www.rericjournal.ait.ac.th

Impact of Installing Small Wind Turbines in Urban Areas on Reducing Pollution – A Case Study

Gazmend Krasniqi *, Shpetim Lajqi *, [1], Bojan Đurin # and Nikola Kranjčić $

ARTICLE INFO

Article history:
Received 30 September 2021
Received in revised form
14 December 2021
Accepted 20 December 2021

Keywords:
Electricity
Environment
Urban area
Wind data
Wind turbines

ABSTRACT

Wind turbines usage is one of the ways to produce electricity from renewable energy resources. Finding a place with enough wind potential is the biggest challenge when it comes to wind turbine power production. Lately, ideas and research have been done to install wind turbines in urban areas. An interesting approach for urban areas is to calculate pollution reduction with the use of renewable energy resources instead of fossil fuels. In the center area of Prishtina, a small horizontal axis wind turbine of 300 watts is installed. The results of the power produced by this turbine for the year 2019 are presented in this paper. In order to gain wind data, a meteorological station is installed near to the wind turbine. The research also includes the pollution from existing coal power plants that supply Prishtina with electricity; Kosova A and Kosova B. Result shows the amount of reduced pollution if the small wind turbines are used in urban areas. Since the installation of only one wind turbine has negligible impact, this paper includes results if a higher number of the same wind turbines is installed.

1. INTRODUCTION

Prishtina, the capital of Kosovo, same as the other areas of this country, is supplied with electricity from two existing coal power plants, Kosova A and Kosova B [1]. Kosova A consists of five units, three of which are working at the moment, while the Kosova B power plant has two identical units with an installed capacity of 339 MW each. The fact that they coal as a fuel, for which Kosovo has quite large reserves of it [2], and the very old technology, makes these power plants one of the biggest polluters of the environment in Kosovo [3].

On the other hand, the use of renewable-energy resources, which are environment friendly, is one of the options to reduce power production from fossil fuels, and consequently, the amount of pollution they release. One of the most-used renewable-energy sources is wind energy. Power from the wind is produced using wind turbines, which have different shapes and types. To raise the power production from the wind turbines, the main factors are wind velocity and turbine size. This is why wind turbines are installed offshore in villages, countryside and on-shore in the sea, where wind velocities are much higher. The installation of wind turbines in these areas far from habitat areas cause one of the problems that producers are trying to avoid: energy losses in transmission. Finding a way to produce power near or inside urban areas seems to be a very good solution.

The application of wind turbines installation inside urban areas has taken place in late years. They were mostly used to cover a percentage of energy needs in the habitat areas or in some cases, they were used to supply houses with electricity or for streetlights. Some of the applications were quite successful, while others were not very likely.

The installation of wind turbines inside urban areas has been part of the study by many researchers. Research include the installation of different types, like horizontal axis wind turbines (HAWT) or vertical axis wind turbines (VAWT), in different spots like rooftops or freestanding near buildings. First, in 1998, a so-called WEB project - Wind Energy for the Built Environment project was implemented by the European Community WEB project included the discovery of a wind turbine to be used especially in urban areas [4]. EU again in 2003 in the UK [5] and 2007 in other regions of Europe [6] implemented studies considering the impact of installing wind turbines in urban areas on reducing the CO_2 emission. In 2001, a prototype WEB concentrator with a HAWT was designed in Rutherford Appleton Laboratory [7]. The study was focused on the performance of this turbine in different wind incidence angles with fixed and free yaw. Deeper research was done in 2006, where TURBY - a wind turbine which was developed to be used especially in urban areas took place. A building-mounted ducted wind turbine was a part of research in 2007 at Loughborough University [8].

In 2014, research on the history of urban climate made it easier for other researchers when aiming for

* Univeristy of Prishtina “HASAN PRISHTINA”, Faculty of Mechanical Engineering, 10 000 Prishtinë, Republic of Kosovo.

University of North, Department of Civil Engineering, 42000 Varaždin, Republic of Croatia.

$ University of Zagreb, Faculty of Geotechnical Engineering, 42000 Zagreb, Republic of Croatia.

[1]Corresponding author:
Tel: + 383 44 259 771.
E-mail: shpetim.lajqi@uni-pr.edu

studies in urban settings [9]. More recent studies were mostly focused on the installation of different types of wind turbines in different urban areas. In 2017, at the Clark University in Worcester, one research took place to compare HAWT and VAWT performance in urban areas [10].

In 2008, the first attempt to integrate wind turbines into the building was done in Green Building in Temple Bar, Dublin [11]. Three HAWTs were installed together with photovoltaic collectors and solar panels. The application of wind turbines, in this case, resulted in high vibrations and noise, so wind turbines were removed and replaced with photovoltaic collectors.

One almost same attempt was done in Kirklees Council Building in Huddersfield, UK [12]. Two 6 kW wind turbines were installed also together with solar panels and photovoltaic collectors. Even in this case, turbines failed to generate reliable energy production, so they were disconnected from the function [12].

Later studies have been made to testify if wind turbines can or cannot be used integrated into buildings. It is discovered that high-rise buildings have a great potential for the integration of wind turbines [13]. For more efficient installation, wind turbines should be installed in the centre of the roof, where the position of the rotor should be at least 30% above the roof level [14].

The main purpose of this research is to show the impact that the installation of wind turbines in urban areas could have on the reduction of pollution. This was achieved by installing a small HAWT on the rooftop of Technical Faculties Laboratories of the University of Prishtina “HASAN PRISHTINA, Kosovo, Prishtina. Power production from this roof-mounted HAWT was then analyzed and the impact it has on reducing pollution has been shown. Of course, this could not be done without having the power production and the amount of pollution data from Kosova A and Kosova B in advance. This power production and pollution data are also presented in this research.

It is very important to be stated that, this research only presents the wind data and power production from HAWT installed in one specific location, which is as mentioned before, the rooftop of the Technical Faculties Laboratory. Other locations inside Urban Area of Prishtina will might give different results, results that cannot be prejudiced by the results shown in this research.

