predicted that, because of the COVID-19 lockdown, NO_2 emission dropped from 30-60% in many European cities such Barcelona, Madrid, Milan, Rome, and Paris [14]. In the USA, NO_2 emissions declined by 25.5% during the lockdown compared with the previous year [15].

Regardless of how virus is spread, scientists are discussing two main differences between air quality and COVID-19. First, the reduced economic activity coupled with early lockdown measures has curbed pollution of air at fairly noticeable rates. The results can be assessed as a "pilot test" of frequently proposed policy reforms to curb air pollution, particularly emissions from transport. Secondly,—the more the populations are subject to respiratory problems and exposed to air pollution, the more vulnerable they are to COVID-19.

In addition, water quality is improved. Due to the lockdown, the Grand Canal of Italy cleared and enabled the reappearance of many aquatic species. Water pollution is also reduced in the beach areas of Bangladesh, Malaysia, Thailand, and Indonesia[13]. [16] reported the reduction of the amount of food waste, which ultimately reduces soil and water pollution. The amount of industrial water consumption and discharges are reduced around the globe [17]. Huge amounts of solid waste responsible for water and soil pollution generated from construction and manufacturing processes are also reduced. The COVID-19 lockdown measures forced people to stay at home reducing communication worldwide, which ultimately reduced noise levels [18].

Monitoring of air quality by the Kosova Environmental Protection Agency, also show a reduction of air emissions by 50% during the period March-April 2020 compared with the same period of 2019. In the Table 2 are presented concentrations of NO_2 and $PM_{2.5}$.

Table 2. Concentrations of NO_2 and $PM_{2.5}$ during March-April 2019 and 2020 [19].

	NO_2	**$PM_{2.5}$**		**NO_2**	**$PM_{2.5}$**
March 2019	30 µg /m^3	21.7 µg /m^3	**April 2019**	23.7 µg /m^3	17 µg / m^3
March 2020	15 µg /m^3	14.9 µg/m^3	**April 2020**	10.4 µg /m^3	10 µg /m^3

Methodology

The purpose of this research is to analyze the students perceptions about observed positive and negative changes in the environment during the time of lockdown March-May 2020. The main research question is: what are the students’ observations regarding changes in the resources consumption and the indirect environmental pressures that it generated like water use, waste generation, air pollution, climate changes, etc. during the period of lockdown? The research used a quantitative approach with a survey design. An online questionnaire was used as instrument for data collection. The questionnaires were filled out in May 2020, by 339 bachelor students of the University of Prishtina, Faculty of Education, studying in four programs: Early childhood, Preschool, Primary Education and Pedagogy. Out of the total, 95.8% of students are female, while 4.2% are male. Most of the students (58.9%) are from rural areas, while 41.1% are from urban areas.

Results

This research was realized in the last week of the first lockdown in Kosova that lasted from mid March-May 2020. Initially, the students gave their opinions regarding the environment in sense of better, worse, or the same situation comparing with other countries of the region. Out of the total, 48.2% of students-considered environmental situation same as that in other countries of the region, 26.5% worse than in the region, while 21.4% consider country environment better than in other countries of the region. In addition, the students have been asked to choose three main problems that mostly affect the environment, both at the global and national level. Responses on this issue are presented in graph shown in the Figure 1.

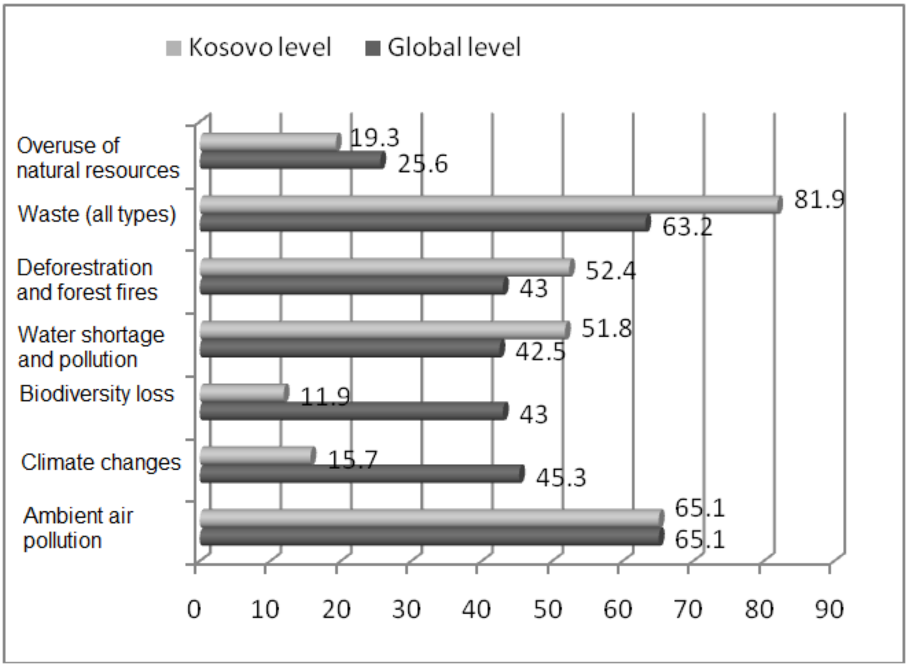

Fig. 1. Ranking of three environmental problems in global and Kosova level

Data from the graph show that the majority of students consider ambient air pollution as the biggest problem at the global and Kosova level. The three biggest environmental problems at the global level are ranked: ambient air pollution (65.1%), waste pollution (62.85%), and climate changes by 45.3% of students. At the country level, the three main environmental problems are: waste pollution (81.2%), ambient air pollution (65.1%), and deforestation (52.4%). The biggest discrepancy for a specific environmental problem is observed about the climate change: as a global problem regarded it 45% of students while only 15.7 % mentioned it as a country problem for Kosova.

Students have been required to give their opinions about the origin of the virus and if they see any connection with environmental factors such as climate changes, nature degradation, overconsumption, and pollution. Results are presented in the Figure 2.

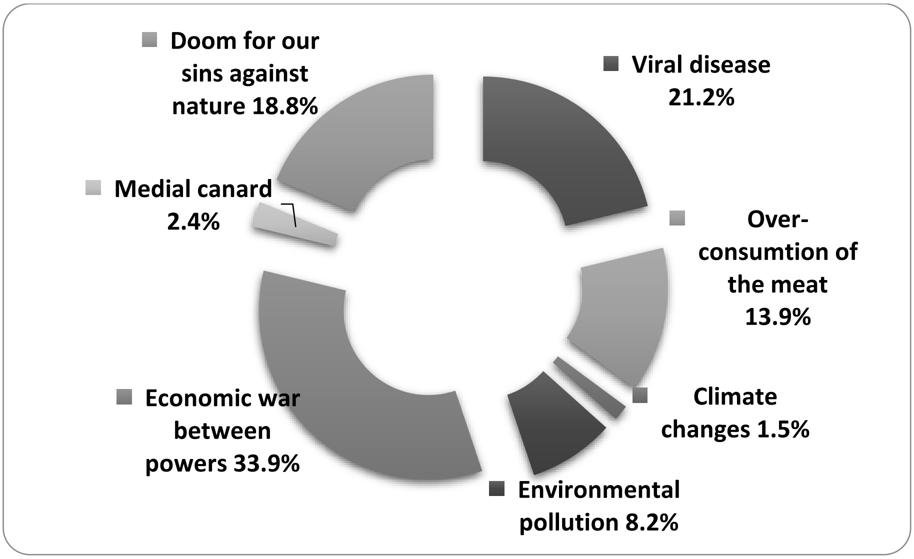

Fig. 2. Sources of COVID-19 pandemics according to the students

Surprisingly, 33.9% of students perceive the virus outbreak as an economic war between the world's powers. The second group, or 21.2%, connect pandemics with a viral disease-and 18.8% of students consider the pandemic as a "doom" for the abuse humans caused to nature. Overconsumption of meat is considered as a source of the virus for 13.9% of students. Only 1.5% of students find some connections between the outbreak and climate changes.

Figure 3 shows the observations on changes of some parameters with impact on environment. An increase in resource consumption is observed in food, water, hygiene products, and energy. The largest increase is identified in water consumption (63.1%) and hygiene products (63.1%).

An increase in the waste generation is observed by 53.2% of students. In connection to this, an increase in food consumption is estimated by 50.2% of them. Decrease of emission with impact on the environment is observed in the air pollutant emissions, fuel consumption, and outdoor noise. The biggest improvement has undoubtedly been assessed in the ambient air quality: 87.3% of students estimated that air pollution improved during the lockdown. This is related to the second parameter: fuel combustion reduction is observed by 78.6% of students. Total lockdown led to the improvement of outdoor noise (76.2% of students).

Remained at the same level as before the lockdown: drug consumption for 69.9% of students, indoor noise for 62.2%, indoor air quality for 62%, and energy consumption ~~by~~ for 51.7% of them.

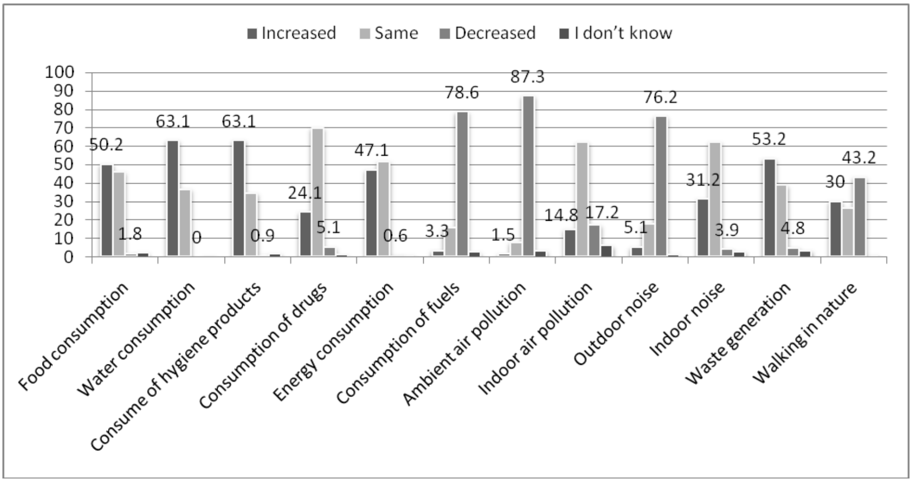

Fig 3. Perceptions about the increase and decrease of parameters with impact on the environment

The research wanted to measure the satisfaction of students with the work of public institutions in charge of health, security, and environment. Results are presented in Figure 4. They show that institutions have generally been perceived as meeting their reponsibilities. The highest rating (grades 5), by 61.1% of students, is given to the institutions of public security (police, army, firefighters), whereas 54.8% of students have rated health institutions (medical staff) in the second place.

More than 50% of students have considered the energy supply company (52%) and the waste company (50.3%) to have delivered outstanding performance. Lower satisfaction is observed with the performance of central government, where only 34.5% of students rated with grade 5, 40.6% for municipal government and 47.7% for the water supply company. Lowest satisfaction is shown for the behavior and responsibility of the citizens when only 4.5 % of students rated it with grade 5 while more than half of them (52.4%) rated with an average grade (3).

