MSc Program
Renewable Energy in Central and Eastern Europe

Wind Energy Potential of Kosovo

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
Dipl.-Ing. Andreas Krenn

Pellumb Gnjinolli, B.A.
0827591

Vienna, November 15, 2010

Affidavit

I, **Pëllumb Gjinolli, BSc**, hereby declare

1. that I am the sole author of the present Master Thesis, "Wind Energy Potential of Kosovo", 70 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, 25.11.2010 ______________________________

Date Signature

Abstract

In this thesis named “Wind Energy Potential of Kosovo” the possible assessment of wind energy potential was discussed, through the steps which led to definition of theoretical wind energy potential and later to the realizable wind potential.

In absence of real time on-site measurements, this work was conducted with the computer modeling named MM5.

Although there were not any measurements done before, the results coming out from this pioneering study would contribute to have clear idea on steps to be taken, before investing in wind energy sector in Kosovo.

Even though there were limitations due to lack of on-site measurements, detailed analysis took place where spatial-technical, environmental and also economical constraints were taken into consideration thus leading to a more specific study.

The calculations were done for the modeled wind speeds of more than 5.5 m/s, where the possible sites were selected.

These sites were selected according to Corine database and in harmony with GIS the sites that came out were helpful in determination of possible and free land for installing wind turbines. Later, the wind turbine type was selected and by this I managed to calculate how many wind turbines could be put in previously specified available land.

After modeling of annual energy yield that a turbine might produce, and after adding other factors such as: inflation rate, operation and maintenance cost, cost of a turbine, it was the turn to have detailed economical study, and to have more information regarding feasibility of these turbines.

The comparison criteria for estimation if whether it is feasible or not, was used the feed-in tariff present for Kosovo, so the results that came out explained that with the modeled wind speed of Kosovo (5.5-5.85 m/s) it is not feasible to invest in wind energy.

Last but not least also legal and procedural approaches were taken into consideration, explaining the importance of energy strategy of Kosovo and the presence and the role of Energy Regulatory Office (ERO) throughout this process.

Contents

List of Figures

List of Tables

1. Introduction

1.1 Motivation of this study

The motivation of this study can be summarized as: the need to see the possibilities of wind energy potential of Kosovo. Till now no study took place about, describing the wind energy potential of Kosovo. It might have a lot of reasons, starting form the past war 1998-1999, till the undefined status until 17 February 2008 where Kosovo declared its independence.

We can consider this period as the born of a new country, where everything started form beginning, so looking also into the energy sector it is also a milestone what we are having now, e.g. the new thermal power plant is being planned to be built, since Kosovo has a lot of lignite sources, so it's primary energy source will be from coal. This doesn't mean that there will not be any place for renewables. Being geographically in Europe and planning to be part of European Union (EU) in the upcoming years, then Kosovo should consider a portion of its primary energy to come from renewables.

Therefore my core motivation of this master thesis was to see, closer how wind energy can be developed in Kosovo, is there enough wind for energy generation, which are best regions to invest, what are the obstacles for the investors etc. although there were not any prior wind energy on-site test done, there is no enough info about theoretical, therefore it was decided about realizable.

1.2 Core question

The core question of this study is to investigate the realizable wind energy potential of Kosovo in general, to define which steps were followed to achieve these results, last but not least also to see the approval procedures that should be taken in development of wind energy.

It must be known that, no on-site measurements were done till now in Kosovo, apart from meteorological institute of Kosovo which does continuous measurements in three different regions (Pristina, Peja and Ferizaj) of Kosovo, but at 10 m, which is not enough for prediction of theoretical wind potential which later would contribute in finding of realizable wind energy potential.

Since there are no on-site measurements of wind, the only option remaining was to go for realizable wind potential of Kosovo, which does not require on-site measurement, but in other hand can be useful to determine and to have a general picture about realizable wind potential of Kosovo which would not be possible if we don't have a theoretical wind potential results.

The constraints that limit the theoretical wind and help in determining realizable wind potential are:

- technical-spatial constraints
- environmental constraints
- economical constraint

So checking all these factors will make a complete study, for determination of realizable wind power potential of Kosovo.

1.3 Data used

As stated above, Kosovo being a newly born country never could give importance to any type of renewable energy except of hydro energy, therefore till now there were not done any wind energy measurements. Therefore for getting data, partnership the web-site of SEEWIND was used, while also in this web-site there is the computer modeling results that were conducted from German company DEWI. The computer modeling used in these estimations named MM5 has produced a wind energy potential of South Eastern Europe including three different wind measurement ranges (50, 70 and 98 m) .

1.4 Citation of literature

Literature cited in this study is mainly about the wind energy potential determination; also it contains statistical material about economics, statistics and future of wind energy in Kosovo mainly.

Also other sources such as: Science Direct, TU Vienna's library and past thesis were used as literature.

2. General information about Kosovo

2.1 Fundamental facts about Kosovo

The facts are as follows:

- Area: 10.908 km^2
- Population (prediction): 2,186,686 capita
- Population density/km^2: 193
- Capital: Pristina

2.2 Economic situation of Kosovo

As a young country, Kosovo faces unique challenges: *Economically*, Kosovo's underdeveloped economy makes the country one of the poorest economies in Europe, with GDP for head of €1,731[1] average public sector wages of €230 per month, private sector €280, 45% of the population in poverty, 15% in extreme poverty, overall unemployment estimated at 40-48% and youth unemployment at 74%, and rising.[2]

Economic growth in Kosovo has been slow during recent years, although immediately after the end of the war, economic growth was rapid. The growth in GDP was estimated at 21 per cent in 2000. However, the average growth in real GDP in 2002–2006 is estimated to be less than one and a half per cent. The short period of growth is explained mainly by the rapid increase in foreign assistance for reconstruction.

Real GDP growth in 2008 was 5.4%, up from 5.0% in 2007. Contrary to 2007, a year in which private sector dynamism was the main source of economic growth, economic activity in 2008 and in the first half of 2009 was increasingly driven by the acceleration

---

[1] See Gjergj Erebara, "Kosovo has highest GDP growth in Balkans," Balkan Insight, 2 October 2009, http://www.balkaninsight.com/en/main/news/22618/.