The first chapter of this paper presents the emission of dangerous gases from specific units of Kosova A and Kosova B power plants Emission is presented for dust, SO_2, NOx and CO_2. The second chapter deals with the wind-energy potential in Kosovo, including units that are in operation, units that have the authorization to start the operation and units that are planned for the future. The third and last chapter deals with the electricity produced by the installation of a 300-Watts wind turbine inside the urban area of Prishtina, and the impact that it has in reducing pollution. Of course, such a small wind turbine will not have such an impact on reducing pollution, so an analysis of the pollution reduction by installing many similar wind turbines has been included in the result discussion part.

1.1 Energy Sector and Pollution in Kosovo

Kosova A units were built in the 1960s and early 1970s [15]. Kosovo A power plant units that are working at the moment, have a potential of maximum available capacity of 400 MW. The first unit of this power plant was put into operation in 1983 while the other in 1984 [16]. Due to the time depreciation and repairs of the units, the current maximum available capacity of both units of Kosova B is now around 500 MW in total. Nor Kosova B has much better results than Kosova A in terms of environmental pollution [17]. Kosova A and Kosova B power plants remain the main suppliers of electricity for the region of Kosovo [18]. The working units of power plants Kosova A and Kosova B and their capacities are presented in Table 1 [2], [16].

Table 1. Capacity of working units of power plants Kosova A and Kosova B.

Power Plants	Units	Max available capacity (MW)
Kosova A	Unit A3	130
	Unit A4	130
	Unit A5	135
Kosova B	Unit B1	240
	Unit B2	260
Total	890	

Kosova A and Kosova B power plants continue to be the main source of electricity in Kosovo. Due to the use of coal as a fuel and old technology used, there are several pollutants that are released to a large extent from both power plants [19]. These power plants release polluters like nitrogen oxides (NO and NO_2 together are called NOx), sulphur dioxide (SO_2), Carbon dioxide (CO_2) and dust [19], [20]. The amount of emission that is released by both power plants for each polluter is shown in the tables below. Table 2 shows the amount of pollution released by three units of Kosova A while Table 3 shows the amount of pollution released by two units of Kosova B.

Data are shown in tons/year and in mg/Nm^3 (milligrams per normal cubic meter) [21] - [26].

Kosovo is not yet part of the European Union (EU). EU has set strict rules on the conditions that must be met by countries aiming to join them. Certain conditions are set in terms of emissions of dangerous gases, both from vehicles and power plants. Thus, based on the directive 2010/75 / EU issued in 2010 by the European Parliament and the Council, the emission limits have been set for dust, NOx and SO_2 [27]. Emission limits have been set in mg/Nm^3. According to this directive, the emission limit of dust, SO_2 and NOx for “coal and lignite and other solid fuels" must meet the minimum conditions as are presented in Table 4 [27].

Table 2. Amount of pollution released by Kosova A.

Year	MWh	Dust	SO_2	NO_x	CO_2
KOSOVA A3 tons/year					
2013	2185530	1749.2	9495	8458.3	3197854
2014	1637886	438	3236	5569	2071823
2015	2056680	432	2846	7200	2637640
2016	2314809	444	3292	8450	3188870
2017	2084002	404	3593	6736	2411173
2018	2240648.0	484.15	5643.2	7910.7	2830579
KOSOVA A3 mg/Nm^3					
2013	2185530	251.0	787.7	701.0	701.0
2014	1637886	57.0	418.0	714.0	714.0
2015	2056680	44.0	289.0	725.0	725.0
2016	2314809	42.5	302.0	724.0	724.0
2017	2084002	44.0	417.0	724.0	724.0
2018	2240648.0	40.2	451.2	625.2	625.2
KOSOVA A4 tons/year					
2013	392635.0	1175	1807	1539.0	571337
2014	403999.0	113	756	1360.0	504073
2015	925997.0	141	1105	2710.0	986110
2016	879870.0	161	1229	3166.0	1169346
2017	824241.0	165	1407	2924.0	1050770
2018	712746.9	177.7	1844	2382.1	888762
KOSOVA A4 mg/Nm^3					
2013	392635.0	649.0	837	716	264200
2014	403999.0	53.0	392	717	263300
2015	925997.0	39.0	281	749	260700
2016	879870.0	40.2	306	723	266400
2017	824241.0	46.0	411	728	274800
2018	712746.9	55.8	558.3	748.6	227974
KOSOVA A5 tons/year					
2013	878253	288	3750	3334.0	1291148
2014	249417	75	478	842	309782
2015	357335	56	371	1231	448875
2016	766707	139	1095	2921	1144104
2017	801622	143	1477	2661	849658
2018	703724.4	107	1734	2399	902377
KOSOVA A5 mg/Nm^3					
2013	878253	51.0	751.0	681.0	263400
2014	249417	54.0	424.0	715.0	265000
2015	357335	33.0	260.0	724.0	261000
2016	766707	37.5	297.0	727.0	266200
2017	801622	40.0	426.0	712.0	276500
2018	703724.4	31.8	537.2	755.9	283700

Although they operate with three and two working units respectively, power plants Kosova A and Kosova B are counted as two complete units, so the emission of gases from these power plants is calculated per unit of the power plant and not the units within the power plants. This way, when calculating the emission of power plants and comparing the results with emission limits set by the EU directives, only Kosova A and Kosova B as a whole are taken into the calculations. According to the Table 1, both power plants have an available capacity of more than 300 MW. This puts Kosova A and Kosova B power plants in section three of the directive in Table 4. Pollution that is released from Kosova A and Kosova B power plants for SO_2, NOx and dust polluters are shown in Figure 1 (a, b, c). These figures show the total amount of pollution from all three units of Kosova A and two units of Kosova B. Those figures also show the maximum allowed emission according to directive 2010/75 / EU, and is compared with emission released from power plants Kosova A and Kosova B.

While the emission limits of NOx, SO_2 and dust, from the European Union directives are given in mg/Nm^3, the emission of CO_2 is given in other units. CO_2 emission limits are given in separate directives for coal-fired power plants. The European Union Agency for the Cooperation of Energy Regulators (ACER), in December 2019 has published OPINION No 22/2019 [28] on the calculation of the values of CO_2 emission limits. According to this opinion, targets that must be reached in order to be committed for receiving payments under a capacity mechanism, is 550 grams CO_2/kWh of electricity and 350 kilograms CO_2/installed capacity of kW. This means that targets set by this opinion are:

– Less emission of CO_2 than 550 grams CO_2/kWh of electricity produced (or 550 kilograms CO_2/MWh) and

– Less emission of CO_2 than 350 kilograms CO_2 per installed capacity of kW [28].