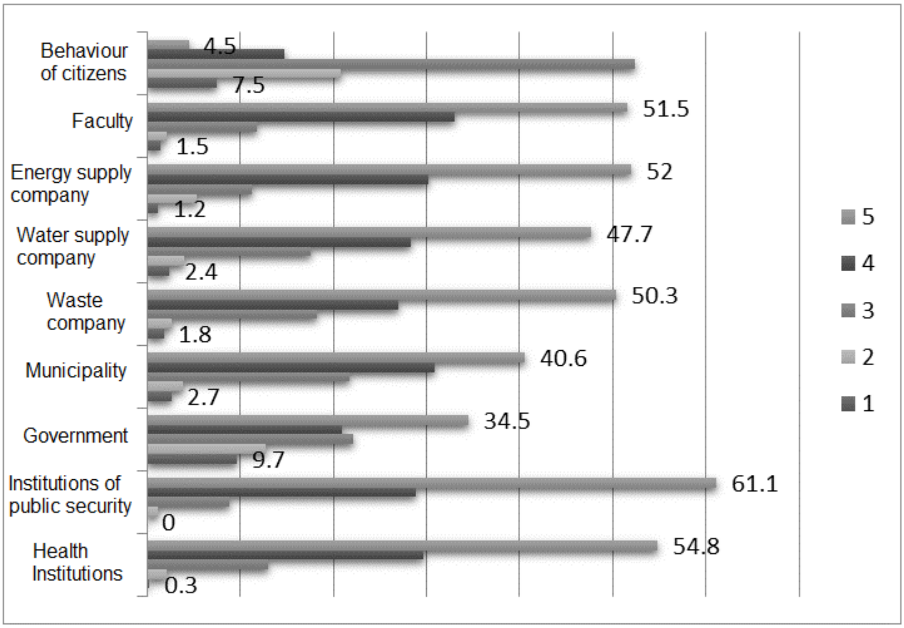

Fig. 4 Assessment (grades from 1-poor to 5-excellent) about the responsibilities of public institutions and citizens during the lockdown

The research has also analyzed students' expectations in regard to the improvement or decline of the situation after the pandemics in three pillars of sustainable development, including economy, social issues, and environment. The results of this section are presented in the Figure

5. From the collected data, improvement of the economy is expected by 29.7%, and significant improvement by 15.6% of students. The deterioration of the economic situation is expected by 31.2% and a significant decline by 13.2% of students. Regarding the social situation, 46.5% of students expect improvement, while 26.% expect significant improvement. The downturn of the social situation is expected by 12.2% of the students, with 2.4% anticipating a major decline. Regarding the environmental improvement or decline, 48.9% of students expect improvement, 27.3% expect significant improvement after the pandemic. The decline of the situation is expected by 12.3%, while 8.3% of the students expect stagnation.

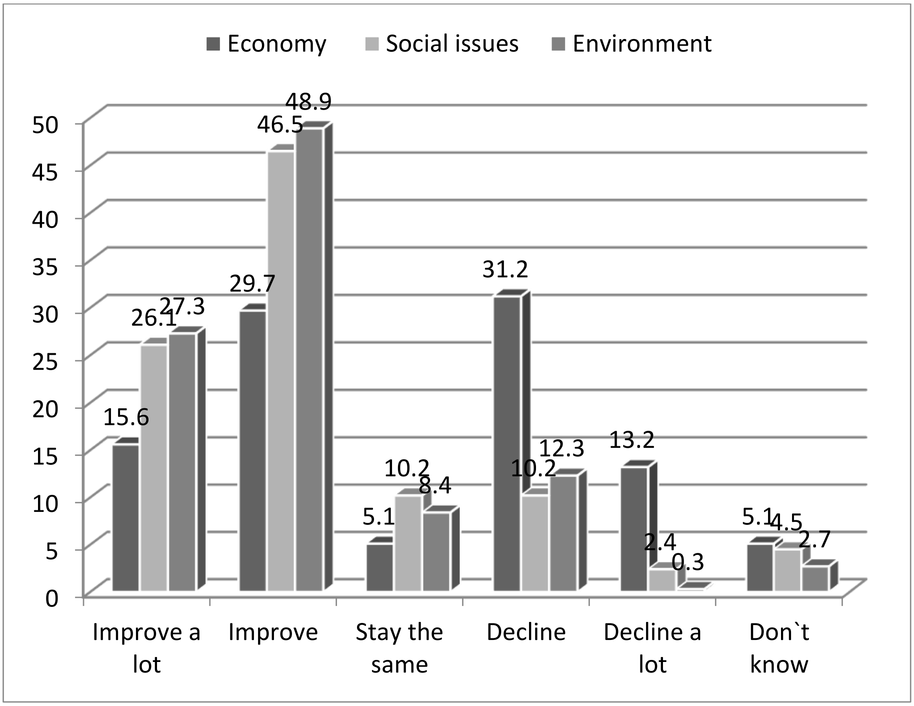

Fig. 5 Expectation of developments after the pandemic in three pillars: economy, social isssues, and environment

Discussion

The first case of COVID-19 infection in Kosova is registered on March 13, 2020 followed by the lockdown of the country two days later.

In the first weeks of the outbreak, it has been a widespread misconception in our society that COVID-19 is “just another type of flu”. This led citizens to take the danger of the virus lightly, whose full implycations were not fully known, and against which immune mechanisms (vaccine) had not yet been developped. Also, it was a general discussion that virus outbreak may be a kind of economic battle between powers (China, USA, and EU). Most students have not found connections between the virus origin and the environmental factors such as pollution, overconsumption of resources, climate changes etc. The lowest number of students connected virus outbreak with climate changes, and this can be interpreted as very low understanding of climate changes. This understanding also supports a huge discrepancy of climate change categorization as a problem at global and Kosova level.

Regarding the environmental impact of the lockdown, the increase in water consumption connected with requirements for hand washing after every contact, raises the issue of scarcity of water resources in Kosova. Conversely, the increase in consumption of hygiene products contributes to the chemical pollution of water bodies, considering that Kosova has no developed water waste treatment system. Increased waste generation is connected with the panic of the outbreak in a country that most of the food products are imported. This fact prompted people to purchase more food and goods that created food stocks.

Similarly to other parts of the world, reduced fuel consumption for transport, industry, etc., and many other polluting activities resulted in the improvement of ambient air quality in Kosova as for the rest of the world. Another aspect that is being analyzed has to do with aerosols and their ability to carry the virus over longer distances, infecting more people.

Generally, public institutions were condidered to meet their responsibilities during the lockdown. Public security and health institutions have been rated as the best performing institutions. The lower satisfaction with the government in both levels: central and local, is connected with lockdown and restrictions imposed. Another fact is that amid the lockdown the central government is overthrown with a vote of confidence, causing frustration in the population considering the pandemic situation. Lower grades are attributed to the behaviour of citizens, many of them being noticed for their unwillingness to comply lockdown measures.

There is an equal split between optimistic and pessimistic students in terms of expectations of the economic situation improvement or decline after the pandemics. It is not clear whether the optimism for improving the economic and social situation comes from, despite the alarms that humanity will enter a deep economic recession which can be reflected in many social indicators: unemployment, poverty, public health, etc. Solidarity between people and the financial support of the Kosovar diaspora during the months of lockdown may be the dispute of such a high level of expectations for social improvement. The environmental optimistic expectation is related to the temporary improvement of air quality and some other types of environmental pressures during the lockdown. However, it is uncertain as to how long this improvement will last after the discharge returns to "normality" after the pandemic lockdown ends.

Conclusion

COVID-19 lockdown during March-May 2020 in Kosova ended with 30 deaths and 1,038 infected persons. Positive and negative effects of lockdown in the environment have been visible. Students participants in this resarch mostly assessed the environmental situation of our country as similar to the situation in countries of the region. Waste and air pollution are ranked as the main environmental problems at both global and country level. About one-third of the students connected the COVID 19 outbreak with a kind of economic war between the powers which show the lack of perception of the danger in the first months of outbreak. Another one-third connected it with environmental degradation such as overconsumption of natural resources, pollution, climate changes. The increase in resources consumption with impact on the environment has been observed for water consumption, hygiene, and waste. Improvements in environmental parameters during lockdown have been perceived in the ambient air quality (due to less fuel combustion) and outdoor noise (due to ban on transport). Students' expectations about improvement or decline of the economic, the social and the environmental situation after the pandemic are surprisingly in favor of a better future: the majority of them expect improvement in the three pillars of sustainable development: economy, society, and environment.

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Zeqir Veselaj

PERCEPTIMET E STUDENTËVE PËR NDIKIMET NË MJEDIS NË KOSOVË SI REZULTAT I MBYLLJES PËR SHKAK TË PANDEMISË COVID -19 GJATË PERIUDHËS MARS-MAJ 2020

Përmbledhje

Pandemia COVID-19 ka shkaktuar izolimin më të madh të njerëzimit në historinë e sëmundjeve virale. Ky hulumtim ka për qëllim të analizojë perceptimet e studentëve gjatë izolimit të parë nga pandemia COVID-19 në Kosovë (periudha maj- mars 2020), si dhe pritjet e tyre rreth zhvillimeve pas saj. Metoda e hulumtimit është sasiore, me pyetësorin si instrument hulumtimi. Mostra përbëhet nga 339 studentë të nivelit bachelor të Fakultetit të Edukimit.

Rreth gjysma e studentëve e vlerësojnë situatën mjedisore të Kosovës të ngjashme me vendet e rajonit, ndërsa mbeturinat dhe ndotjen e ajrit si problemet kryesore mjedisore. Një e treta e pjesëmarrësve besojnë se pandemia është si rezultat i luftës ekonomike midis fuqive botërore. Rezultatet e hulumtimit tregojnë se përmirësime në parametrat mjedisorë gjatë izolimit janë identifikuar në: cilësinë e ajrit ambiental, nivelin e zhurmës së jashtme dhe zvogëlimin e konsumit të karburanteve fosile.

Rritje e konsumit të burimeve me ndikim në mjedis është vëzhguar te konsumi i ujit, produktet higjienike dhe ushqimi. Mbi gjysma e studentëve e vlerësuan si të shkëlqyer punën e institucioneve të sigurisë publike, të institucioneve shëndetësore, si dhe të ndërmarrjeve të shërbimeve publike gjatë periudhës së izolimit nga pandemia. Kënaqshmëri pak më e ulët e studentëve të anketuar paraqitet kur vlerësohet puna e qeverisë qendrore, si dhe e komunave, ndërsa sjellja e qytetarëve ka marrë vlerësimin më të ulët. Shumica e studentëve presin një përmirësim të situatës në të tri shtyllat e zhvillimit të qëndrueshëm: ekonomisë, situatës sociale dhe mjedisit pas pandemisë.

KDU 621.3.049.73(496.51)(05)

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ANALYSIS AND EVALUATION OF ELECTRIC POWER SUPPLY OPTIONS OF KOSOVA

Abstract

For sustainable economic and social development of the country and based on current demand for electric power, uninterrupted supply of sufficient and high-quality electric power is indispensable. One of the most important challenges the energy system of Kosova faces today is the difficulty to meet all the demand for electricity. The regular supply of consumers in Kosova (individual, commercial and industrial) with high quality and abundant electricity is a great challenge for all stakeholders involved in this issue. There is no simple, fast, and easy solution to this complex problem, because it depends on many multidisciplinary factors. The main weaknesses of the country's power system are low operating efficiency and high release of greenhouse gas emissions, but specifically a large source of carbon dioxide (CO_2). This paper analyzes the alternatives and realistic possibilities for Kosova to meet the demand for electricity, including the environmental aspects of each alternative. Previous studies conducted by the European Commission, the World Bank, and other donors, have concluded that in Kosova, electricity generation from coal is the cheapest option compared with others, in order for the whole country to meet its demand for power supply. It also highlights that the most sustainable and low-cost solution is the construction of new generation capacities based on local lignite reserves, followed by the construction of modest capacities in renewable energy sources (RES).

Keywords: energy system analysis; transmission and distribution system; thermal power plant; sustainable energy system; renewable energy; environment; CO_2 emissions.

1. Introduction

Kosova's Electric Energy System is relatively old, and faced with problems, beside improvement stability in power supplies. Series of undertaken actions, such as maintenance and regular repair of Thermal Power Plan (TPP) Kosova A and Kosova B TPP, investments in the

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transmission and distribution network, direct investments in the opening of the Sibovc southwest mine, re-functionalization of existing small hydropower plants, privatization of the distribution and supply network, the reduction of technical and non-technical losses. Have had direct impact in the improvement of situation.

Despite conspicuous investments in this sector and the improvement of the overall situation in the Electric Energy System, Kosova still imports around 10% of its electricity demand and faces major problems from the point of view of securing the necessary capacities to cover the maximum energy demand (peak) during the winter season. A separate problem is meeting the requirements for necessary reserve capacities and the regulation of stability (balancing) of the Electric Energy System as a whole.

2. Kosova's Electric Energy System (EES)

In each Electric Energy System, a number of generators are designed to supply different parts of the daily load (energy market or consumer demand), others are designed to operate continuously for around-the-clock power supply (basic supply), while some are designed to operate at short intervals, usually at peak demand. Kosova A and B TPPs use lignite as primary sorce, Ujmani HPP, Lumbardhi Deçan HPP, Radavc HPP, Burimi HPP use water, Wind Power and Air Energy-Kitka use wind. A neww wind farm with a capacity of 105 MW is under construction, while PV Onix-Spa, PV Birra Peja and PV Frigo Food Kosova use solar energy [1].

The Zhur hydropower plant designed, but not realized, expect to generate 305 MW electricity in a time interval of only 1-2 months during the year. Electricity generation from RES is, in most cases directly connected to the distribution network to individual consumers (commercial and industrial) to meet their own needs, and do not contribute significantly to the overall transmission system.