[2] Youth initiative for human rights, "State of constriction? Governance and Free Expression in Kosovo", May 2010.

of public capital spending. Annual growth in private consumption stood at 11.3%, public consumption grew by 3%, and while public investment increased by 194%, private sector investment declined by 10.2%. The latter resulted partly from the decline in foreign direct investment and the stagnation of the privatization process. As a consequence of the global economic crisis, since late 2008 exports have been decreasing. However, Kosovo's limited integration into the global economy and a stable financial sector pursuing conservative strategies have so far delayed a stronger impact of the crisis. In addition, the persisting weakness of the statistical system does not allow for a comprehensive assessment of the economic situation in Kosovo.[3]

According to IMF estimates, GDP per capita in 2008 reached €1,726, which corresponded to 6.9% of the EU-27 average compared with 6.5% in 2007. Overall, the unfolding of the crisis affected Kosovo's economy to a limited extent so far. However, the lack of data does not allow a robust assessment for the previous or current year.[4]

In 2008, exports of goods increased by 20.2% reaching 5.3% as a share of GDP. As in previous years, they were driven by base metals and base metal products, accounting for more than 60% of overall exports in 2008 and increasing 67% over 2007. The second most important export category, mineral products, showed a decrease of about 32% in 2008 vis-àvis 2007, as international demand fell due to the crisis. In the first half of 2009 exports fell substantially by 39.9%, with the base metals category shrinking by close to 60%. Imports of goods increased by 22.1% in 2008, reaching 50.2% of GDP up from 44.2% of GDP in 2007. Mineral products (mainly oil), prepared foodstuffs, base metals and machinery remained the largest import categories. Total imports decreased by 1.6% but more than two thirds of the commodity groups still registered positive growth rates.[5]

---

[3] The Statistical Office of Kosovo (SOK) has published nominal GDP figures for the years 2004-2007, stressing at the same time that the number and the quality of existing statistical surveys are insufficient for successful implementation of national accounts according to ESA 95 standards.

[4] Commission of the European Communities, "Kosovo Under UNSCR 1244/99 2009 Progress Report", http://www.delprn.ec.europa.eu/repository/docs/ks_rapport_2009_en.pdf.

[5] Commission of the European Communities, "Kosovo Under UNSCR 1244/99 2009 Progress Report", http://www.delprn.ec.europa.eu/repository/docs/ks_rapport_2009_en.pdf.

About 45 percent of the population in Kosovo is poor, with another 18 percent vulnerable to poverty. The persistence of poverty levels in the first half of this decade is not surprising within the context of prevailing macro-economic conditions characterized by slow growth, low incomes and tight expenditure constraints. Without the safety net provided through migration and remittances, the welfare of a large fraction of the population would have been even worse.

However, the good news is that poverty is shallow in the sense that many people are just above or just below the poverty line. The shallowness of poverty also implies that a small positive change in incomes, through employment generating growth, can pull many people out of poverty.[6]

The level of poverty is evidenced to be in families with more than 7 members, households with female heads, low educational level and the un-employment. According to the World Bank poverty assessment report the level of society with the highest poverty incidence are households with female heads and un-employed people. Nevertheless this report shows that the education level of family members have a large impact on the income. In addition, it is reported that the rural areas account to have a low level of economic development compared to urban areas and especially in Mitrovica and Ferizaj regions.

Unemployment and remittances

According to the Progress Report of Kosovo 2009, registered unemployment in Kosovo accounts for 43% of the economically active population. Over 338,000 persons were registered unemployed by the public employment services of Kosovo at the end of June 2009. Over 90% of all registered job seekers have been on the unemployment register for more than 12 months. Disabled people remain among the most disadvantaged groups, along with Roma, Ashkali and Egyptians. Female employment remains very low

---

[6] World Bank, "Kosovo Powerty Assessment", October 3, 2007, http://web.worldbank.org/WBSITE/EXTERNAL/COUNTRIES/ECAEXT/KOSOVOEXTN/0,,contentMDK:21761784~menuPK:297788~pagePK:64027988~piPK:64027986~theSitePK:297770~isCURL:Y,00.html

[55%], and youth unemployment particularly high. Transition from school to employment is difficult, with only 5% of young people making a successful transition. Those facing the greatest barriers to accessing the formal labor market are often attracted into the informal economy as an available alternative to combat poverty.[7]

The current account deficit, including official grants, increased from 10.2% of GDP in 2007 to 16.3% in 2008. Remittances and foreign assistance amounted to 12.1% of GDP (12.5% in 2007) and 7.7% of GDP respectively. Foreign direct investment (FDI) was 13.1% in 2008, compared to 16.7% in 2007. In 2007, about half of FDI was linked to the privatization process and the licensing of the second mobile telephony operator, while in 2008 the privatization process stagnated.[8]

As a conclusion it is observed that Kosovo's greatest challenge is the need to create high-quality, attractive jobs for the growing number of young people, particularly women and minorities, entering the workforce. Doing so necessitates creating a business environment that is conducive to businesses innovation and growth and makes Kosovo an attractive investment destination. *Internationally*, Kosovo is constrained from taking full advantage of international trade agreements, such as CEFTA, and fully pursuing EU and WTO accession, for political reasons that are sometimes beyond its control. Kosovo is hard at work to gain further international recognitions, which will give the county greater voice in the international arena. At the same time, Kosovo must build its capacity to understand and implement effectively the benefits that are now available to Kosovo exporters under CEFTA, eliminating impediments to trade with its neighbors and in the region, and prepare to lead CEFTA as Chair in 2011.

Kosovo has in place a national level commercial law framework that is pro-business with a number of important regulatory functions devolved to the municipalities for implementation at the administrative level closest to local businesses. A lack of a clear understanding of the commercial law framework and of uniformity in its application at

[7] Commission of the European Communities, "Kosovo Under UNSCR 1244/99 2009 Progress Report", http://www.delprn.ec.europa.eu/repository/docs/ks_rapport_2009_en.pdf.
[8] Commission of the European Communities, "Kosovo Under UNSCR 1244/99 2009 Progress Report", http://www.delprn.ec.europa.eu/repository/docs/ks_rapport_2009_en.pdf.

both the national and municipal level, have led to disparities in the implementation of laws and regulations – essentially resulting in 30+ different business environments, leading to uncertainty and increased risks for investors. In addition, many of the commercial laws in effect reflect an international standard and were adopted without full consideration of conditions in Kosovo, and should be revised to reflect the country's current economic activity, regional orientation, and international aspirations.