For Kosova A and Kosova B power plants, the emission of CO_2 per kWh has to be calculated. The amount of pollution of CO_2 for Kosova A and Kosova B power plants is shown in Tables 2 and 3 for years 2013-2018, and for years 2019 and 2020 can be taken from Energy Regulatory Office (ERO) webpage [29], [30] and other sources [31]. This way, the amount of emission of CO_2 in kg/MWh is calculated for each year and is presented in Figure 1(d). The amount of CO_2 released from Kosova A and Kosova B power plants in this figure is also shown as a total amount, which includes units blocks of Kosova A and two units of Kosova B.

It is very clear from the results shown in Figure 1 that Kosovo lacks in fulfilling the targets of emission of hazardous gases set by the EU. In all the results gained both power plants has given better results only in emitting dust in recent years. These results come from the installation of dust filters in all units of these power plants. In other cases, Kosova A and Kosova B power plants release much more amount of pollution than the limits set by EU directives for all four polluters analysed in this paper. They exceed the limit by many times, releasing large amounts of dust, CO_2, SO_2 and NOx. Residences in the neighbourhood of power plants are more endangered by these emissions [32].

People in Kosovo, for sure need both, clean air and electricity [33]. Despite the installation of filters in both power plants and repairs in the units of the power plants, the emission of harmful gases and dust continues to be quite high. Given this reality, and the fact that energy consumption in Kosovo continues to increase [34], Kosovo needs to make strong progress in applying methods to reduce pollution from energy production, by rehabilitating existing units of the power plants and focusing on energy production from environmentally friendly sources.

Table. 3. Amount of pollution released by Kosova B.

Year	MWh	Dust	SO_2	NO_x	CO_2
KOSOVA B1 tons/year					
2013	1927945	5041.9	5858	7215.1	2252335
2014	1597707	6290	4423	6043	1709773
2015	1986124	3922	2723	6982	2196342
2016	1919950	3210	3443	6974	2099531
2017	1857690	2628	4435	6673	2245401
2018	1074987	1425	2692	3747	1203985
KOSOVA B1 mg/Nm^3					
2013	1927945	672.0	664.0	840.0	237300
2014	1597707	863.0	499.0	817.0	215000
2015	1986124	650.0	305.0	817.0	220800
2016	1919950	409.0	403.0	772.0	209800
2017	1857690	335.0	525.0	804.0	223100
2018	1074987	212.4	329.1	451.6	144200
KOSOVA B2 tons/year					
2013	2169082	4790.6	6171	6860.3	2189936
2014	2048927	7667	4759	7138	1911977
2015	1935890	3652	2428	6315	1998242
2016	2014009	3254	3555	7007	2199983
2017	1784272	2633	3705	5936	1894311
2018	2284915	3134.3	5901	7525	2410909
KOSOVA B2 mg/Nm^3					
2013	2169082	657.0	692.0	829.0	239200
2014	2048927	857.0	523.0	813.0	217000
2015	1935890	640.0	349.0	825.0	220600
2016	2014009	375.0	432.0	781.0	201500
2017	1784272	350.0	537.0	802.0	210600
2018	2284915	398.9	607.0	775.2	249000

Table 4. Emission limits according to the Directive 2010/75 / EU.

Total rated thermal input (MW)	Coal and lignite and other solid fuels (mg/Nm^3)		
	SO_2	NO_x	Dust
50 - 100	400	300	30
100 - 300	250	200	25
>300	200	200	20

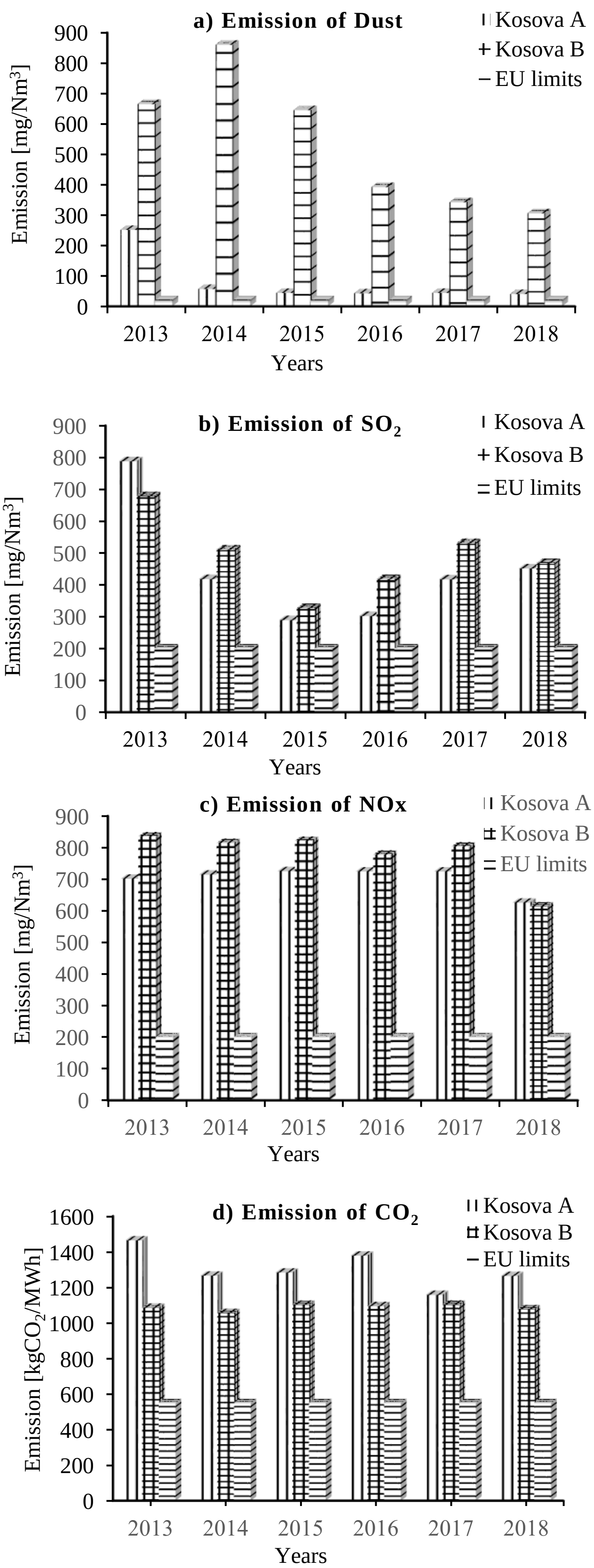

Fig. 1. Emission of gases from thermal power plants Kosova A and Kosova B and EU emission limits.