Each Electric Energy System must have a reserve amount of electric power. In some electric energy systems, which mainly have hydropower-based generation, the required energy reserve should be approximately 12%, while in systems where the generation is based on gas, oil, coal or nuclear power, the required reserve should be approximately 16-24% of electric power, but in Kosova this amount of energy is completely lacking.

2.1. *Transmission and distribution system*

Overhead power lines, underground cable lines, etc., serve to transmit and distribute electricity from generating units to consumers. In some countries, this distribution system is divided into several parts, such as: transmission that includes voltages from 115 kV, 138 kV, 230 kV, 380 kV, 500 kV and 750 kV, then the 10 kV, 20 kV primary distribution, and finally the 0.4 kV secondary distribution (end consumers).

Kosova's, energy system managed by Kosova System, of Transmission and Market Operator (KOSTT, figure 1), consist from transmission system voltage levels 110 kV, 220 kV and 400 kV voltage levels, and distribution system voltage levels 35 kV, 20 kV, 10 kV and 0.4 kV. This sector is privatized and is now owned by KEDS.

The electricity transmission system in Kosova, operated by KOSTT, is responsible for the safety and reliability of the operation of the Electric.

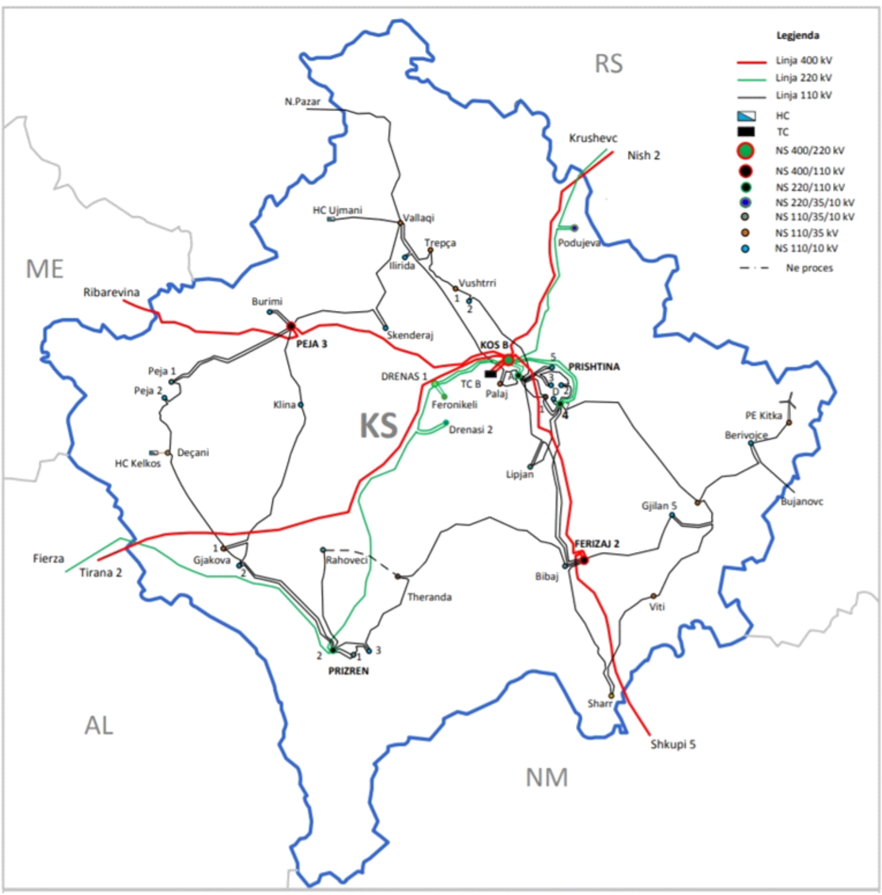

Figure 1. Electricity transmission system of the Republic of Kosova

Energy System. The transmission network has sufficient capacity to withstand power flows from generators or external interconnections in the system, to the distribution. The transmission network hase goodconnections with regional and European system through exsisting interconnection lines:

- Albania, Macedonia, Montenegro and Serbia - 400 kV lines;
- Albania and Serbia - with 220 kV lines, and
- Serbia - with two 110 kV lines.
- The 400 kV interconnection line between SS Kosova B - SS Kashar (Tirana) recently finalized.

The Agreement signed for the secondary frequency/power regulation between KOSTT and the OST of Albania started operating as a regulatory area/block within ENTSO-E (European Network of Transmission System Operators for Electricity). The transmission network of the Kosova Electric Energy System meets the local transmission needs. There may be considerable energy flows through the transmission network to meet consumer demand with domestic generation and imports, but also for eventual exports of surplus electricity and for transiting energy from other countries. The transit of electricity through Kosova's network in 2018 was about 32% compared to consumption, and this energy overloads the network and increase network losses, network depreciation, and the need for maintenance of the transmission network.

The demand, generation and exchange of electricity for 2018 presented in Figure 2. shows that generation is higher than demand during night hours, while demand rises considerably and is higher than generation during daytime. Thus, within the same day, during daytime (high tariff) .

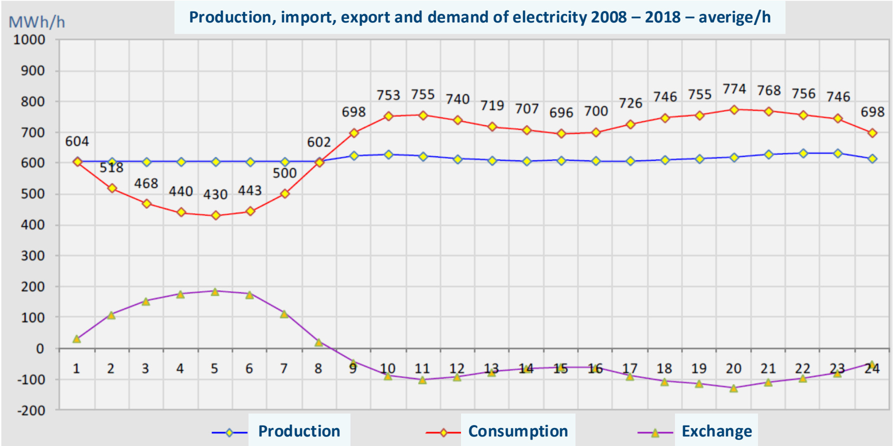

Figure 2. Daily diagram given as annual average for 24 hours of generation, consumption and exchange for 2018.

For reliable supply of consumers (with guaranteed quality and sufficient energy to meet e actual demand), long-term planning of electricity consumption for a country is necessary, and requires prediction of the demand and consumption structure, maximum load (peak load), optimal structure of sources for electricity generation based on the principles of economic efficiency, at the lowest possible cost [2].

The optimal structure of new energy sources (Kosova e Re TPP, wind energy, hydropower and solar energy), which are proposed for generation at reasonable costs, is in accordance with the objectives of the Kosova Energy Strategy for the period 2017-2026 and operation according to technical requirements from ENTSO.

For prediction of the required energy reserves for emergencies (in cases of falling out of system some of any generating units) is necessary to compare the data for the maximum installed load in the energy system. It is worth mentioning that Kosova’s Electric Energy System (EES) operates without energy reserves capacities. For operation according to the standards, Kosova’s EES should have about 1,300 MW of operating capacities and about 300 MW reserves of available electricity. With the decommissioning of Kosova A TPP, the demand for electricity will increase and the import of electricity pronounced until the construction of new generation capacities, such as construction of the Kosova e Re TPP [1].

On the other hand, a number of studies have identified that wind energy potential is around 318 MW. But in most of the geographical locations identified in Kosova, wind speed is below 6 m/s, which is not sufficient and favorable for energy generation for commercial operation of these capacities.

2.2. Kosova A Thermal Power Plant

The Kosova A Thermal Power Plant (Kosova A TPP) consists of five independent generation units (blocks) with characteristics shown in Table 2. Blocks Kosova A1 and Kosova A2 are obsolete, and from 2000 are out of operation without any specific status. The annual generation of electricity from Kosova A TPP is about 1,500 GWh. The water supplied to these blocks comes from the Llap river site, while in drought conditions a quantity of water from the Iber-Lepenc system is used. A power plant with a power of 200 MW consumes about 300 t/h of coal with a heat of combustion of about 7,500 kJ/kg, respectively

1,800,000 tons of coal, with estimation of operation per unit around 6,000 h/year. Thus, the three active units of Kosova A TPP consume about 5,400,000 tons of coal/year.

2.3. Kosova B Thermal Power Plant

The Kosova B Thermal Power Plant (Kosova B TPP) consists of two independent generation units (blocks). The annual generation of electricity from Kosova B TPP is about 3,650 GWh. The water supply of Kosova B TPP come from the Ujman Lake through the Iber-Lepenc system.

Water consumption for the three units of the Kosova A TPP is about 3,000 m3/h, while for the two units of the Kosova B TPP is about 2x1,410 m3/h = 2,820 m3/h. Thus, when all the blocks are in operation, they consume about 5,820 m3 of water/h. A quantity of water must also be provided for the hydraulic transport of ash and slag. For this purpose, only in one block of 200 MW about 500 m3 of water/h are consumed. In the Kosova A TPP and Kosova B TPP, ash and slag are removed via the hydraulic system, and once the hydro-mixture is shaped (ash, slag and water) it is sent via special pumps to the Sitnica landfill.

One block of a thermal power plant has a lifespan of about 40 years assuming that a general overhaul is performed once that block has been in operation for about 25 years. It follows that all units of Kosova A TPP should have been out of use, while the units of Kosova B TPP are at the end of their operations.

2.4. Cogeneration

Cogeneration means the combined generation of electricity and thermal energy in a power plant using a certain amount of steam, which after initially producing mechanical work (electricity) in the high-pressure steam turbine (HPST) and the medium-pressure steam turbine (MPST) for the heating needs of the city of Prishtina; for this purpose, from the pipeline between HPST and MPST are taken about 100 tons/hour = 27.715 kg/s of water vapor with the following parameters: pressure 2.405 bar and temperature about 191.80 C. This steam is sent to the surface heat exchanger, which is located near the thermal power plant, and thus generates about 70 MW of energy for thermal consumers.

Cogeneration from the Kosova B thermal power plant has started to be applied in the 2014/2015 heating season, and for this reason the city heating has consumed significantly less heavy oil. Now the cogeneration system operates from both units of the Kosova B thermal power plant.

3. Energy resources in the Republic of Kosova

The variety of resources for electricity generation in Kosova is limited, except for coal, whose reserves are estimated to be 12.5 billion tons, of which 10.9 billion tons are exploitable. Lignite-type coal is the only local fuel for electricity generation.

The Sibovc mine (in the Kosova basin) is considered as the most acceptable option from an economic, social and environmental perspective, and it has enough lignite to supply the existing generating capacities until the end of their operational life, as well as to supply new generation capacities of 600 - 700 MW for around forty years.

3.1. Coal

Coal is the most important energy resource of Kosova, as it is used to generate around 97% of electricity in Kosova. According to the quality, Kosova has lignite coal with low combustion heat (5,860-8,360) kJ/kg. It is distinguished by its brown, dark brown to black color. Coal with combustion heat lower than 5,860 kJ/kg usually is accounted in coal reserves [1]. In Kosova coal is found in three basins: in the Kosova Plain, Dukagjini Plain and Drenica Plain. In the Kosova Plain, coal has been extracted since the 1960s in the villages: Mirash (Dobrosellë), Bardhi i Madh, Hade and Sibovc [3].

The Kosova Plain lignite contains: moisture (38 -48)%, ash (9.84-21.32)%, hydrogen (2.01 - 2.25)%, sulfur (0.68 - 1.51)% of which only (0.07-0.49)% is combustible sulfur, as well as about 38% combustible matter [4,5].

The combustible elements of solid fuels are: carbon C, hydrogen H and sulfur S. Non-combustible elements, components of fuel are: Nitrogen N, oxygen O, ash A and moisture W. Their elemental content is determined experimentally. In the whole basin of the Kosova Plain the waste/coal ratio is 1.5/1, while in the more profitable northern areas of the basin this ratio reaches 1/1.

The annual consumption of coal for the generation of 800MWh of electricity (approximately how much is currently generated by all power plants) with an efficiency of about ηTEC = 30%, is about 8 million tons/year [6].