2.3 Energy situation of Kosovo

Kosovo's main primary energy resource is from its lignite deposits (3 billion t_{ce}), since it the most abundant source. Other fossil fuels are imported. Contribution from renewable energy resources is very small and consists from small hydro potential (0.7 TWh/a), biomass, solar and wind energy.

Energy demand realized for the period 2004-2007 and also contribution of each sector is presented in the Figure 1. Data in this figure are presented in (ktoe).

Source: Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, Ministry of Energy and Mining

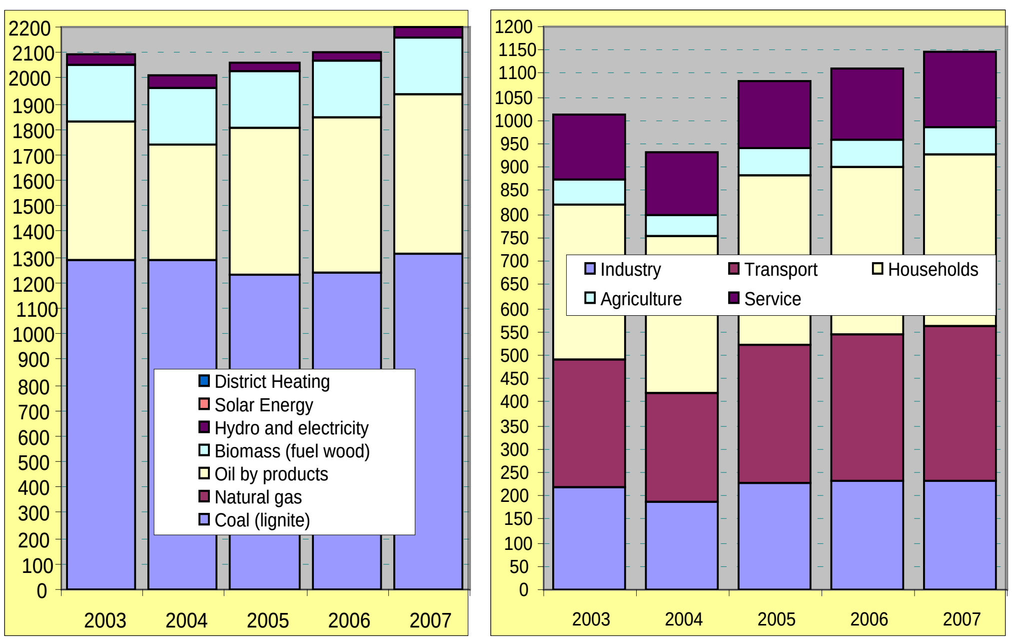
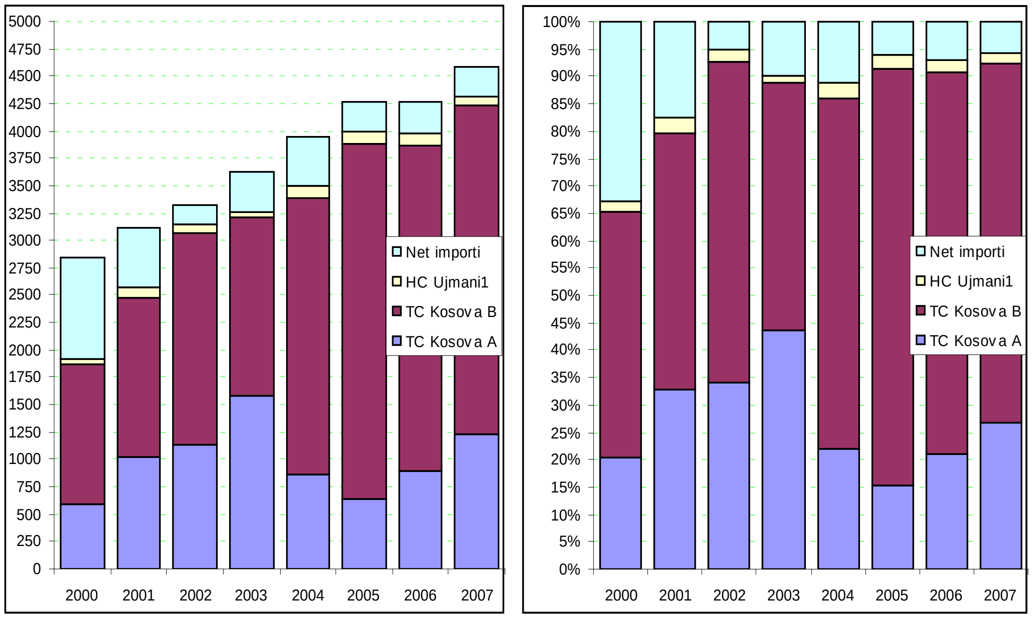


Figure 1: Contributions of each primary energy source in Kosovo also by sector (ktoe)

Figure 2: Shows the electricity produced between the years 2000-2007, in these figures prepared from MEM, Kosovo's power system, power grid technical losses and import are calculated.

Source: Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, Ministry of Energy and Mining (MEM)



1. With production of HPPs connected at the power distribution network
2. Technical losses in transmission and distribution have been estimated at around 17-18%
3. Supply operation according to the 5:1 scheme

Figure 2: Electricity production, 2000-07

Figure 3. Shows the electricity supply with total system losses and billing distribution

Source: Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, Ministry of energy and Mining (MEM)