2. WIND ENERGY IN KOSOVO

Wind energy has taken the first place as the main source of renewable energy in Kosovo. In fact, until late there were no wind turbines at all in the region of Kosovo. In 2010, the first wind turbines were installed in Golesh with a capacity of 1.35 MW [35]. This comes from three turbines installed in this plant, each of them with a capacity of 450 kW. Since then, there were no investments in this technology until late.

Kosovo announced the first wind farm inauguration in October 2018 [36]. The wind far KITKA officially started sending electricity to the grid. Nine turbines were installed by the Turkish company Güriş Holding, each of them with a capacity of 3.6 MW [37]. The total capacity of the Wind Farm KITKA is 32.4 MW and projected annual output of the power plant is 95.6 GWh.

Another project that is under construction in Kosovo is the Bajgora wind park. The Wind Park consists of 27 wind turbine generators located in three areas named Selac I (1-9), Selac II (10 - 18) and Selac III (19 - 27) [38]. The project consists of 27 turbines, each with an installed capacity of 3.83 MW. The total installed capacity of the wind park is 105 MW. The project is nearing completion and is expected to be operational by 2021. Project is being built by Sowi Kosova Sh.p.k., an enterprise established for the purpose of the project, jointly owned by Enlight Renewable Energy with Kosovar and German partners [38].

Energy Regulatory Office (ERO) is responsible for the regulation of the energy sector in Kosovo, including power plants Kosova A and Kosova B [39]. ERO is an independent institution, which has the duty to regulate activities in the energy sector in Kosovo, including any form of energy. ERO has the authority to approve the tariffs for activities of public services issue, to give licenses and monitor whether these licenses are respected by energy companies, to impose obligations on the supply of the population. ERO is also responsible for setting and fulfilling the feed-in tariffs for the amount of electricity that is shared from renewable resources [39]. The whole renewable energy capacities, according to ERO are separated into three categories: a) capacities that are in operation, b) capacities that have gained the final authorization for starting the operation and c) capacities that have gained the preliminary authorization and are in procedures of getting the final authorization [40]. Information about feed-in tariffs and other information about the Wind energy sector in Kosovo are shown in Table 5 [41].

Wind energy is projected to be the most important energy source from all the renewable resources in the Republic of Kosovo. It will also be one of the most important energy sources, including fossil fuels-based power plants. Together with all capacities, wind energy is planned to cover around 1/3 of the total electricity consumption in the area of Kosovo. Since wind energy is very environmentally friendly technology, it will for sure reduce the emission of dangerous gases and make Kosovo a country with a better and cleaner environment.

Table 5. Information about wind energy in Kosovo.

Resources	Feed in tariff (€/MWh)	Cap. in operation (MW)	Cap. final auth. (MW)	Cap. prelim. auth. (MW)	Cap. in total (MW)
Wind Energy	85.00	33.8	114	235	382.8

3. CASE STUDY – PRISHTINA URBAN AREA

The main purpose of this study is to show the amount of pollution that is reduced by applying small wind turbines in urban areas to produce electricity. In the Urban areas, together with the huge amount of energy consumption, a high amount of energy is lost. While the amount of energy lost depend on many factors, the challenge these days is to reduce both, energy consumption and energy losses, both being very closely related to each other. Reducing energy losses will also reduce energy consumption, for the same reduced amount of energy losses. This because, less amount of energy will be needed to cover electricity needs, again for the same reduced amount of energy losses.

The highest amount of energy is lost in transmission and distribution. One of the ways to reduce the energy losses in transmission is to build power plants near to the consumers. This cannot be done with fossil fuels power plants due to the emission of gases, so the plants that could be installed near to the consumer must be environmentally friendly, must be renewable. Wind turbines have been installed near or inside urban areas to produce electricity. These wind turbines in some cases were quite big, producing electricity for residential needs. But mostly, wind turbines in urban areas are installed to produce electricity for streetlights or small needs.

This way, a small wind turbine of 300 watts is installed inside the urban area of Prishtina to produce electricity. This turbine is installed on the rooftop of the laboratory building of the Technical Faculties of University of Prishtina “HASAN PRISHTINA”. It has an installed capacity of 300 watts and it has a horizontal axe. This horizontal axis wind turbine (HAWT) is called S-300W wind turbine generator, it has three blades made of nylon composite materials and has an electric potential of 12 volts. For more secure results on wind data, a small meteorological station was also installed near the HAWT. It serves to gain information on the wind velocity and direction while having the results in the amount of energy produced. The wind turbine is installed with all necessary devices, like controllers, data loggers, batteries, inverters and other necessary equipment. A view of HAWT S-300 and the meteorological station is shown in Figure 2.

This wind turbine is installed in this spot before January 2019 and it is still producing electricity. Together with other equipment installed in this spot, the supply with electricity two classrooms of the laboratory. The data taken in this research are for the year 2019. Thus, wind data, such as wind velocity and direction and power produced by this wind turbine are taken for this research.

The weather station is made from two main devices: the outside device, which provides the outside data, and the inside device, which provides some inside data, like humidity and temperature. The inside device also serves as a small monitor where the online data could be seen. Outside and inside devices communicate through radio waves and provide results every 16 seconds. All the data are stored online in the webpage (https://app.weathercloud.net/d3674916986#profile) which is provided in this research. Here, the data are taken from the inside device every minute, and the average is then collected and saved online every five minutes. Monthly average wind velocities and electricity produced for the year 2019 are shown in Table 6.