3.2. Natural gas

Kosova has no natural gas resources or connection to any pipeline network for the gas supply system. Importing gas for electricity generation requires extending existing pipelines from Skopje (Northern Macedonia) or Nis (Serbia) to connect Prishtina and the Obiliq power plant locations. The operation of the gas-fired power plant requires the purchase, transport of gas, namely additional costs. This is not impossible, but it is hardly the case due to the relatively low demand and the seasonal nature of the demand. The study on the gasification of Southeast Europe conducted by the World Bank (October 2007) also analyzed the economic aspect of gas supply in Kosova. The study had concluded that from a financial point of view the establishment of the gas transmission line is not reasonable for any country in the region, except Romania, due to small markets. From this aspect, the option of building new generation capacities based on natural gas, would be much higher cost than the option with lignite as fuel, therefore the construction of new generation capacities based on natural gas is considered economically unreasonable for local circumstances.

3.3. Oil

Kosova has no identified oil resources. All liquid fuels have to be are imported by rail or land routes from Northern Macedonia and Albania. The construction of an oil-fired power plant, as a possible option, would depend on the import of inputs and oil price variations in the international market. As with the option of building a natural gas-fired power plant, buying oil would require additional substantial costs that would make the operation expensive and unsuitable for Kosova’s conditions.

3.4. Hydropower potentials

Kosova has modest hydro capacities for electricity generation, given that the rivers in our country have mainly small water flows and short streams, which reduces the geographical options of building water reservoirs for hydropower plants.

The most serious plan for a medium-sized hydropower plant in Kosova has been the Zhur hydropower plant project, located southwest of Prizren in the Sharr region. The designed capacity of the hydropower plant is projected to 305 MW to generate approximately 400 GWh of electricity per year in average hydrological conditions. It would function as complementary energy in the period of maximum consumption. This project is designed since the 1980s, but it has been abandoned due to lack of investment and uncertainties about water storage capacity for this installed power.

Other studies conducted by various international institutions have identified 18-20 locations for smaller hydropower plants with a total capacity of about 70 MW, which can generate about 300 GWh per year in average hydrological conditions. Some of these small HPPs have already been built with investments from the private sector and are in operation. For a period of time, the Government has supported (subsidized) these capacities with incentivizing tariffs. But during the issuance of construction permits and licensing of these capacities by the local authorities, very little attention has been paid to the protection of the environment, meaning that the construction of these hydropower plants has caused significant damage to the environment due to diversion of streams and rivers and reduction of the free amount of water for use by local residents, with serious consequences for agriculture and the flora of construction sites. These constructions have often been accompanied by objections and protests from local residents, but without any effect on the authorities' awareness of environmental issues and irreparable consequences. Therefore, in the future this issue should be clearly addressed and regulated by relevant laws, so that environmental protection is a priority when issuing permits and licensing new facilities.

3.5. Wind potentials

Although wind resource maps are not yet complete for the geographical extent of Kosova, private investors have done some monitoring of locations with relevant wind values. So far, less than 34 MW have been installed. The "Mercados Energy" international company, for the needs of the World Bank, based on the assessment of resource availability, has calculated that the potential for wind energy generation in Kosova is about 2,000 GWh per year, which is equal to 1,000 MW of installed capacity with a capacity factor of 25%. This is also a rather optimistic and controversial assessment in public opinion. A 2010 study funded by the Swiss organization entitled "Promotion of renewable energy and energy savings in international cooperation", conducted by consultants of "NEC Technologies", has concluded that wind resources in our country are substantially more modest, and that there are very few areas where wind speed exceeds 6 m/s, which is the minimum required for commercial potential in the region. The report also concluded that winds in Kosova mostly reach average levels. More rigorous identification of wind speed and duration may indicate areas where winds are strongest in more complex terrains, but the utilization of those resources may be hampered by space and access problems. Furthermore, Kosova's small Electric Energy System most likely cannot absorb more than a quarter of the total technical wind potential given the requirements for reliable operation of the Electric Energy System.

3.6. Photovoltaic capacities

Kosova's geographical position conditions the climate features to be of Mediterranean and continental character. In Kosova's latitudes (42^o-43^o) the annual insolation (sunny weather) should last 4,450-4,460 h/year (or 12.2 h/day on average). But the insolation in Kosova lasts 2,079 h/year or 5.7 h/day, which is 47% of the possible insolation. Although accurate solar maps for our country have not yet been drawn up, a few measurements have been made for some cities. According to the accounts of a foreign company interested in investing in photovoltaic potentials for electricity generation, Kosova has a solar photovoltaic potential of about 160 GW h/year on average, which means about 77 MW of installed capacity, with 22 -25% utilization factor [6]. Studies conducted in recent years show the climatic conditions and sunny days for some locations in Kosova and confirm the limited capacity of economically reasonable use of this potential for the generation of electricity that meets the standards for connection to Kosova's transmission system.

The largest amount of global solar radiation energy in Kosova arrives in the March - September period, at an inclination of 30° to the south. Whereas in the October-February period, the greatest amount of global solar radiation energy falls at an inclination of 60° also to the south.

Figure 3 shows the average monthly global solar radiation during 2009 from the data obtained from the Hydrometeorological Institute of Kosova (HIK), from the respective metering stations in Prishtina, Peja and Prizren.

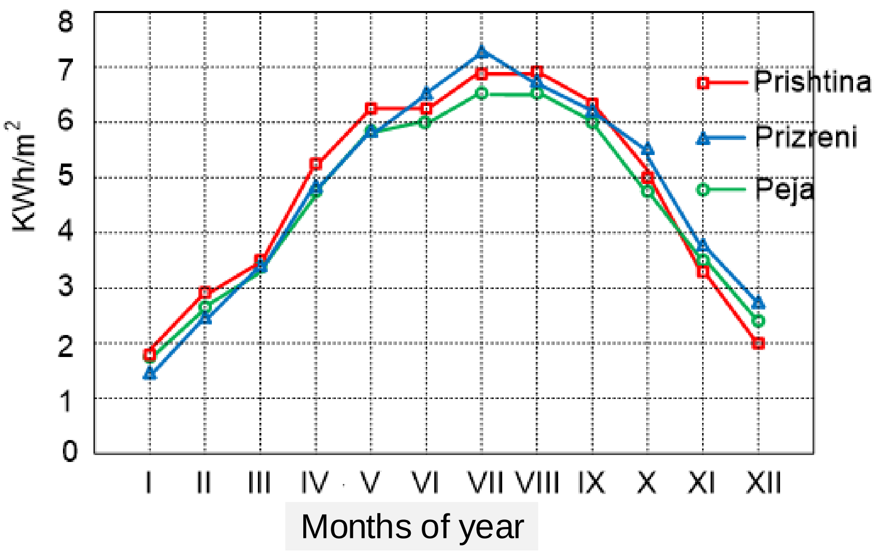

Figure 3. Average daily global radiation on the horizontal plain in the cities of Prishtina, Peja and Prizren for 2009

The average daily and annual values of global solar radiation energy in Kosova during the year are approximate and have the values as in Table 1 [7].

Table 1. Average daily and annual value of global solar radiation energy

Location	Average daily value kWh/m^2	Average annual value kWh/m^2
Prizreni	4.14	1512.25
Peja	4.24	1546.25
Prishtina	4.32	1578.25

Sunny weather and cloudy skies in Kosova vary according to the months of the year. Based on HIK observations of sunshine in four meteorological stations (Prishtina, Ferizaj, Prizren, Peja), Kosova has an average of 2,066 hours of sunshine during the year, or about 5.7 hours a day. Within the year, July has the sunniest weather (during summer over 250 hours per month or 8.3 hours/day), while December has the least (about 54 hours in total or 1.7 hours/day). On average, December has around 5.3 times less sunny hours than July.

From the presented data, although modest, it can be concluded that the solar energy capacities in Kosova are modest in terms of meeting the requirements for the construction of solar plants that generate electricity with sufficient quality and quantity to connect to the transmission system. But this energy can be used in small plants for individual needs by connecting to the electricity supply system, and for thermal energy for the heating of domestic water.

For the construction of photovoltaic capacities with significant contribution for the EES system, very large areas are needed for the installation of solar-photovoltaic panels, and the price per MWh still remains high.

3.7. Biogas and biomass

In Kosova, biogas based on organic livestock manure is found in many parts of the country, but in small quantities, and has little potential to be converted to gas for the movement of turbines of electricity generators. On the other hand, most of the raw material for biomass comes from wood, and a small amount from agricultural waste converted into biogas. Kosova's wealth of timber is considerable, but using wood for electricity generation would have very high costs and cause irreparable degradation of forest regions. Projects funded by various international organizations have estimated the share of biogas for electricity generation to be significant at around 13% (according to the data presented in Figure 4), moreover in this study this share is projected to be even higher than the hydropower potential, which is estimated at 11%. In our assessment, this forecast for electricity generation from biogas and biomass is overestimated and does not represent a realistic and economically favorable option for implementation in practice.

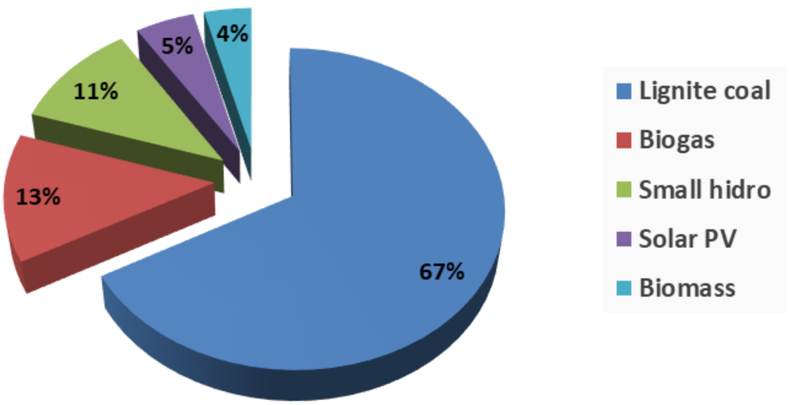

Figure 4. Forecast of electricity generation potentials by 2020 (According to Mercado Energy estimates [8])

4. Current balance of consumption and supply in Kosova

This section provides a brief overview of the equilibrium between market demand and supply for electricity supply, based on the characteristics of existing generating capacities for electricity generation, as well as the transmission and distribution lines available to cover the energy market demand.

4.1 Consumption (demand for electricity)

In Kosova, electricity consumption and maximum demand periods increased by more than 90% between 2000 and 2010, and this energy consumption increased by an average annual rate of 6.7%, while maximum demand by an average annual rate of close to 6%. The trend of electricity demand and consumption is presented in Figure 5.

Frequent reductions and unplanned power outages also have a major impact on the energy situation in Kosova, and these outages limit the increase in demand and reduce the large difference in demand manifested according to the seasons of the year. The System, Transmission and Market Operator - KOSTT controls energy reductions during periods of maximum load in situations when domestic generation and energy imports are not sufficient to cover the grid demand for energy. According to an estimate by KOSST, during the years 2001-2007 if the reductions had not been implemented, the annual demand for electricity would have been 300-700 GWh higher. In 2009 and 2010 the reductions are estimated to be 373 and 205 MW [9]. Unplanned power outages are the result of failures of all network segments: generation, transmission and distribution [10].

The regulator sets regulated tariffs for consumers who enjoy the right to supply in terms of universal service. The table below presents the structure of retail tariffs and, according to ERO, with the application of these tariffs it is expected that the supplier will invoice the allowed level of maximum allowed revenues. This tariff structure is being applied from November 1, 2018.

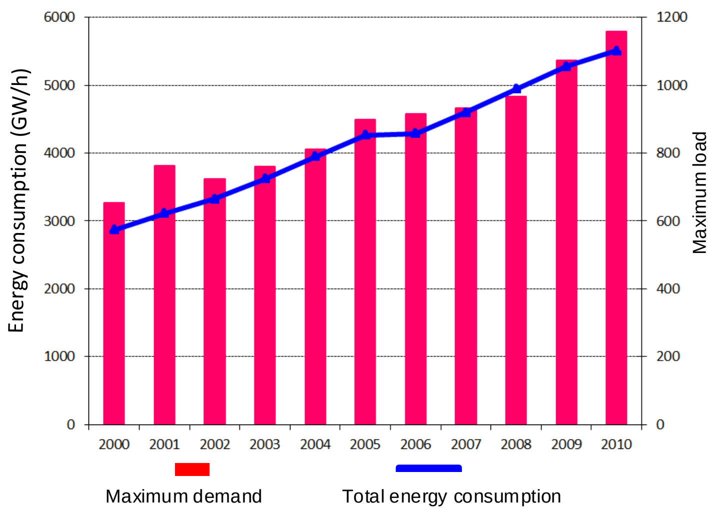

Figure 5. Consumption and maximum demand curve in Kosova in the 2000-2010 period [11].