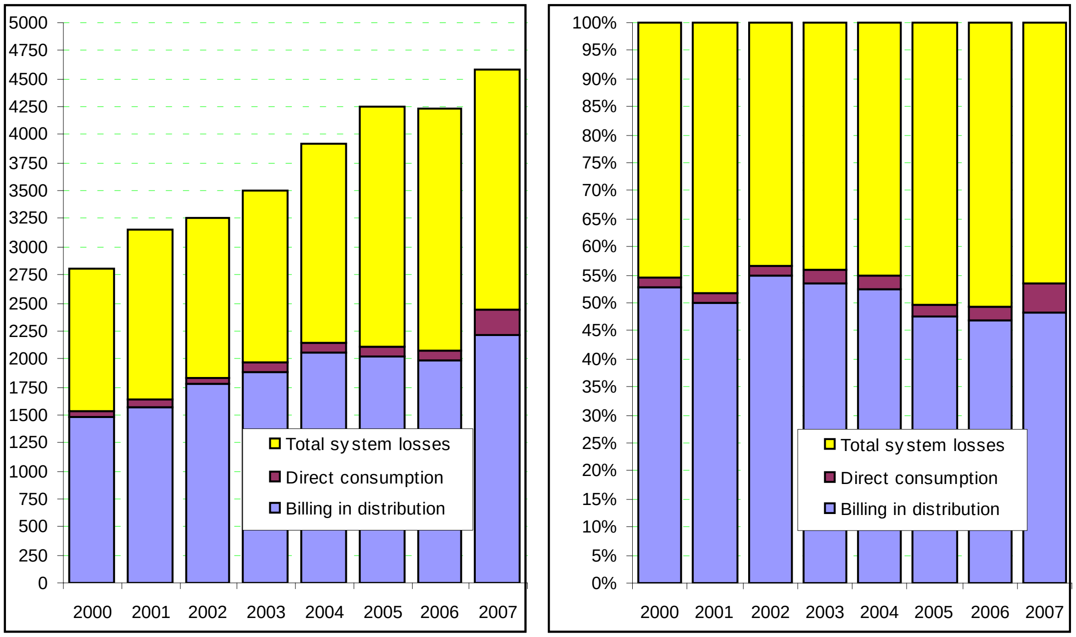


Figure 3: Electricity supply during period 2000-2007

The total installed generation capacity of Kosovo, which consist of two power plants, is (Kosovo A and B): around 1,500 MW; 800 MW in Kosovo A, which is older and less efficient plant, and 680 MW in Kosovo B power plant, and around 45 MW of hydro energy (from several small Hydro Power Plants). Kosovo A less efficient and having poor performance because of system's oldness, produces only 800 MW of net capacity. During the peak demand the existing capacity often exceeds, thus, forcing KEK JSC to import energy from the neighboring countries (e.g. 12.6 % in 2008) and/or apply supply cuts[9].

[9] Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, Ministry of energy and Mining (MEM)

Kosovo B thermal power plant is relatively new when compared to Kosovo A, with the maintenance done in recent years and with many new parts being installed, to support the functioning and improve the performance; we see also contribution to environmental performance.

With these two power plants not being fully efficient, Kosovo Government has decided for development of a new power plant named Kosova e Re (New Kosovo) Project which includes the construction of the new lignite power plant, development of the new lignite mine and rehabilitation of the TPP Kosovo B, while Kosova A will be decommissioned since it is old and does not meet the environmental criteria. Kosova e Re project will be developed through private capital investments.

District heating systems exist only in Prishtina, Gjakova and Mitrovica. These systems meet only 3% of heating demand. Existing heating technologies are based on residual fuel oil and diesel[10].

Being in favorable position geographically Kosovo also benefits form the transmission network and we can say that is an important part of the regional transmission system via interconnections with Serbia, Macedonia, Montenegro, and Albania. Kosovo's location makes it at the center of the north-south transmission interface of the South East European market, which is considered important also for power flows to and from Serbia, Macedonia, Albania and Greece.

Prior to restructuring, Korporata Energjetike e Kosovës (Kosovo Energy Corporation, KEK) was a vertically integrated utility incorporating five core businesses: lignite mines, power generation, transmission and dispatching, network, and supply. In 2006 the transmission business was detached from KEK, which resulted in the establishment of two separated companies: KEK JSC and KOSTT JSC. In 2009, the Government strived

[10] Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, p.21, Ministry of energy and Mining (MEM)

to further unbundle KEK JSC by taking a decision to establish the power distribution and supply company (DisCo)[11].

The Kosovo transmission system and market operation responsibilities were transferred to KOSTT. KOSTT is responsible for planning, development and maintenance of the electricity transmission system, as well as ensuring open and non-discriminatory access based on the requirements of Energy Community Treaty in Southeast Europe, to which Kosovo is a party[12].

Year 2004 was the year when the Energy Regulatory Office was established, it was established according to the Law on Energy Regulation, and has the role of regulating tariffs set by KEK JSC as well as the transmission charges levied by KOSTT. It has an important role in the operation and monitoring of the market, granting of licenses for the market participants as well as transformation of the energy sector.

[11] Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, p.5, Ministry of energy and Mining (MEM)
[12] Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, p.6, Ministry of energy and Mining (MEM)

2.4 Wind and other renewable energy sources in Kosovo

Legislation in Kosovo

The Law on Energy stipulates in article 12 that the Ministry responsible for Energy shall each year establish indicative targets for the consumption of electricity or heat generated from renewable energy resources or cogeneration for the whole of Kosovo for the following ten years. The indicative targets shall be accompanied by a report that outlines the measures taken or planned to achieve these targets.

Legislation in EU

The EU Directive 2001/77/EC requests from all member states to define and monitor, and to report to the EU Commission indicative targets for the consumption of electricity from renewable energy sources. These indicative targets shall take into consideration the existing power generation capacities and the natural and technical potentials for future development.

The EU Directive 2004/8/EC on the promotion of cogeneration includes definitions and calculation methodologies for heat and power production in cogeneration which should be used also for the formulation and monitoring of indicative targets in Kosovo for this area

Under the provisions of the Energy Community Treaty, Kosovo is committed to increase the share of renewable energy in its generation portfolio. The Government has set as a target for Kosovo to reach a renewable share of 7% by 2016[13].

As stated, in the previous section, usage of renewable energy sources in Kosovo is at very low levels, from renewables, hydro energy is the one used most, and it consist

---

[13] Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018, p.61, Ministry of energy and Mining (MEM)

about 3% of total energy production, another renewable source is Biomass which is considered to be between 216-250 ktoe[14].

Solar energy usage is at very low levels but it has shown a progress in last years.

Till now three wind turbines with total capacity of 1.35MW (3 x 0.45 MW) have been installed, and they have already been tested and are feeding energy onto the power distribution system (10 kV), these turbines belong to Wind Power sh.p.k company, they are already authorized from ERO and the Power Purchase Agreement (PPA) between Wind Power sh.p.k. and KEK sh.a. will be settled very soon.

So far there have been submitted three wind applications (100 MW, 26 MW and 0.9 MW) to the ERO; two of them were preliminary authorized.