(a)

(b)

Fig. 2. Installed a) wind turbine and b) metrological station at the rooftop of the laboratory building. https://app.weathercloud.net/d3674916986#profile

Table 6. Average wind velocity and electricity produced for the year 2019

MONTHS, 2019	Average Wind Velocity (m/s)	El. Produced (kWh)
January	0.94	10.252
February	1.80	19.631
March	1.55	16.905
April	1.88	20.504
May	1.66	18.105
June	1.36	14.833
July	1.44	15.705
August	1.14	12.433
September	1.31	14.287
October	0.95	10.361
November	1.75	19.086
December	1.55	16.905
Avg. total	1.44	189.008

The wind data can be presented in different forms. One of the most preferred methods to present the wind data is through wind-roses. Wind-roses show how wind direction distribution and frequency change. They can be used to show both the wind velocity and direction. A software called Pavanaarekh, a free tool for research purposes, is used to draw the wind-rose. The wind-rose for laboratory building where HAWT is installed, for the year 2019 is shown in Figure 3.

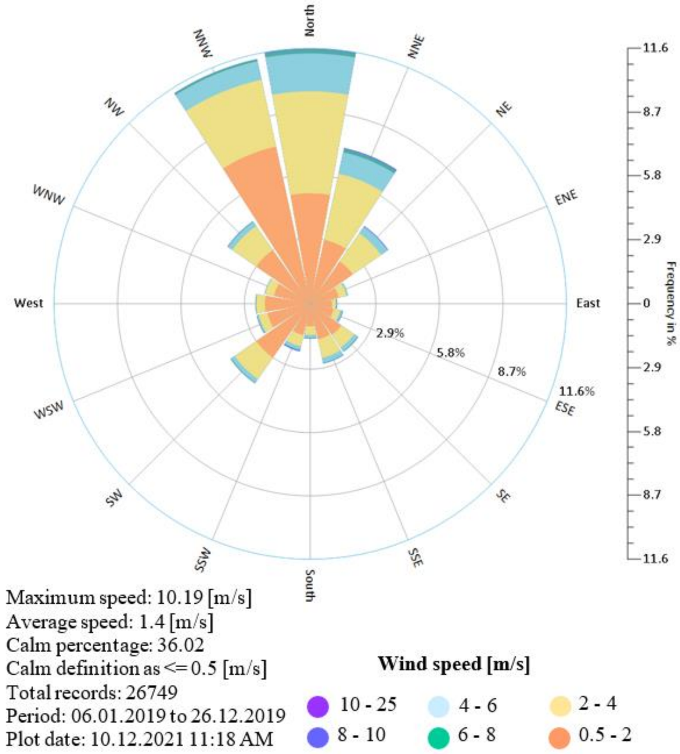

Fig. 3. Wind-rose for laboratory building spot in Prishtina for the year 2019.

HAWT starts producing electricity at the wind velocity of around 1.0 m/s [42]. The amount of power produced at low wind velocities is also very low. The power production increases with the increase of wind velocity. The highest registered power production by the HAWT is registered on 23 April 2019. The amount of power produced was 263.9 Watts at the wind velocity of 10.19 m/s. Wind direction most of the time is north and north-north-west. This direction is verified also by other researches done before for Prishtina wind-roses, that wind in Prishtina blows mostly from the North direction [43].

From the results presented in Table 6 and the wind-rose presented in figure 3, the average wind velocity for the year 2019 is 1.44 m/s. The highest registered average wind velocities were in February and April, registering an average of 1.8 and 1.88 m/s. The lowest wind velocity are registered in January and October, when average velocities were below 1.0 m/s.

The power produced by the wind turbine is the most important data required for this study. Wind turbine power production data are required for the same period of time that wind velocity and direction are shown in Table 6. The power production data are registered in data loggers installed with the wind turbine. The wind turbine is firstly connected to the wind controller, where current power production data can be seen. To register these data, the appropriate data logger is connected to the controller. Data are saved and collected in one SD card which is inserted in the data logger. Data are saved and collected for every minute. The monthly amount of power produced by HAWT is shown graphically in Figure 3, where the average monthly wind velocity is also shown for the amount of the power that is produced every month.

The power produced by the wind turbine changes, as shown in Table 6, with the change of average wind velocities. Thus, the highest amount of power produced monthly is registered in April, when wind average wind velocity was higher. Anyhow, there are some gaps in the amount of power production and average wind velocities. For example, during the registration of data, it was seen that on some days, even though the wind velocity was higher, HAWT produced less amount of electricity. This can be explained if most of the time during the day the wind velocity was low, but it was very high for a short time, increasing here the average wind velocity but not that much the amount of power production. Anyhow, this gap remains to be studied in further investigation, as it is not the study case of this research.

The total electricity produced in 2019 by HAWT is 189008 Watt-hours or 189 Kilowatt-hours. According to the results gained by data loggers, wind turbine, because of the low wind velocity, was able to work only around 30% of the time. The other period of time HAWT did not send electricity to the batteries, mostly because of the wind velocity or also the batteries level of charge. In any case, only 30 percent of the time during the year, the wind turbine was able to produce electricity and charge the batteries.

As shown in Table 6, the results of the wind velocity and electricity production are not satisfying at all. This comes from a number of factors, and the main one is the position where wind turbine and meteorological station are installed. The idea of the research was to provide the power production potential at the rooftop of the laboratory building. The laboratory building is placed in the center of Prishtina, and wind velocity in this area is quite lower than in some other parts of the city. The buildings around the laboratory also play a crucial role as obstacles to change the direction of the wind and reduce the wind velocity that hits the turbine blades. From our side this was expected, it was just necessary to be proofed experimentally.

It is very important to state that, the results shown in this research are only for one specific location. Wind data in some other areas inside the Urban Environment of Prishtina have shown better results. Some parts of Prishtina, like Sunny Hill or Velania neighborhood are more suitable for producing energy from the wind, as their altitude is higher and there are fewer obstacles that change the direction of the wind. Consequently, the installation of wind turbines in those areas will give quite different results and cannot be prejudiced by the results given in this research. Every area has its own characteristics and results can only be taken from measurements taken from those specific locations.

Another very important issue when installing wind turbines in urban areas, is the possibility of combining them with photovoltaic systems, since they also have impact in the reduction of pollution. Of course, in Urban Areas, buildings cause shadows, which have a very high impact in the efficiency of the photovoltaic systems. Anyhow, research in this step only show the power production from the wind turbine, as power production from photovoltaic systems and combination of them with wind turbines remain a part of future investigations.