Current consumer tariffs do not reflect the real cost charged to household consumers. Household tariffs are generally estimated to be approximately 20-30% below the supplier's total cost, while some industrial tariffs significantly exceed the cost level. The price increase towards tariffs that reflect the real cost will have a significant impact on the demand of different categories of consumers, so this impact will largely depend on the conditions in which the construction of new generation capacities is planned.

Kosova currently has eight tariff groups that reflect different operating voltages and consumption power. Tariffs for high voltage consumers, whose meters apply mostly a dual tariff (in other words they have a fixed and variable component). Tariffs for all consumers whose meters are measured, and which vary according to the season and by day (for high voltage consumers and for some settlements) that have dual tariff meters.

Tariffs for household consumers follow a cost-increasing schedule, i.e. higher tariffs for higher levels of consumption. Household consumers, whose meters are not measured, pay a fixed monthly amount, based on their estimated monthly consumption. Electricity consumption in Kosova tends to reach the maximum load in the winter season. For the category of household consumers, the average price of electricity is 5.65cent/kWh, and compared to 2017 there is a price reduction of 6.4%, while for industrial and commercial consumers the average price is 7.94 cents/kWh.

4.2. Existing electricity generation capacities in Kosova

Kosova's Electric Energy System is designed mainly for the generation of electricity based on significant reserves of lignite as a raw material, but not to cover the maximum loads and balance the system. Balancing the system remains a major challenge for all participants in the sector, as it depends on Serbia's Electric Energy System. The balance of installed generation capacities in 2018 was 1,409 MW, including generating capacities from RES. The TPP installation capacity was 1,288 MW (91.41%) of the total installed capacity, while RES installation capacity was 121 MW (8.59%).

The net capacity is considered to be 1,075 MW, of which TPPs constituted 960 MW (89.29%), while RES the rest with a total of 115 MW (about 10.71%). This includes Ujmani HPP with 32 MW (2.98%), other HPPs and solar panels with 83.17 MW (7.74%), including the generation of Kitka wind farm with a capacity of 32.4 MW, which has started commercial operation in October 2018.

From the above notes it appears that all types of renewable electricity sources connected to the EES and those connected to distribution account for only 115.17 MW (10.71%). Kosova has installed generation capacities of 1,409 MW, including generation capacities from RES. These capacities in most of the year would be enough to cover the demand of the domestic market, as well as a quantity of electricity that would be available for export, but due to the age of the power plants and insufficient flexibility to adapt to the demand in different periods and especially at the peak time (maximum demand), then imports are needed, but sometimes also exports to balance the system. The introduction of generators by RES increases the operating capacity of the generation, but in most cases they are unpredictable and are in the priority mode of dispatch, so they have no impact on improving the balance of the Electric Energy System, and sometimes even increase imbalances. The figure below shows the generation, import, export and demand of electricity over the last ten years.

As shown in the diagram below, in recent years, electricity generation has been almost sufficient to cover consumption, and in two of these years Kosova has been an exporter of a quantity of electricity, but over the years it has predominantly been an importer. The maximum load in the energy system of Kosova is almost twice as high as the minimum load, and these changes cannot be followed by local generation, so it is necessary to contract import or export within the same day.

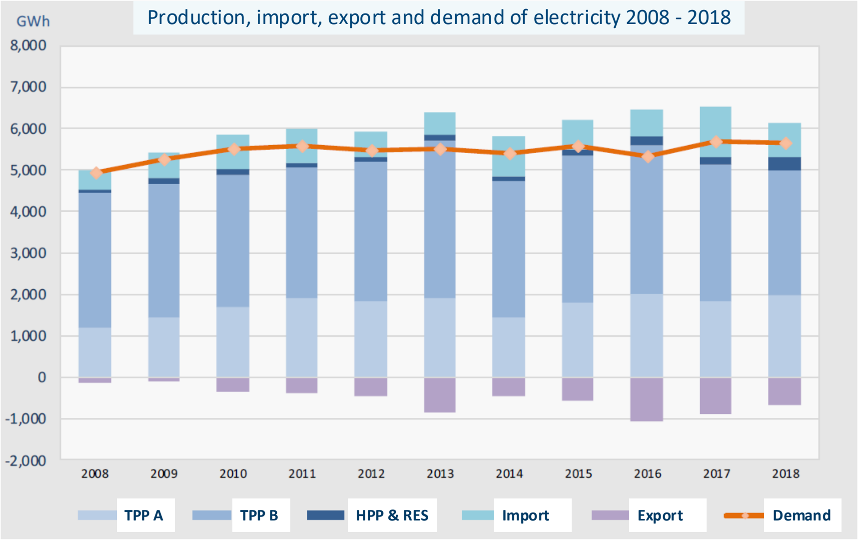

Figure 6. Generation, demand, export and import of electricity in Kosova in the 2008-2018 period [12].

The largest share of metered electricity demand comes from households (approximately 63%), which is followed by industry demand. Technical and non-technical distribution losses together represent 40% of the total electricity generated. Technical and non-technical losses have decreased in recent years, and recently are at the level of approximately 23% recorded in 2018. Reductions in non-technical losses will reduce electricity consumption, because non-metered households have been shown to use significantly larger amounts of electricity (in some cases close to twice the amount utilized by metered households). [13]. Theft and non-payment of consumed energy has significantly decreased and thus has reduced the demand for energy (because a large part of non-technical 'losses' is actually related to electricity consumed, but that has not been paid).

The share of household consumers in the total consumption billed in distribution still remains dominant with about 59.01%, followed by commercial consumption at 22.89%, then by industrial consumption at 17.51%, and finally by consumption in public lighting at 0.59 %. While gross consumption is approximately at the same level as the previous year, household consumption has increased by about 3.6%, commercial consumer consumption has also increased by 6.5%, while industrial consumption in 2018 has decreased by 15.2% compared to the previous year. The figure below shows the share in percentage of consumption categories compared to total consumption (presented with loss and no loss in distribution).

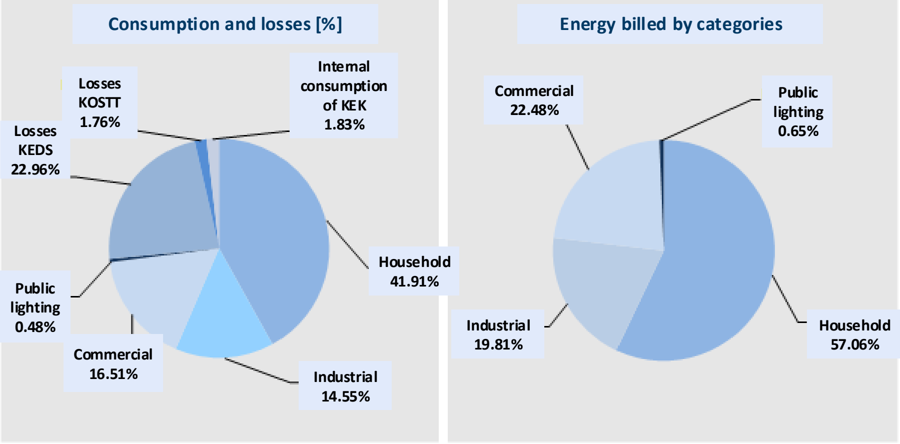

Figure 7. Participation of consumption categories with loss and no loss 2011

Electricity generation capacities in Kosova are mainly from thermal power plants which make up 91.41% of the installed capacities, or 89.29% of the net capacities, and the rest are hydropower plants and renewable energy sources (RES), wind farms and solar panels. The capacity of generating units by type of primary source, installed and operating capacity, minimum and maximum generation limits, and year of commissioning, is presented in Table 2.

Table 2. Generation capacities in Kosova's Electric Energy System

Generation unit	Unit capacity MW		Commissioning
	Installed	Net	
Kosova A1 TPP	65	Non operational	1962
Kosova A2 TPP	125	Non operational	1964
Kosova A3 TPP	200	144	1970
Kosova A4 TPP	200	144	1974
Kosova A5 TPP	210	144	1975
Kosova A TPP	610	432	
Kosova B1 TPP	339	264	1983
Kosova B2 TPP	339	264	1984
Kosova B TPP	678	528	
Ujmani HPP	35	32	1983
Lumbardhi Deçan HPP	8.08	8	(1956) 2006
Dikanci HPP	4.02		(1957) 2013
Radavci HPP	1	0.9	(1934) 2010
Burimi HPP	0.95	0.85	(1948) 2011
Total HPPs (out of support scheme)	49.05	45.09	
EGU Belaja	8.06	7.5	2016
EGU Deçani	9.81	9.5	2016
Hydroline-Albaniku III HPP	4.27	4.27	2016
Brod II HPP	4.8	4.8	2015
Restelica 1&2 HPP	2.28	2.28	2016

Generation unit	Unit capacity MW			Commissioning
	Installed	Net		
Brezovica HPP	2.1	2.1		2017
Wind Power	1.35	1.35		2010
Air Energy-Kitka	32.4	32.4		2018
PV-LedLight Technology	0.1	0.1		
PV Onix-Spa	0.5	0.5		2016
PV Birra Peja	3	3		2018
PV Frigo Food Kosova	3	3		2018
Total RES (in support scheme)	71.67	70.08		
Total	1.409	1.075		

As seen from Table 3, total electricity generation in 2018 was 5,311 GWh, while in 2017 it was 5,300 GWh, which means that there is an increase of 0.2%. Generation, including own costs, by units and months during 2018, is presented in Table 3.

It should be noted that 11.84% of the energy from the gross generation of thermal power plants is consumed by the power plants themselves as their own expense. A part of these own costs (for both generators, Kosova A TPP and Kosova B TPP) is realized directly from the internal plants, while the rest is introduced in the transmission system and then consumed by the thermal power plants.

In recent years there has been an increase in installed RES generation capacities, which continue to be put into use. RES generation connected to the transmission network in 2018 was 245.1 GWh, and is higher by 79.81% compared to 2017, influenced by the generation of the Kitka wind farm with a capacity of 32.4 MW. Also, the 58.2 GWh RES generation connected to the distribution network in 2018 increased by 35.40% compared to 2017 due to the connection of two photovoltaic generators with solar panels with a capacity of 3 MW each. The following tables 4 and 5 present the generation of electricity from RES connected to the transmission network, respectively to the distribution network.

Table 3. 2018 Electricity Generation

Generator MWh	Total	January	February	March	April	May	June	July	August	September	October	November	December
A3 TPP gross	824,177	15,163	95,952	29,400	35,432	108,569	103,412	87,140	106,785	83,587	18,985	98,276	50,476
A4 TPP gross	712,747	97,395	42,058	110,758	91,247	0	0	0	33,334	70,422	115,457	63,254	88,823
A5 TPP gross	703, 724	0	24,749	78,474	1	32,201	82,729	110,009	77,684	107,511	105,129	28,362	56,873
A TPP Own Cost	273,457	13,205	19,854	26,045	15,285	17,039	22,655	24,571	27,024	31,150	28,613	22,781	25,035
TC A thre.	1,967,192	99,352	142,905	192,588	111,395	123,731	163,487	172,578	190,778	230,170	210,958	158,111	171,137
B1 TPP gross	1,074,986	208,587	176,334	191,948	168,195	201,112	31	0	0	0	0	0	128,780
B2 TPP gross	2,284,913	206,019	184,132	196,485	185,932	206,033	187,608	206,724	189,474	105,780	209,005	200,005	207,718
B TPP Own Cost	319,371	38,586	34,229	37,315	33,719	37,174	18,345	19,831	18,061	10,894	19,459	19,588	32,169
TC B thre.	3,040,529	376,019	326,237	351,117	320,408	369,971	169,293	186,893	171,413	94,886	189,545	180,417	304,329
HPP+RES Dist.	245,095	7,330	11,395	33,132	37,869	32,125	22,977	23,208	15,831	12,542	14,635	16,774	17,276
RES Dist.	58,155	3,631	4,743	8,893	9,924	9,196	5,545	5,168	3,579	2,092	1,639	1,769	1,976
Total	5,310,970	436,333	485,280	585,730	479,597	535,023	361,303	387,847	381,602	339,689	416,778	357,071	494,718

Table 4. RES generation connected to the transmission network in 2018

RES in transmission	Installed Capacity/MW	Generation/MWh	Generation share*/%
Ujmani HPP	35	98,199	40.07
Kaskada Lumbardh HPP	25.95	117,16	47.8
Air Energy/Kitka	32.4	29,736	12.13
Total RES	93.35	245,095	100

*Share of generating units in RES generation in transmission

Table 5. RES generation connected to the distribution network in the year

RES in distribution (distribution)	Installed Capacity/MW	Generation/MWh	Generation share*/%
Hydroline	4.27	11,697	20.11
Dikanci	4.02	10,453	17.97
Radavci	1	4,182	7.19
Burimi	0.95	1,790	3.08
Eurokos-JH	4.8	22,817	39.23
Brezovica HPP	2.1	5,168	8.89
Wind Power	1.35	17	0.03
Solar-LLT	0.1	123	0.21
Solar-Feti	0.1	93	0.16
Solar Onix	0.5	661	1.14
Solar Birra Peja	3	578	0.99
Solar Frigo Food	3	576	0.99
Total RES	25.19	58.155	100

*Share of generating units in RES generation in distribution

With careful analysis of data on the generation, demand, export and import of electricity in Kosova for a period of ten years (Figure 6), it can be concluded that the existing electricity generation capacities in Kosova, of which thermal power plants constitute 91.41% of the installed capacities, or 94.3% of the operating capacities, and the rest coming from hydropower plants and renewable energy sources (RES) (hydropower plants, wind farms and solar panels), meet the energy demand for the most part. The largest share is supplied by the energy generated in the two TPPs (TPP A and TPP B) and a modest amount from HPP and RES sources. Furthermore, after 2010, although we have an increase in demand, domestic generation for most of the year has met this demand, and in certain periods of time Kosova has exported electricity.