Looking at feed-in tariffs till now, wind and hydro power tariffs were presented from ERO (Energy Regulatory Office) and according to them, generation of electricity form wind sources will be 8.4 eurocent/kWh as for hydro it varies from 5.2 to 6.7 (eurocent/kWh) according to the generation capacity.

Tables below will show in details the feed-in tariffs present in Kosovo (Energy Regulatory Office-Kosovo)

Small Hydro power plant	Feed-in Tariff (eurocent/kWh)
Up to 2 MW	6.7
From 2-5 MW	5.9
From 5-10 MW	5.2

Table 1: Feed-in tariffs for small hydro power plants (SHPP)

Wind Energy	Feed-in Tariff (eurocent/kWh)
For new generators	8.4

Table 2: Feed-in tariffs for wind energy with new generators

All above mentioned feed-in tariffs are meant for the period of 10 years and in case that engines used to provide electricity are new.

[14] Lecture notes “Energy situation in Kosovo” by Besim Islami, from Energy audit training program April-May2010

2.5 Wind Energy in world

This section will help to have a comparison idea between Kosovo and other developed countries that are using wind energy in considerable amounts.

Throughout the world wind energy sector is booming. The table below shows the recent trend in installed wind power in countries which this renewable source is used most. When we check also the markets, there is considerable growth in wind shares, which means that the interest in wind energy is growing day by day.

Worldwide, by the end of 2005, there were 58,982 MW installed. Europe is still the market leader (with growth of 18% in 2005), but North America (36% growth in 2005) and especially Asia (48% growth in 2005 thanks to India and China) are now growing faster[15].

Source: Renewable energies, wind energy systems p.103, Régine BELHOMME, Daniel ROYE and Nicolas LAVERDURE

Country	2000 (MW)	2004 (MW)	2005 (MW)
Germany	5,432	16,629	18,428
Spain	2,235	8,263	10,027
USA	2,568	6,725	9,149
India	1,150	3,000	4,430
Denmark	2,181	3,124	3,128
Great Britain	391	888	1,353
Netherlands	444	1,078	1,219
China	302	764	1,260
France	69	386	757

Table 3: Total installation of wind energy in a number of countries

[15] Renewable energies, wind energy systems p.103, Régine BELHOMME, Daniel ROYE and Nicolas LAVERDURE

2.6 Working Principle of wind turbine

Wind turbines working principle consist of following energy conversion steps:

- Kinetic energy is converted into mechanical energy at the level of the turbine,
- While already converted mechanical energy is converted into electrical energy at the generator, later to be transmitted to the utility grid.

Therefore there should be balanced conversion and transmission of energy given that there is only the possibility of inertial storage at the price of acceleration of the turbine.

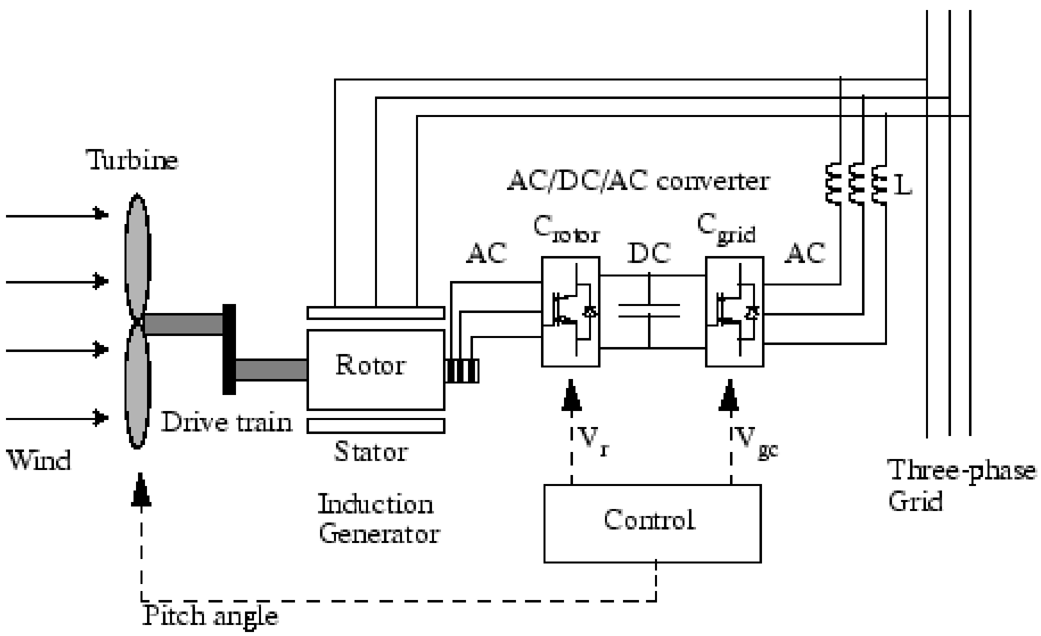


Figure 4: Working principle of wind turbine

2.7 Composition of wind turbine

A typical wind turbine is composed of several elements that are presented in Figure 5.