One of the issues to be considered when installing wind turbines in urban areas is placing of the wind turbines in spots where their shadow doesn't make any negative effect and the noise they make is acceptable. Placing them along the streets is more acceptable because of the noise, either for power production or street lighting. When installing hybrid systems with solar panels, it is necessary to make sure that wind turbines don't affect the solar power production by giving shadows to the panels. Otherwise, installation of wind turbines in rooftops of the buildings or attached to them, must be considered after studies have been done in the noise and vibrations they cause to the building itself.

4. DISCUSSION OF RESULTS

The amount of emission of gases from the installation of HAWT can be calculated when the amount of specific pollution is known for the unit of MWh or kWh. Tables presented at the beginning of this research will be used to calculate the specific emission for each polluter. The specific amount of pollution for emission dust and dangerous gases is shown in Table 7. Emission is shown in tons per year per MWh, which will help in calculating the amount of pollution that is reduced when installing small wind turbines inside the urban area of Prishtina.

For the HAWT chosen for this research, the amount of electricity produced for the year 2019 is shown in the previous table. Having in possession data from Table 6 and Table 7, makes it possible to calculate the amount of pollution that is reduced by the usage of this turbine in this year. Table 8 shows the amount of reduced pollution for the four polluters that are analyzed in this research.

As presumed at the beginning of this research, the impact of installing only one wind turbine will have an unneglectable impact. Anyhow, the wind turbine that is installed in this location, has made some impact, especially in reducing the amount of CO_2 emitted. The amount of pollution that is reduced by this HAWT is more than 1.3 kg per year of NOx and more than 441 kg of CO_2.

Table 7. Specific emission of gases in tons/year/MWh (or kg/year/kWh).

Year	Dust	SO_2	NO_x	CO_2
2013	0.0032	0.0073	0.0073	2.5481
2014	0.0042	0.0046	0.0072	2.3201
2015	0.0024	0.0028	0.0070	2.3840
2016	0.0018	0.0032	0.0072	2.4722
2017	0.0016	0.0040	0.0067	2.2592
2018	0.0016	0.0051	0.0069	2.3392
2019	0.0004	0.0051	0.0069	2.3383
2020	0.0004	0.0044	0.0066	2.5083
Average	0.0020	0.0046	0.0070	2.3962

Table 8. Amount of pollution reduced by the usage of HAWT in kg/year.

Year	Dust	SO_2	NO_x	CO_2
2019	0.082345	0.957965	1.301098	441.9573

Table 9. Amount of pollution reduced by installation of 100 similar HAWT in kg/year.

Year	Dust	SO_2	NO_x	CO_2
2019	1.82	95.8	130.11	44195.73

Since these kinds of turbines most of the time are installed for covering lighting needs for parks and streets, installation of similar wind turbines will help to reduce more the amount of pollution that is released by Kosova A and Kosova B power plants. For example, only around the technical faculty, for the streetlights and the park where faculty is built, around 100 similar wind turbines could be installed. Installing a higher number of similar wind turbines will surely reduce the amount of pollution that is released by the power plants, since streetlights at the moment also are supplied by these power plants. The amount of pollution that would be reduced with the installation of a higher number of turbines is presented in Table 9.

Table 9 shows that the installation of a higher number of similar wind turbines in urban areas will have a slightly good impact on reducing the pollution emitted by coal-based power plants. Although the reduced emission is not that high compared with the pollution that is emitted by the power plants, it has anyhow some impact. Wind turbines will not only reduce pollution. Especially if they are installed in urban areas, they will produce and use electricity without losses in transmission and distribution. They will also help on building an environment more familiar with renewable resources, thus helping generations to dispel any hesitations they may have about renewables.

Installation of these wind turbines inside urban areas might be difficult, as it requires much data and preliminary preparation. So, it is required to have a proper place where these turbines could be installed, with measured data taken in advance. The methodology to reach the objectives of installing many wind turbines in urban areas is explained below:

1. Finding a place where these turbines could be installed, with taking all the necessary preventions that the noise, vibrations and shadow effect caused by them is eliminated as much as possible;
2. Take the wind data for this location. This could either be done by previously installing measuring devices or approximate data could also be taken from data that are generated from satellites;
3. Designing and finding the proper wind turbines to be installed in this area, including the capacities of the turbines and other characteristics. Design of the towers takes place here if the turbines are freestanding. If there is a possibility of installation of hybrid systems with solar panels, towers must be designed to reach the maximum efficiency for both wind and solar energy;
4. Take the permissions from local authorities to install these turbines on the location that is chosen;
5. Find investors that could be interested in participating in the project.
6. Installation of the turbines to produce electricity. Real data then could be taken on the power production and pollution reduced from them.

5. CONCLUSIONS

The electricity demand in Kosovo is around 5000 GWh of electricity per year [44]. Most of this electricity demand is met by two power plants, Kosovo A and Kosovo B. These two power plants use coal as a raw material for electricity generation. Due to outdated technology and the use of coal, Kosovo A and Kosovo B are the largest polluters of the environment in Kosovo, and among the largest polluters in Europe. The emission of gases from power plants in Kosovo exceeds the limits set by the directives and articles of the European Union for power plants with combustion of solid fuels. Gaseous emissions are exceeded in all gas measurements, such as for CO_2, NOx, SO_2 and dust.

In strategies for the near future, Kosovo plans to increase electricity production from renewable sources. In terms of wind turbines, there are two wind farms operating in Kosovo with an installed capacity of 33.5 MW. The wind farm in Bajgora, Mitrovica, is also under construction, which is being built in three areas, each with nine turbines. This wind farm is expected to be put into operation this year and has an installed capacity of 114 MW. Some other capacities for the production of electricity from wind turbines have received final authorization and will start operating in the near future. Other capacities which have the final authorization and can start operating, have an installed capacity of 235 MW. This will make wind energy one of the main energy sources in Kosovo, with an installed wind energy capacity of 382.8 MW. These data are presented in the second section of the paper.

This paper is initially focused on the emergence of this problem of gas emissions, and then in the main part is analyzed the reduction of emissions of these gases, if small wind turbines are installed in urban areas. For the interest of the research, wind turbine was installed in the laboratory building rooftop, which is not a very favorable spot to install wind turbines because of the low attitude and many obstacles that surround the laboratory. Anyhow, the results are quite interesting, where the best results have been shown in reducing CO_2 emission, which is also emitted the most.