When it comes to building new generation capacities, the presented data strongly argue that the best strategy for the stability of the energy system of Kosova is the construction of a new thermal power plant which would replace TPP A after its decommissioning. This means that the construction of generating units with a capacity of about 600 MW is needed.

On the other hand, HPPs and other RES with small and unstable generation capacities do not have much impact on meeting the demand for electricity. The suggestions of part of the public opinion that oppose the construction of new capacities based on lignite, for orientation in clean energy based on renewable energy sources, are not a feasible option that offers the possibility of meeting the needs for electricity and independence of Kosova’s energy system, because Kosova with its geography and climate (few rivers with short discharge, no locations with strong winds) does not have very favorable preconditions for the development of new capacities. The RES capacities installed in recent years prove this.

5. New generation resources in Kosova’s EES

As can be seen from the above analysis, in 2018 consumers were supplied with electricity mainly from fossil energy sources with 5,008 GWh (94.3%), while the share of electricity generation from renewable sources was 303 GWh (5.7%). The total output from all sources was 5311 GWh. This low share of RES contribution to the supply of electricity to consumers should be accompanied by an increase in electricity generation capacities from these resources although, as noted above, these resources are quite limited for commercial operation. Ideally (see Figure 4), even if all the theoretically predicted capacities of renewable energy sources are used, the share of these sources in the total electricity generation would barely reach 33% of the total generation. It should be noted that even this projection presents an ideal forecast, which in practical circumstances is unachievable precisely due to limited potentials and high costs. Thus, this option turns out to be unfeasible and economically unreasonable.

Thus, in 2018 TPP A generated 1,967 GWh, while TPP B (3,041 GWh), and together generated 5,008 GWh. In the same year, the generation of RES in the system was 245 GWh, while the generation of RES in distribution was only 58 GWh (see Tables 4 and 5). Therefore, the joint generation of connected capacities in the system and those in distribution was only 303 GWh, respectively only 5.7% of the total energy generated.

It is worth mentioning that the electricity supply in Kosova is based on old thermal power plants which do not provide security of regular energy supply, while unreliable electricity is the main obstacle to sustainable economic development of the country, and thus energy stability still remains the main challenge of the state of Kosova.

As a solution for sustainable supply of the Republic of Kosova with electricity, the working group thinks that there are two real options:

1. Construction of new capacities based on fossil fuels accompanied by the increase of new capacities of renewable energy, but it should be noted that so far very limited sources have been identified, and
2. Import of electricity

The working group, critically analyzing all the possibilities and energy potentials of the country, estimates that the first option, i.e. sustainable electricity supply should be achieved from local energy sources based on lignite reserves. To achieve this goal, in addition to the decommissioning of the Kosova A thermal power plant and the rehabilitation of Kosova B, the country needs new generation capacities based on fossil fuels and a number of new renewable energy capacities. In this regard, we support the construction of new energy capacities based on lignite, namely two thermal power plants of 300 to 350 MW each.

5.1. New generation capacities

Given the real objective limitations in building RES capacities in Kosova, despite the goals for building these capacities, meeting the basic needs for electricity in our country still has to rely on local energy potentials and is conditioned by the construction of thermal power plants, taking into account the highest European standards for environmental issues.

Instead of building the KRTPP with a capacity of 500 MW (gross), respectively 450 MW (net) electricity (according to the now defaulted contract), we suggest building two units, each of 300 to 350 MW, in five-year stages of construction. The first stage (Block I) to be completed and put into operation by 2025, while the second stage (Block II) to be completed by 2030. Both blocks must have subcritical parameters (SC) with pressure and temperature 170 bar/5,400 C that achieve efficiency of about 40%. Each of these units must have the possibility of cogeneration (joint generation of electricity and thermal energy) with at least (6-10) % of the nominal capacity of electricity generation (300 to 350 MW).

The proposed variant with installed power of 300 to 350 MW will be compatible with one block of the Kosova B TPP, so in case of fall from the system of the respective block, the EES of the country would not suffer imbalance and major disruption, compared to the previously proposed single unit of 500 MW if eventually this unit for various technical reasons would fall out of operation.

The use of coal as a fuel for electricity generation, despite the global trend to reduce the use of this resource due to environmental and climatic consequences, continues to dominate. According to the report of the World Energy Resources Institute, Europe alone by 2030 foresees the construction of over 70 fossil fuel power plants with a total capacity of over 65,421 MW [14].

The construction of new capacities would enable the replacement of the old generating units of Kosova A TPP and would ensure the increase of security in the energy supply, and at the same time would provide the necessary reserve capacity for uninterrupted supply of electricity. On the other hand, reliance on domestic resources, mainly lignite, and partially on renewable energy sources, would significantly reduce the country’s dependence on electricity imports and the unpredictability of prices in the regional market.

The commissioning of new units and the rehabilitation of Kosova B TPP will replace the generation of electricity generated by the three units of Kosova A TPP, as well as reduce the need to import energy for average market demands. The new thermal power plant should also reduce the emission of gases into the atmosphere compared to those of the existing power plants, Kosova B and especially Kosova A, as advanced technologies will be applied, which are available today and which meet the requirements according to IED/BAT and in accordance with EU's IED.

Commercial operation of new generation capacities will ensure a stable supply of electricity and thermal energy as a precondition for future investments that will contribute to Kosova's economic development.

The working group also suggests that the Government consider the option of building new capacities with self-financing accompanied by soft loans for a period of ten years.

6. Environment and impact on public health

The operation of thermal power plants, in most parts of the world, is based on the use of coal as a raw material for heating and boiling water at high pressures and temperatures. According to data available at Kosova A and B power plants, yearly consumption is about 8 million tons of lignite. In 2019, TPP A spent 3,616,773 t of coal, while TPP B 4,763,859 t of coal/year. Such mass of lignite was calculated by the photogrammetric method. The main product during the combustion of lignite in TPP A and TPP B is CO_2. Because of this process, for the calculated mass of lignite it turns out that the mass of CO_2 released is around 7 million t/year. Also, based on the values of electricity generated for 2019, the ratio is 1.53 t of lignite, 1.304 t CO_2 for 1 MWh generated in TPP A, while for TPP B this ratio is 1.298 t of lignite, 1.107 t CO_2 for 1 MWh generated. So, for 1 MWh of energy generated, in TPP A 1.118 times more coal is consumed than in TPP B. On average, 206.8 g of CO_2 were emitted from the Kosova B smokestacks in 2019 per m^3N of gases, i.e. the volumetric share of CO_2 in the released gases was $\varphi(CO_2) = 0.1053 = 10.53\%$, while the partial pressure of this gas was 10.5 kPa. Based on the calculated CO_2 emission values, it turns out that the average annual volume of gases emitted within 1 s is 391 m^3N for TPP B1 and 323 m^3N for TPP B2. Therefore, within 1 s during 2019 both smokestacks of TPP B have emitted an average of 131.1 kg/s CO2, while all three smokestacks of TPP A have emitted 95.3 kg/s. In addition to CO_2, during the combustion of coal, depending on its quality and the conditions in which it burns in the presence of oxygen, carbon monoxide CO is also formed to a certain extent, which is a harmful substance for the environment. During the year, in the Kosova B power plant are released over 1000 t of CO, respectively about 51 mg CO/m^3N, or based on the flow of gases 42.6 g/s are released.

These two coal combustion products, CO and CO_2, have harmful effects on the environment. The high concentration of CO_2 in the environment is considered to be the main cause of global warming or the greenhouse effect, accounting for about 55% of the impact [15]. CO is a harmful substance because it directly affects human health. In small concentrations it causes headaches, lethargy and vision problems, while in large concentrations, depending on the time of exposure, it can also cause death [16].

In modern thermal power plants, the efficiency of electricity generation has increased due to the use of advanced technologies, reducing by 25 - 30% the ratio of coal consumed for electricity generated. This release less CO_2 for the same amount of electricity generated and at the same time reduces the cost of energy generation due to the reduction of coal costs. Simultaneously, in such installations the so-called system of carbon separation, transport and storage is used (Carbon Capture and Storage). In such facilities, CO_2 is first separated from the mixture of other gases by adsorption filters or specific membranes or absorption with aqueous solutions of amines, then depending on the distance to the landfill where it is deposited deep into the ground, CO_2 is transferred in gaseous state at high pressure through pipelines or is converted to liquid state [17].

Since the lignite used in TPP A and TPP B contains sulfur at > 1%, based on KEK data for 2019 in the ratio of Inorganic S to Organic S is 1.89. The combustion of coal in the presence of oxygen leads to the oxidation of sulfur up to SO_2. This substance in the presence of water is converted to sulfuric acid, while when SO_2 is further oxidized it is converted to SO_3, which then when reacts with water is converted to sulfuric acid. Therefore, SO_2 is the cause of acid rain that is a source of damage to plants, but also to various facilities. SO_2 is also known as a substance that is aggressive to human health. This substance attacks the lungs and can cause pulmonary and laryngotracheal edema.

In TPP B, the analyzers for measuring the emissions of gases and dust are not operational; therefore, the calculated stoichiometric values of SO_2, based on the share of this element in the used lignite, are employed. The values obtained during the 2016 - 2019 period are presented in Table 6. Such results are higher than they are in reality, due to the desulfurization process. According to these calculations, it turns out that TPP B has dumped about 634.5 mg SO_2 / m^3N during 2019.

Table 6. Average values of SO_2 concentration released by TPP B during 2016-2019.

Year	Average concentration of SO_2 / mg/m^3_N / B TPP	Allowed norm / mg/m^3N
2016	495.5	400
2017	603.2	400
2018	618.8	400
2019	634.5	400

Figure 8 below shows the monthly values of SO_2 emissions for 2019 based on the report of the Kosova Environmental Protection Agency [18].

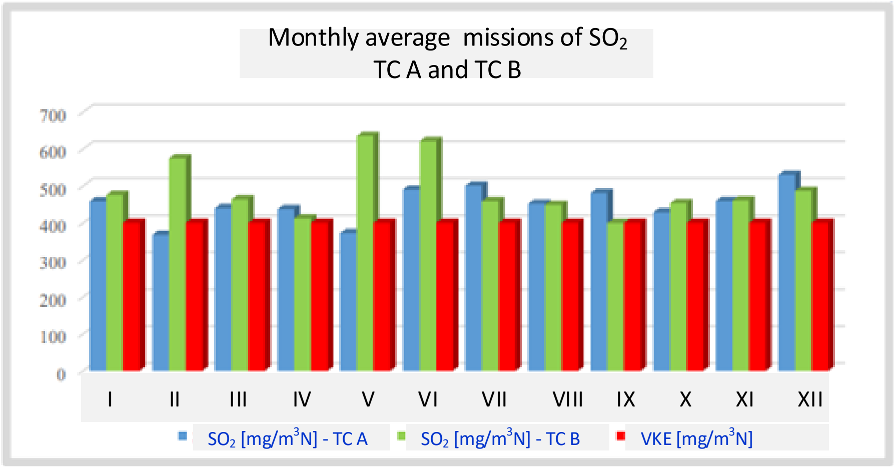

Figure 8. Average monthly emission values of SO_2 in mg/m^3N for 2019

Based on the emission measurements in the industrial zone of the Generation Division, it was found that the release of SO_2 based on the emissions made in Obiliq is within the allowed norms according to the standard.