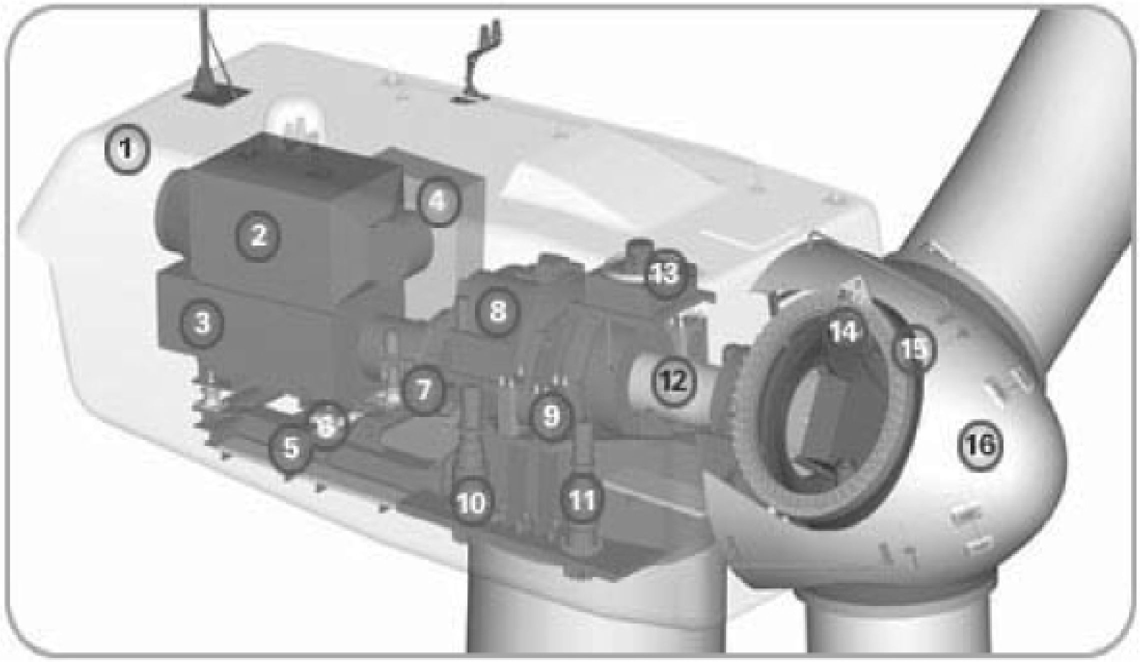


Figure 5: Example of wind energy system (GE)

One mast, or tower, supports the nacelle (1) and turbine (16). It is important that the tower be high due to the increase in wind speed with height. It is tubular and houses a ladder or even an elevator. The nacelle (1), partially soundproofed (6), (9), with a metal skeleton (5), houses the generator (3) and cooling system (2), the gearbox (8) and various pieces of electronic control equipment (4) that allow control of the various orientation mechanisms and the overall operation of the turbine.

The gearbox has a slow shaft (12) supporting the turbine (16), and a high speed shaft (1,000 to 2,000 rpm). It is equipped with a mechanical disk brake (7), to which the generator is coupled (3). The gearbox is equipped with a cooling system (13) for the oil. The turbine (16) generally has three blades (15) used to capture wind energy and transfer it to the slow shaft. An electromechanical system (14) generally allows orientation of the blades to control the torque of the turbine and regulate the rotation speed. The blades also work as an aerodynamic brake by unfurling or only by the rotation of their extremities. A mechanism using electrical servomotors (10), (11) helps *to orient the nacelle to the wind. An anemometer and wind vane on the roof of the nacelle supply the data necessary to the control system to guide the turbine and to trigger or stop it depending on the wind speed*[16].

The wind systems are composed of three important parts, the turbine, nacelle and the tower.

It is obvious that most important part of a turbine is the turbine rotor, which is also considered as a first motor. In most of the cases rotor is connected to a generator with a box, corresponding to the speed of rotation.

The turbine captures the wind's energy by spinning a generator in the nacelle. The nacelle houses the electric generator, mechanical gearing, speed and wind sensor, control systems and portions of the yaw mechanism that orients the turbine into the wind. The tower contains the electrical conduits and yaw motor (usually), supports the nacelle, and provides access to the nacelle for maintenance[17].

---

[16] Renewable energies, wind energy systems p.106, Régine BELHOMME, Daniel ROYE and Nicolas LAVERDURE

[17] web.media.mit.edu/~nate/AES/**Wind_**Theory_II.pdf, p.1

3. Defining theoretical wind potential of Kosovo

3.1 Wind and wind measurements in Kosovo

In this section, it will be described about wind measurement techniques, on-site measurements if available, computer modeling, which all of them would contribute in determination of theoretical wind potential of one place.

We can say that all renewable energy sources except from geothermal and tidal come from the sun, even fossil fuel sources.

According to Danish Wind Energy Association 1-2% of the energy coming form the sun is converted into wind energy.

There are a lot of factors that cause wind to blow (Coriolis force, global winds, geostrophic wind, mountain winds and local winds), but to use the energy from wind the most important things are air density, wind speed and rotor area.

Air density is important in wind energy since the working principle of the wind turbine is according to a kinetic energy; this kinetic energy of a moving body (wind) is proportional with its weight, so we may say heavier the air the more energy is received by turbine.

Wind speed is one of the most important components, when deciding to generate electricity, it is important because under some level of wind speed 4 m/s most of the turbines will not work, it is also important because it is directly connected with feed-in tariff that a country gives for wind energy generation.

Wind Speed Distributions:

Wind speed distribution is mainly used to show the yearly available wind for one location and they can be derived from results of measurements by using on-site measurements, or computer modeling as in this case.

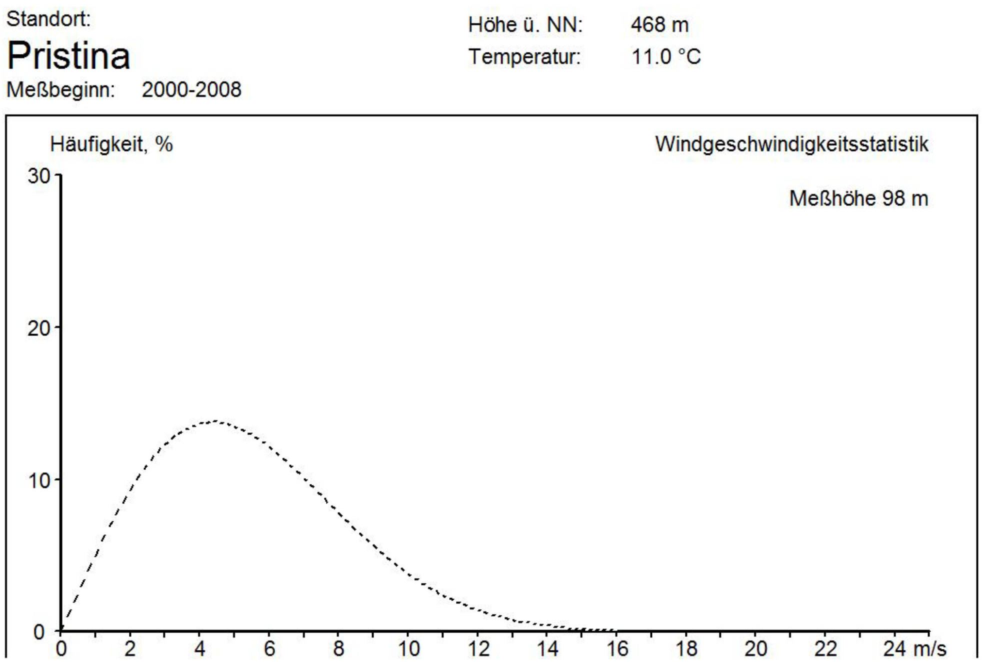


Figure 6: Wind distribution from computer modeling "ALWIN" software

The most common methods used for wind speed distribution are either Rayleigh or Weibull distribution. Above figure shows the Rayleigh distribution from the results of MM5 modeling, in area near Pristina. It must be stated that to have a proper distribution which in this case is Rayleigh distribution, we need to have an average mean wind speed is needed, as it is seen in Figure 3, the distribution made for Pristina is with the average speed of 5.5 m/s.