Finally, the impact of reducing pollution from these power plants is presented, if a larger number of similar turbines are installed in urban areas. It has to be considered that the installation of wind turbines in urban areas has an impact not only on reducing pollution, but also on reducing electricity losses in transmission and distribution, losses which in Kosovo are quite large. This is because the turbines are installed close to the customer, and in the case of the installation of these turbines for the needs of street and park lighting, the losses are eliminated almost completely.

REFERENCES

[1] Wynn G. and A. Flora. 2020. Beyond Coal: Investing in Kosovo's Energy Future. October 2020. *Institute for Energy Economics and Financial Analysis (IEEFA)*. Retrieved in December 2021 from World Wide Web: https://ieefa.org/wp-content/uploads/2020/09/BeyondCoal_Investing-inKosovosEnergyFuture_October2020.pdf?utm_source=rss&utm_medium=rss&utm_campaign=beyond-coal_investing-in-kosovosenergyfuture_october2020.

[2] Bytyqi V. and I. Ramadani. 2018. Environmental Changes from Coal Surface Mining in Kosovo.

Ecoforum Journal 15(2), North America, 7 May 2018.

[3] Kabashi S., Bekteshi S., Ahmetaj S., Kabashi G., Najdovski D., . Zidanšekd A., and Šlaus I., 2011. Effects of Kosovo's energy use scenarios and associated gas emissions on its climate change and sustainable development. *Applied Energy* 88(2): 473-478. doi: 10.1016/j.apenergy.2010.06.023.

[4] Blanch M.J., 2022. Wind energy technologies for use in the built environment *Wind Engineering*, 26(3): 125-14326. doi: 10.1260/030952402762056054

[5] van Bussel G., Mertens S., Polinder H., and Sidler H., 2004. TURBY, concept and realisation of a small VAWT for the built environment. In *Proceedings of the global windpower 2004 conference & exhibition.* Washington, USA, 28-31 March. American Wind Energy Association (AWEA).

[6] Murakami S. and K.A.H. Komine. 1979. Amplification of wind speed at ground level due to construction of high-rise building in urban area. *Journal of Wind Engineering and Industrial Aerodynamics* 4 (3-4): 343-370. doi: 10.1016/0167-6105(79)90012-6

[7] Dutton A.G., Halliday J.A., and Blanch M.J., 2005. The Feasibility of Building-Mounted/Integrated Wind Turbines. Final Report of Carbon Trust Contract. Retrieved in December 2021 from World Wide Web: https://ukerc.rl.ac.uk/pdf/BUWT_final_v004_full.pdf

[8] Watson S., Infield D., Barton J., and Wylie S.J., 2007. Modelling of the Performance of a Building-Mounted Ducted Wind Turbine. *Journal of Physics: Conference Series 75*: 1-12. doi: 10.1088/1742-6596/75/1/012001.

[9] Mills G., 2014. Urban climatology: History, status and prospects. *Urban Climate* 10(03): 479-489. DOI: 10.1016/j.uclim.2014.06.004

[10] Winslow A.R., 2017. Urban wind generation: comparing horizontal and vertical axis wind turbines at Clark University in Worcester, Massachusetts. MS Thesis. Clark University, Worcester, Massachusetts, USA .

[11] Hamza N., 2016. The sustainable high-rise building renewables and public perceptions. In A. Sayigh (Red). *Sustainable High Rise Buildings in Urban Zones: Advantages, Challenges, and Global Case Studies.* Cham, 2017, pp. 103-116. DOI: 10.1007/978-3-319-17756-4_6

[12] KMC, 2005. Detailed technical information: Civic Centre 3 – Energy from the Sun and the Wind. *Kirklees Metropolitan Council*. Retrieved in December 2021 from World Wide Web: http://www.urbanwind.net/pdf/Case_Study_UK1_Detailed_Summary.pdf

[13] Denoon R., Banks D., Cochran B. and Wood G., 2008. Harvesting wind power from tall buildings. In *Congress Proceeding of CTBUH 2008, 8th World Congress - Tall and Green: Typology for a Sustainable Urban Future*.

[14] Abohela I., Hamza N., and Dudek S. 2011. Effect of roof shape on energy yield and positioning of roof mounted wind turbines. In *Proceedings of Building Simulation 2011: 12th Conference of International Building Performance Simulation Association.*

[15] KEK 2021. Power Plant Kosova A – Main Information. Kosovo Energy Corporation J.S.C. Retrieved in December 2021 from World Wide Web: http://kek-energy.com/kek/termocentrali-kosova-a.

[16] KEK 2021. Power Plant Kosova B – Main Information. Kosovo Energy Corporation J.S.C. Retrieved in December 2021 from World Wide Web: http://kek-energy.com/kek/termocentrali-kosova-b.

[17] Kajtazi B. and T. Floqi. 2011. Thermo Power Plant "Kosovo B"– A Pollution Source for Sitnica River. *European Journal of Engineering and Technology Research* 6(3): 63-65. DOI: 10.24018/ejers.2021.6.3.2379.

[18] Bajcinovci B., 2017. Environment quality: impact from traffic, power plant and land morphology, a case study of Prishtina. *Environmental and Climate Technologies* 19(01): 65-74. DOI: 10.1515/rtuect-2017-0006.

[19] Bekteshi S., Kabashi S., Šlaus I., Zidanšek A., and Podrimqaku K., 2012. Model analyses of long and short term pollution emission reduction. *International Journal of Environment and Sustainable Development* 11(03) 293-303. DOI: 10.1504/IJESD.2012.050464

[20] Kabashi S., Bekteshi S., Ahmetaj S., Kabashi G., Podrimqaku K., Veliu V. Jonuzaj A., and Zidanšek A., 2012. Dynamic modeling of air pollution and acid rain from energy system and transport in Kosovo. *Open Journal of Air Pollution*, 3(01): 82-96. DOI: 10.4236/ojap.2012.13011.