According to the EU directives, TPP A and TPP B are required to control the amount of SO_2 released, and from 2023 it should be 200 mg/m^3N. In order to significantly reduce the emission of this gas, additional measures should be used that reduce the percentage of SO_2, e.g. using $CaCO_3$ limestone which dissolves at high temperatures (800 to 900 ^0C) and then CaO reacts with SO_2 in the presence of oxygen to form $CaSO_4$. In this way a high percentage of desulfurization is accomplished. The reaction which takes place is given below:

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g),$$

where (s) represents the solid aggregate state and (g) the gaseous one.

This process can take place in a furnace in a clean environment away from the power plant, as CO_2 is released. Subsequently, when calcium oxide in powder form is poured into the steam generator furnace at the same time as the introduction of powdered coal, in the furnace, in addition to the combustion of the fuel, the desulfurization reaction also takes place according to the reaction:

$$CaO(s) + SO_2(g) + \frac{1}{2} O_2(g) \rightarrow CaSO_4(s)$$

Calcium sulfate together with a quantity of ash from the fuel is separated from the gases and together with the slag and a quantity of ash falls down into the water tank of the steam generator.

Within the operation of the TPP are released quite a lot of nitrogen oxide gases, among which are NO and NO_2 which are written with the general formula NOx. These gases are a source of acid rain and in large concentrations are very harmful to health. During the winter season, these gases are a source of smog, a mixture of smoke and fog, when there are no air currents. The estimated values of NOx for TPP A and TPP B for 2019 are: 639 mg NOx/m^3N and 650 mg NOx/m^3N, while the allowed rate is 500 mg NOx/m^3N. While for the years 2015-18, for TPP B these values have been: 821, 680, 669; 746 mg NOx/m^3N.

Figure 9 shows the monthly values of NOx emissions for 2019 based on the report of the Kosova Environmental Protection Agency [17].

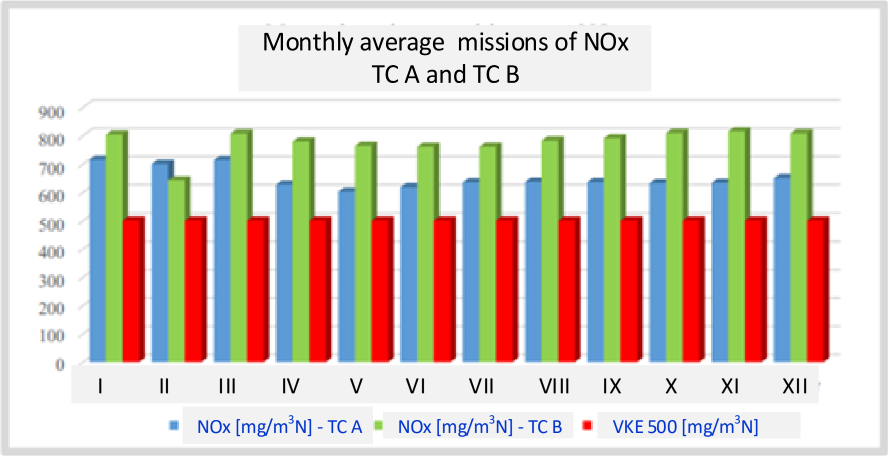

Figure 9. Average monthly NOx emission values in mg/m^{3}N for 2019

NOx gases are also responsible for increasing the concentration of ozone near the earth's surface, because they, under the influence of UV rays, react with oxygen and after a series of intermediate reactions ozone is released as a product of this reaction.

Measures to reduce NOx emissions are:

- Recirculation of gases from the steam generator outlet and their introduction into the steam generator furnace. This step reduces their temperature and the concentration of oxygen in the combustion zone.
- Reducing the coefficient of excess air.

This measure reduces the emission of nitrogen oxides. This is an effective measure that achieves a significant reduction in nitrogen oxide emissions, while its implementation does not require additional investment and does not increase operating costs. The use of this method is limited to the occurrence of incomplete combustion of the fuel. Under these conditions other pollutants would be generated such as carbon monoxide CO.

NO_2 is an irritating gas that is absorbed through the mucosa of the respiratory tract and causes undesirable effects on the lungs depending on the duration of exposure. Small concentrations of this gas cause an inflammation of the bronchial trachea, while higher concentrations can cause bronchitis, bronchopneumonia and acute pulmonary edema. This substance is also toxic to other biological systems and can affect the cellular immune system [19]. Large concentrations of NO_2 in the air can affect the spread of fires [20].

According to EU directives, TPP A and TPP B are required to control the amount of NOx released, and by 2026 it should be 200 mg/m^{3}N. [21] The European Commission has invested € 76.4 M in 2020 in the installation of filters in the smokestacks of TPP B, [22] in order to reduce by 4 times the amount of NOx gases and to keep it within the prescribed norms of the rules of EU [20].

In modern TPPs, the amount of NOx released into the environment is reduced by the denitrification process, in which case the reduction of these substances into elemental nitrogen is done during their treatment with ammonia (selective non-catalytic reduction) and with catalyst of vanadium or titanium dioxide (selective catalytic reduction).

Lignite used for combustion in TPPs releases many dust particles, which have different composition and dimensions. The emission value for dust particles in TPP A is around 45 mg/m^{3}N, while in TPP B this value is 5-14 times higher as shown in Figure 10 [17].

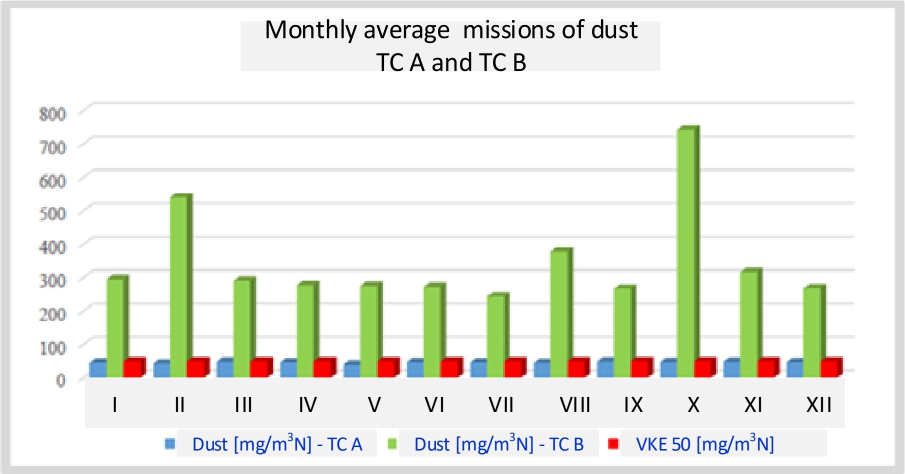

Figure 10. Average monthly dust emission values in mg/m^{3}N for 2019

The TPP B is currently installing new electrostatic precipitators to reduce dust and NOx emissions in accordance with the European Commission Directive on Large Coal-Fired Plants, which enters into force in 2023. This European Commission Directive or Regulation requires that large coal-fired power plants be able to reach dust emission values of less than 20 mg/m^{3}N. Therefore, the EU investment for the installation of filters in the smokestacks of TPP B will also affect the reduction by 35 times of the amount of dust they emit, and it will be within the norms provided by the EU Regulation [20 21].

Within the dust particles, particles with dimensions 2.5 - 10μm are distinguished, marked PM10, and those with dimensions less than 2.5μm, PM 2.5, which by means of winds can be carried over long distances up to 100 km.

PM2.5 particles, due to their very small dimensions, pass unhindered through the human body through respiration and are the cause of many problems in human health, including chronic lung diseases and malign diseases.

Measurements of PM10 and PM2.5 parameters made at air quality monitoring stations in Obiliq and Dardhishte for 2018 show high values during the autumn-winter period. Data are presented in Figure 11 [22].

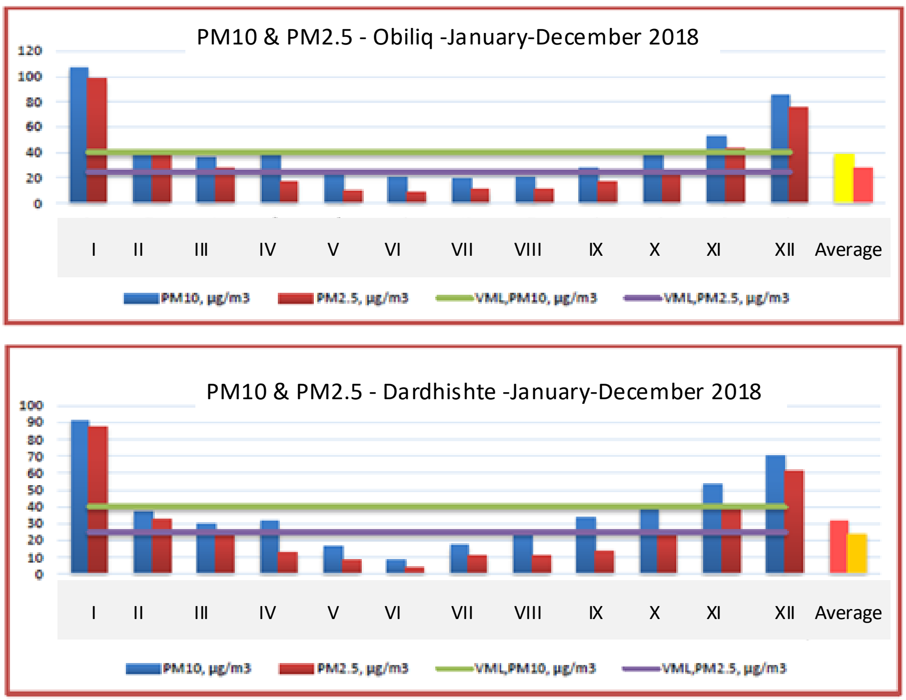

Figure 11. Measurements of PM10 and PM2.5 values in μg/m^{3}N in air quality monitoring stations in Obiliq and Dardhishte for 2018

According to a report presenting the detrimental effect of coal utilization for electricity generation, TPP B was the largest polluter in the Balkans and in Europe with PM10 dust particles emitted in 2016 [23].

The biggest causes of solid matter particles are the flying particles of burnt coal as well as to a lesser extent nitrates and sulfates. Such coal particles contain easily volatile organic substances and also contain quite a lot of SiO_2 (in amorphous and crystalline form), Al_2O_3 and CaO. Depending on the ratio of calcium and sulfur, they can be acidic, neutral or basic [24]. Such particles also contain trace metals, such as mercury, lead, cadmium and arsenic. These metals cause very harmful effects on the body [25]. Easily volatile organic substances are harmful to the body and cause the formation of ozone in the atmosphere and near the earth's surface, which is also harmful to the body.

Lignite usually contains less SiO_2 and more Al_2O_3 and CaO. During the burning of 4 tons of coal, about 1 ton of ash is generated. Most of the ash is deposited through the hydraulic transport system in the emptied spaces after the extraction of coal. Due to the high content of metal oxides, the ash raises the pH value of the water too much, above the normal value of 7, therefore such landfills must be constantly monitored so that the pollution of river water does not occur, because it causes large damages in the environment.

High values of these air pollution parameters: SO_2, NOx and PM10 and PM2.5 solids, separately and especially when present together, have a detrimental effect on the health of citizens. According to information published by the European Environment Agency for 2018, air pollution is the leading cause of premature death and disease, and therefore poses the greatest health risk in Europe [26]. Exposure of children and adults for short or long periods of time to polluted air can cause decreased respiratory function, respiratory infections and even asthma. In the family medicine centers of Prishtina and Obiliq during the autumn and winter months an increase of > 50% has been observed in the number of patients suffering from respiratory problems [17].

Although there is a lack of more data on the direct effect of pollution from TPP A and TPP B on the health of patients, based on the scientific studies highlighted above, we can emphasize that these factors can cause serious problems especially in children and adults who suffer from respiratory and cardiovascular diseases.