Roughness and Height

Another important factor to be taken into consideration is the roughness and height of the area where turbines are going to be installed.

The table above explains clearly the roughness types according to their geographical locations (Understanding the Renewable Energy Systems" from Volker Quaschning)

Ground class	Roughness length z0 in m	Description
1 – Sea	0.0002	Open sea
2 – Smooth	0.005	Mud flats
3 – Open	0.03	Open flat terrain, pasture
4 – Open to rough	0.1	Agricultural land with a low population
5 – Rough	0.25	Agricultural land with a high population
6 – Very rough	0.5	Park landscape with bushes and trees
7 – Closed	1	Regular obstacles (woods, village, suburb)
8 – Inner city	2	Centres of big cities with low and high buildings

Table 4: Roughness lengths z0 for Different Ground Classes

In previous sections, it was mentioned that wind speed measurements (meteorological) are at height of 10 m, but it must be taken into account that elevation can change the speed of wind even for several hundred meters; therefore it must be known that hills or mountains nearby the installment areas can affect the wind speed significantly.

It can easily be explained by an example; the mountain which stands up directly to the wind, the wind speed can increase in such way that it can become double of the given speed, while if we take a point close to zero at the sea level, it can be observed that the wind speed at this point is much lower[18].

[18] The Economics of Wind Energy
http://www.awea.org/pubs/factsheets/EconomicsOfWind-Feb2005.pdf p.4

There are also some obstacles that should be considered, in most cases these obstacles are analyzed well before the installation of turbines and usually there are not any troubles with single obstacles, since they may not have huge impact; however it must be studied carefully the surrounding area, since this kind of obstacles may significantly reduce the wind speed[19].

Rotor area

Rotor area is the component in which investor will decide, according to his plans how much energy he wants to harvest, since the area of a rotor in wind turbine is the main part that tells you how much energy there will be harvested from the wind, if all criteria are met.

In most cases wind is measured with instruments named anemometers, these instruments are not very complicated, are easily calibrated, but always there should be paid attention that these anemometers are not cheap and low quality, which as a result may give errors up to 10% and when calculated it will give results of 33% of more energy content in the wind then it is in reality[20].

To measure the wind speed, the best suggested practice is to place anemometer at the top of the mast which will be at the same height of the turbine. This way one avoids the uncertainty involved in recalculating the wind speeds to a different height[21].

On a broader scale, wind speeds can be modeled using computer programs which describe the effects on the wind of parameters such as elevation, topography and ground surface cover. These models must be primed with some values at a known location, and usually this role is fulfilled by local meteorological station measurements or other weather-related recorded data, or data extracted from numerical weather prediction models, such as those used by national weather services[22].

---

[19] The Economics of Wind Energy
http://www.awea.org/pubs/factsheets/EconomicsOfWind-Feb2005.pdf p.4
[20] http://guidedtour.windpower.org/en/tour/wres/wndspeed.htm
[21] http://guidedtour.windpower.org/en/tour/wres/wndsprac.htm
[22] Wind Energy-The facts, p.33

Apart form wind speed there is another factor which is connected to the wind, and that is wind direction, it also an important component prior to investing in wind energy. Therefore wind roses are drawn, to see where the wind is blowing most, and how wind is distributed. The wind rose is important to see, the wind direction where the wind is blowing most, so that the turbines would be oriented opposite of that direction, in order to have maximum efficiency. When wind rose is analyzed, there are some longer spokes that shows us the wind directions with the greatest frequency.

source: http://www.mathworks.com/matlabcentral/fx_files/17748/5/wind_rose.png&imgrefurl)

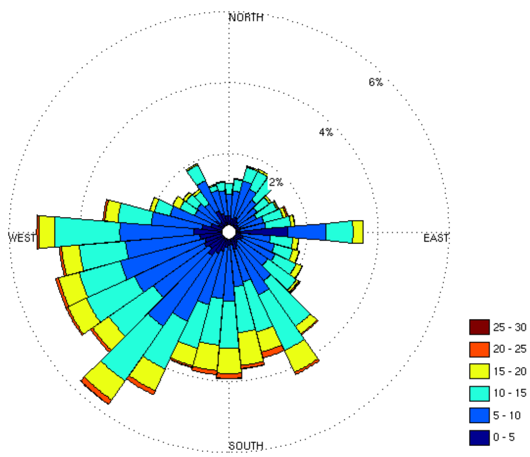


Figure 7: wind rose

According to Hydro Meteorological Institute of Kosovo (HMIK) the only measurement done for wind, are those of meteorological importance (at 10 m height), which for our case are not helpful, since we know that in various heights the wind speed might change significantly therefore leading to technical mistakes.

As stated above, apart from the Hydro-Meteorological Institute of Kosovo there were not done any continuous measurements of the wind speed, direction etc.

Measurements form this institute are available only for the after war period (2000-2010), since the conflict affected also the measurement results done for those years. The tables below will show the measurements for three different regions in Kosovo at 10 m height: but it must be noted that these different measurements of three different locations of

Kosovo, don’t tell us much about wind speed, and also they are not enough in defining the theoretical wind potential. These tables will serve only to see the wind over the months from three different locations.