[21] KEPA 2021. Report on Environmental Indicators. *Kosovo Environmental Protection Agency (KEPA)*. Retrieved in December 2021 from World Wide Web: https://www.amm-krks.net/repository/docs/Mjedisi_i_Kosov%C3%ABs_2020_Raport_i_treguesve_mjedisor%C3%AB_-_ANGLISHT.pdf

[22] KAS 2015. Greenhouse Gas Emissions in Kosovo 2014-2015. *Kosovo Agency of Statistics (KAS)*. Retrieved in December 2021 from World Wide Web: http://ask.rks-gov.net/media/2471/ghg-emissions-in-osovo-2014-2015.pdf

[23] KEPA 2016. Report on the State of the Environment in Kosovo 2015. *Kosovo Environmental Protection Agency (KEPA)*. Retrieved in December 2021 from World Wide Web: https://www.ammk-rks.net/repository/docs/Anglisht-final.pdf

[24] KEPA 2017. Annual Report State of the Environment in Kosovo 2016. *Kosovo Environmental Protection Agency (KEPA)*. Retrieved in December 2021 from World Wide Web: https://www.ammk-rks.net/repository/docs/Raporti_i_mjedisit_2016_web_format_eng_22817.pdf

[25] KEPA 2018. Annual Report State of the Environment in Kosovo 2017. *Kosovo Environmental Protection Agency (KEPA)*. Retrieved in December 2021 from World Wide Web: https://www.ammk-rks.net/repository/docs/Raporti_M_2017_english.pdf

[26] KEPA 2019. Annual Report State of the Environment in Kosovo 2018-2019. *Kosovo Environmental Protection Agency (KEPA)*. Retrieved in December 2021 from World Wide Web: https://www.ammk-rks.net/repository/docs/Anglisht_WEB_(ok).pdf

[27] EU, 2010. Directive 2010/75/EU. *European Parliament and of the Council, Official Journal of*

the European Union. Retrieved in December 2021 from World Wide Web: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0075&from=EN

[28] ACER, 2019. OPINION No 22/2019. *The European Union Agency for The Cooperation of Energy Regulators.* Retrieved in December 2021 from World Wide Web: https://documents.acer.europa.eu/Official_documents/Acts_of_the_Agency/Opinions/Opinions/ACER%20Opinion%2022-2019%20on%20the%20calculation%20values%20of%20CO2%20emission%20limits.pdf

[29] ERO 2020. Electricity and Thermal Energy Balance 2020 *Energy Regulatory Office (ERO)*. Retrieved in December 2020 from World Wide Web: http://ero-ks.org/2020/Sektoret/ELECTRICITY%20AND%20THERMAL%20ENERGY%20ANNUAL%20BALANCE%202020.pdf

[30] ERO 2021. Electricity and Thermal Energy Balance 2021 *Energy Regulatory Office (ERO)*. Retrieved in December 2021 from World Wide Web: https://www.ero-ks.org/zrre/sites/default/files/Publikimet/Bilancet/Bilanci%20vjetor%20i%20energjise%20Elektrike%20dhe%20Termike%202021.pdf

[31] Ibrahimi N.A., Gebremedhin A., and Sahit A., 2019. Achieving a flexible and sustainable energy system: the Case of Kosovo. *Energies* 12(24): 4753. DOI: 10.3390/en12244753.

[32] Morina I. and M.H. Spahiu. 2014. Environmental threatened places – hotspots in Kosovo. *National Institute of Environmental Health Sciences*. Abstract number 3367.

[33] Bajcinovci B., 2019. Environmental and climate dilemma: coal for heating or clean air for breathing: a case of Prishtina. *Sciendo* 23 (01): 41-51. DOI: 10.2478/rtuect-2019-0003.

[34] Doroci L., 2021. A Comprehensive Review of Kosovo Energy Efficiency Policy. *Resarchgate 01.2021*. DOI: 10.13140/RG.2.2.19699.86567.

[35] Bualoti R., Gjukaj A., and Bardhi A., 2014. Monitoring the power quality for wind power plant of Golesh. *Researchgate.* MEDPOWER 2014, 9th Mediterranean Conference on Power Generation, Transmission, Distribution and Energy Conversion At: Athens, Greece, Volume ID121.

[36] MWSR 2018. Inauguration-the-first-wind-power-plant-in-Kitka. *Municipalities Web Sites of the Republic of Kosovo* (MWSR). Retrieved in December 2021 from World Wide Web: https://kk.rks-gov.net/kamenice/news/perurohet-centrali-i-pare-i-energjise-me-ere-ne-kitke/

[37] WB 2021. Final Report of the low-cost renewable energy mix. *World Bank (WB)*. Retrieved in December 2021 from World Wide Web: https://akee.rks-gov.net/wp-content/uploads/2021/02/RAPORTI.pdf

[38] GA 2019. Bajgora wind project environmental and social impact assessment. *Golder Associates S.r.l. - Euopean Bank for Reconstruction and Development*. Retrieved in December 2021 from World Wide Web: https://www.ebrd.com/documents/comms-and-bis/esia-50423-nts-eng.pdf

[39] ERO 2021. Establishment of energy regulatory office. *Energy Regulatory Office.* Retrieved in December 2021 from World Wide Web: https://www.ero-ks.org/zrre/en/per-ne

[40] ERO 2017. Rule on authorization procedure for construction of new generation capacities from renewable energy sources. *Energy Regulatory Office*. Retrieved in December 2021 from World Wide Web: http://ero-ks.org/2017/Rregullat/Rule%20on%20Authorization%20Procedure%20for%20Construction%20of%20New%20Generation%20Capacities%20from%20RES.pdf

[41] Lajqi Sh., Đurin B., Berisha Xh. and Plantak L., 2020. Analysis of the potential for renewable utilization in Kosovo power sector. *Environments* 07(06): 49. DOI: 10.3390/environments7060049.

[42] Krasniqi G., 2021. Application of wind energy in urban areas - modelling of urban wind turbines. PhD Thesis, published. University “St. Kliment Ohridski”, Bitola, North Macedonia.

[43] Prebreza B., Krasniqi I., Kabashi G., and Pula G., 2013. Disturbances of the normal operation of Kosovo power system regarding atmospheric discharges. *International Journal of Electrical Engineering World Academy of Science, Engineering and Technology* 01.2013: 711-717.

[44] ERO 2019. Annual Report 2019. *Energy Regulatory Office.* Retrieved in December 2021 from World Wide Web: https://www.ero-ks.org/zrre/sites/default/files/Publikimet/Raportet%20Vjetor/Annual%20Report%202019_%20ERO.pdf