At the same time, the treatment of these patients and medical leaves from work increase the cost of economic damages as a result of the use of coal as an energy source.

Air pollution from the above substances also causes damage to vegetation and the ecosystem in general. NOx, ozone and SO_2 are particularly impactful in this aspect.

7. Conclusions

The existing electricity generation capacities in Kosova, of which thermal power plants constitute 91.41% of the installed capacities, or 94.3% of the generation capacities, and the rest coming from and renewable energy sources (RES, hydropower plants, wind farms and solar panels), meet the energy demand for most of the year. The largest share is supplied by the energy generated in the two TPPs (Kosova A TPP and Kosova B TPP) and a modest amount from HPP and RES sources. Furthermore, after 2010, although we have an increase in demand, domestic generation for most of the year has met this demand, and in certain periods of time, Kosova has exported electricity.

The presented data strongly argue that the best strategy for the stability of the energy system of Kosova is the construction of a new generation capacities based on lignite, which would replace TPP A after its decommissioning. This means that the construction of generation units of about 600 -700 MW is needed.

Electricity imports through regional interconnections, during the periods of high demand, remain an important part of energy supply, and the value of the imported quantity is around 5-7% of the total annual consumption. The volume of imports is limited by energy surplus in exporting countries, interconnection capacity, and energy cost. The interconnection with Serbia is not secure, while the availability of electricity from Albania for sale or exchange depends on hydrological conditions. Kosova's Electric Energy System (based on lignite generation) and Albania's Electric Energy System (based on hydropower) are systems that can complement each other in periods of power shortages and should consider a complementary development to meet the requirements in their markets.

Electricity consumption has increased in average rate of 4.6% per year, while maximum demand levels on an annual basis have increased around 4%. Most of the demand for electricity in Kosova comes from households (about 60%), followed by the commercial sector and the industrial sector. Technical and non-technical network losses remain high and together account for about 35% of gross energy consumption.

According to the analysis made, it is necessary further reduction of technical and non-technical losses. Technical losses are projected to decrease from 16.6% of gross supplied energy in 2010 to 8.0% in 2025. It is also assumed that reducing non-technical losses will reduce demand, as consumers will reduce energy consumption in kWh which must be paid [27].

As numerous studies have shown, Kosova has significant potential for improving energy economy and increasing energy efficiency. In this regard, through projects for increasing energy efficiency in public buildings, certain progress is made.

On the other hand, HPPs and other RES with small and unstable generation capacities do not have much impact on meeting the demand for electricity. If the latest technologies of carbon dioxide storage and emission reduction of dust and dust particles are used, the option of building new lignite-based generation capacities, according to all analyzes, is the option that best fits to Kosova's conditions.

The critical analysis of all options and environmental challenges, country's energy potentials and the unpredictability of energy prices and security of supply, realistic conclusion for sustainable supply of electricity from local energy sources based on lignite reserves is most realistic option. This must be followed by expansion of the heat supply network for the thermal energy cogenerated from the TPP.

The construction of new capacities would enable the replacement of the old generating units of Kosova A TPP and would ensure the increase of security in the energy supply, and at the same time would provide the necessary reserve for stable supply of electricity. On the other hand, reliance on domestic resources, mainly lignite, and partially on renewable energy sources, would significantly reduce the country's dependence on electricity imports and the unpredictability of prices in the regional market.

Regarding the impact on environmental, authors suggest reduction of the amount of SO_2 emissions and NOx gases to the value of up to 200 mg/m^3N by 2026, so that they are within the values allowed under EU norms to enter into force in 2023. Efforts should be made to reduce SO2 levels through the CaO desulfurization process as proposed in this report: repair the electrostatic precipitators of Kosova B TPP in the gas tract in order to reduce the amount of dust emitted, which must be below 50 mg/m^{3}N under current conditions and up to 20 mg/m^{3}N by 2026; introduction of the pollutant gas analyzers in all blocks and make continuous and accurate monitoring of the emission of air pollutants; reduce the amount of CO_2 emitted by smokestacks, which in 2019 was 95.3 kg CO_2/s for the three units of Kosova A TPP and 131.1 kg CO_2/s for the two units of Kosova B TPP, due to its effect on global warming, while the ecological tax should be imposed in the future for every ton of CO_2 generated. Currently this tax is applied in EU countries; Carry out continuous monitoring of water and soil pollution in the area of the Municipality of Obiliq and the surrounding area due to the impact of various ash components; continue to follow the data and number of patients coming from the Obiliq and Prishtina region, who suffer from respiratory and cardiovascular diseases, in order to immediately notice the negative impact of the effect of air pollution on quality of life, and mitigate it.

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ANALIZA DHE VLERËSIMI I OPSIONEVE TË FURNIZIMIT ME ENERGJI ELEKTRIKE PËR KOSOVËN

Përmbledhje

Kapacitetet ekzistuese të prodhimit të energjisë elektrike në Kosovë, nga të cilat termocentralet përbëjnë 91.41% të kapaciteteve të instaluara, ose 94.3% të kapaciteteve gjeneruese, dhe pjesa tjetër vjen nga burimet e energjisë së rinovueshme (BRE, hidrocentralet, fermat e erës dhe panelet diellore), plotësojnë kërkesën për energji për pjesën më të madhe të vitit. Pjesa më e madhe furnizohet nga energjia e gjeneruar në dy TC (TC Kosova A dhe TC Kosova B) dhe një sasi modeste nga burimet e HEC -eve dhe BRE. Për më tepër, pas vitit 2010, edhe pse kemi një rritje të kërkesës, prodhimi vendës për pjesën më të madhe të vitit, e ka përmbushur këtë kërkesë dhe në periudha të caktuara kohore, Kosova ka eksportuar energji elektrike.

Të dhënat e paraqitura argumentojnë fuqimisht se strategjia më e mirë për stabilitetin e sistemit energjetik të Kosovës është ndërtimi i kapaciteteve të reja gjeneruese të bazuara në linjit, i cili do të zëvendësonte TC A pas dekomisionimit të tij. Kjo do të thotë se nevojitet ndërtimi i njësive gjeneruese prej rreth 600 -700 MW.

Importet e energjisë elektrike përmes ndërlidhjeve rajonale, gjatë periudhave të kërkesës së lartë, mbeten një pjesë e rëndësishme e furnizimit me energji dhe vlera e sasisë së importuar është rreth 5-7% të konsumit të përgjithshëm vjetor. Vëllimi i importeve është i kufizuar nga teprica e energjisë në vendet eksportuese, kapaciteti i ndërlidhjes dhe kostoja e energjisë. Ndërlidhja me Serbinë nuk është e sigurt, ndërsa disponueshmëria e energjisë elektrike nga Shqipëria për shitje ose këmbim, varet nga kushtet hidrologjike. Sistemi i Energjisë Elektrike të Kosovës (bazuar në prodhimin e linjitit) dhe Sistemi i Energjisë Elektrike të Shqipërisë (bazuar në hidrocentrale) janë sisteme që mund ta plotësojnë njëri-tjetrin në periudhat e mungesave të energjisë dhe duhet të marrin në konsideratë një zhvillim plotësues për të përmbushur kërkesat në tregjet e tyre.

Konsumi i energjisë elektrike është rritur në normën mesatare prej 4.6% në vit, ndërsa nivelet maksimale të kërkesës në bazë vjetore janë rritur rreth 4%. Shumica e kërkesës për energji elektrike në Kosovë vjen

nga ekonomitë familjare (rreth 60%), e përcjellë nga sektori komercial dhe ai industrial. Humbjet teknike dhe joteknike të rrjetit mbeten të larta dhe së bashku përbëjnë rreth 35% të konsumit bruto të energjisë.

Sipas analizave të bëra, është e nevojshme të zvogëlohen më tej humbjet teknike dhe joteknike. Humbjet teknike parashikohen të ulen nga 16.6% e energjisë të furnizimit bruto në vitin 2010, në vlerën 8.0% deri në vitin 2025. Gjithashtu supozohet se reduktimi i humbjeve joteknike do ta zvogëlojë kërkesën, pasi konsumatorët do ta zvogëlojnë konsumin e energjisë që duhet të paguhet në kWh [27].

Siç kanë treguar studimet e shumta, Kosova ka potencial domethënës për përmirësimin e ekonomisë energjetike dhe rritjen e efikasitetit energjetik. Në këtë drejtim, përmes projekteve për rritjen e efikasitetit të energjisë në ndërtesat publike, është arritur përparim i caktuar.

Nga ana tjetër, HEC -et dhe BRE -të e tjera me kapacitete gjeneruese të vogla dhe prodhim të paqëndrueshëm, nuk kanë shumë ndikim në plotësimin e kërkesës për energji elektrike. Nëse përdoren teknologjitë më të fundit të uljes së emetimit të dyoksidit të karbonit dhe të zvogëlimit të emetimit të pluhurit dhe grimcave të pluhurit, opsioni i ndërtimit të kapaciteteve të reja gjeneruese me bazë linjitin, sipas të gjitha analizave, është opsioni që i përshtatet më së miri kushteve të Kosovës.

Analiza kritike e të gjitha opsioneve dhe sfidave mjedisore, potencialet e energjisë së vendit dhe çmimet e paparashikueshme të energjisë dhe të sigurisë së furnizimit, përfundimi realist për furnizimin e qëndrueshëm të energjisë elektrike nga burimet lokale të energjisë bazuar në rezervat e linjitit është opsioni më realist. Kjo duhet të pasohet nga zgjerimi i rrjetit të furnizimit me ngrohje për energjinë termike të prodhuar nga TC.

Ndërtimi i kapaciteteve të reja do të mundësonte zëvendësimin e njësive të vjetra prodhuese të TC Kosova A dhe do të siguronte rritjen e sigurisë në furnizimin me energji dhe, në të njëjtën kohë, do të siguronte rezervën e nevojshme për furnizim të qëndrueshëm të energjisë elektrike. Nga ana tjetër, mbështetja në burimet e brendshme, kryesisht të linjitit, dhe pjesërisht në burimet e energjisë së rinovuar, do të zvogëlonte ndjeshëm varësinë e vendit nga importet e energjisë elektrike me çmime të paparashikueshme në tregun rajonal të energjisë.

Lidhur me ndikimin mjedisor, autorët sugjerojnë zvogëlimin e sasisë së emetimeve të SO_2 dhe gazeve NOx në vlerën deri në 200 mg/m3N deri në vitin 2026, në mënyrë që ato të jenë brenda vlerave të lejuara sipas normave të BE -së për të hyrë në fuqi në vitin 2023. Duhet të bëhen përpjekje për të zvogëluar nivelet e SO_2 përmes procesit të desulfurizimit të CaO. Ky proces, siç propozohet në këtë punim duhet të bëhet përmes riparimit të filtrave elektrostatikë të TC Kosova B në tymtarë, në mënyrë që të zvogëlohet sasia e pluhurit të emetuar, i cili duhet të jetë nën 50 mg/m3N në kushtet aktuale, dhe deri në 20 mg/m^3N deri në vitin 2026. Futja e analizatorëve të gazit ndotës në të gjitha blloqet do të bënte monitorimin e vazhdueshëm dhe të saktë të emetimit të ndotësve të ajrit. Zvogëlimi i sasisë së CO_2 të emetuar, i cili në vitin 2019 ishte 95.3 kg CO_2/s për tre njësitë e TC Kosova A, dhe 131.1 kg CO_2/s për dy njësitë e TC Kosova B, duhet të merret parasysh me prioritet, për shkak të efektit të tij në ngrohjen globale dhe në të ardhmen për çdo ton CO_2 të gjeneruar duhet të vendoset. Aktualisht kjo taksë aplikohet në vendet e BE –së. Duhet të bëhet monitorimi i vazhdueshëm i ndotjes së ujit dhe tokës në zonën e Komunës së Obiliqit dhe zonës përreth, për shkak të ndikimit të përbërësve të ndryshëm të hirit dhe duhet të vazhdohet me përcjelljen e të dhënave mbi numrin e pacientëve që vijnë nga rajoni i Obiliqit dhe i Prishtinës, të cilët vuajnë nga sëmundjet e frymëmarrjes dhe kardiovaskulare, në mënyrë që të vlerësohet menjëherë ndikimi negativ i ndotjes së ajrit në cilësinë e jetës dhe të ndërmerren masat e nevojshme për zbutjen e këtij ndikimi.

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