2006	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Avg.
Wind speed m/s	1.2	1.2	2.0	1.2	1.5	0.9	1.4	1.0	1.0	1.3	0.9	2.2	1.3

Table 5: Annual wind speed of Pristina (576 m above sea level)

2009	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Avg.
Wind speed m/s	1.0	2.0	2.0	2.4	1.1	0.4	1.2	1.1	0.9	1.5	0.8	2.2	1.38

Table 6: Annual wind speed of Ferizaj (578 m above sea level)

2009	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Avg.
Wind speed m/s	0.5	1.1	0.8	0.9	1.1	1.1	0.9	1.2	0.8	0.6	0.8	0.9	0.89

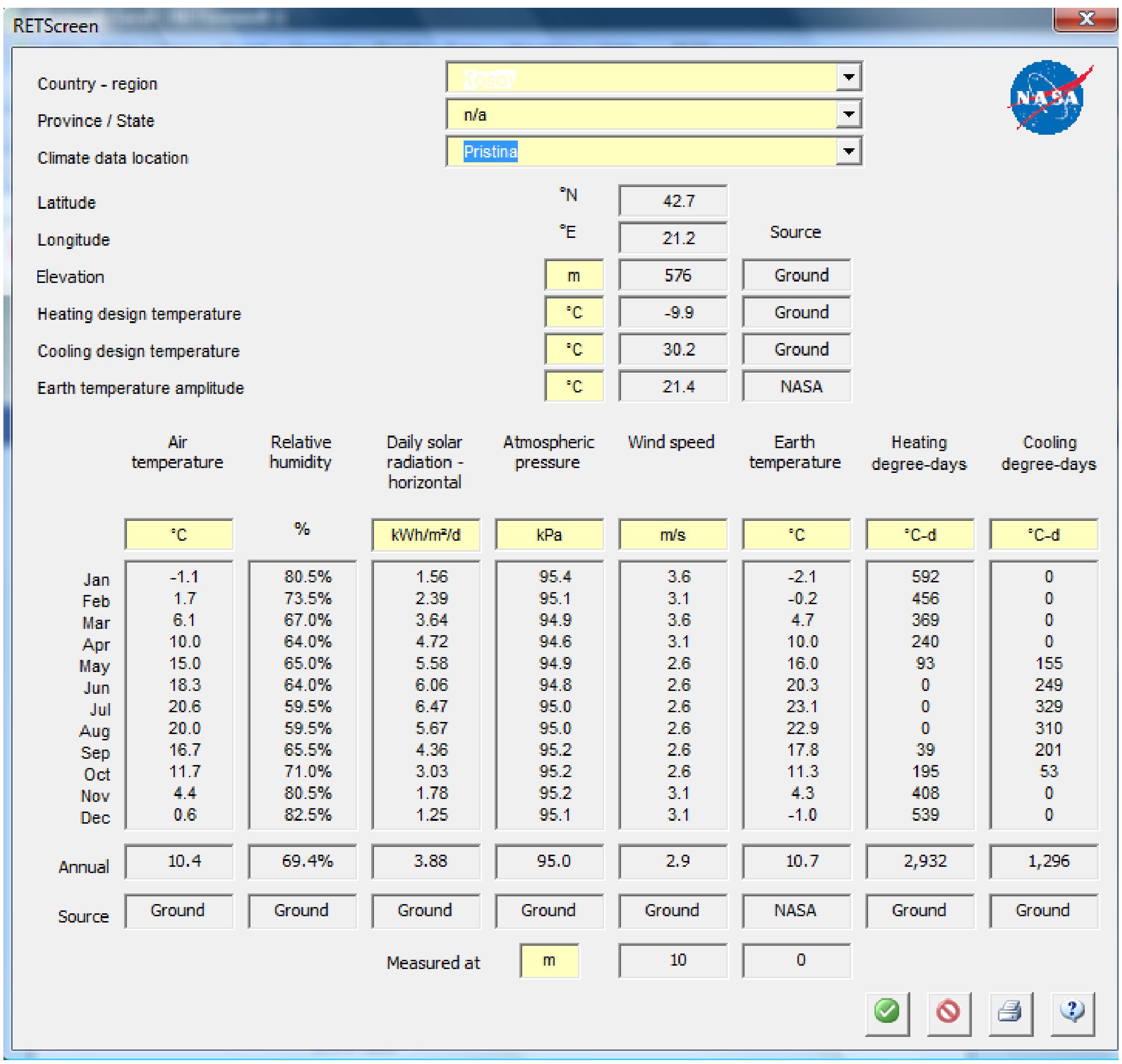
Table 7: Annual wind speed of Peje (498 m above sea level)

Above tables show the wind speed of three different locations in Kosovo (Pristina, Ferizaj and Peja) at 10 m through different months of the year.

The retscreen

There is another source that contributed to have an idea about the wind speed for two out of three regions (Pristina and Peja) mentioned above.

RETScreen Canadian software (fig.8,) used to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs), this software also has the climate database, which also in this thesis was used to see the wind speed for two locations in Kosovo. The climate database is taken from ground monitoring stations and/or from NASA's global satellite/analysis data. The figure above will give some information, regarding climate database for Pristina where there is also wind speed at 10 m :



	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	-1.1	80.5%	1.56	95.4	3.6	-2.1	592	0
Feb	1.7	73.5%	2.39	95.1	3.1	-0.2	456	0
Mar	6.1	67.0%	3.64	94.9	3.6	4.7	369	0
Apr	10.0	64.0%	4.72	94.6	3.1	10.0	240	0
May	15.0	65.0%	5.58	94.9	2.6	16.0	93	155
Jun	18.3	64.0%	6.06	94.8	2.6	20.3	0	249
Jul	20.6	59.5%	6.47	95.0	2.6	23.1	0	329
Aug	20.0	59.5%	5.67	95.0	2.6	22.9	0	310
Sep	16.7	65.5%	4.36	95.2	2.6	17.8	39	201
Oct	11.7	71.0%	3.03	95.2	2.6	11.3	195	53
Nov	4.4	80.5%	1.78	95.2	3.1	4.3	408	0
Dec	0.6	82.5%	1.25	95.1	3.1	-1.0	539	0
Annual	10.4	69.4%	3.88	95.0	2.9	10.7	2,932	1,296
Source	Ground	Ground	Ground	Ground	Ground	NASA	Ground	Ground

Figure 8: details about meteorological data, including wind speed for Pristina

Last but not least is the computer modeling results from German company DEWI who produced three different wind maps together with the speed for the region of SEE Balkans where Kosovo was also included.

Figure below will show an example of how computer modeling resulted for wind speed measurement at 98 m

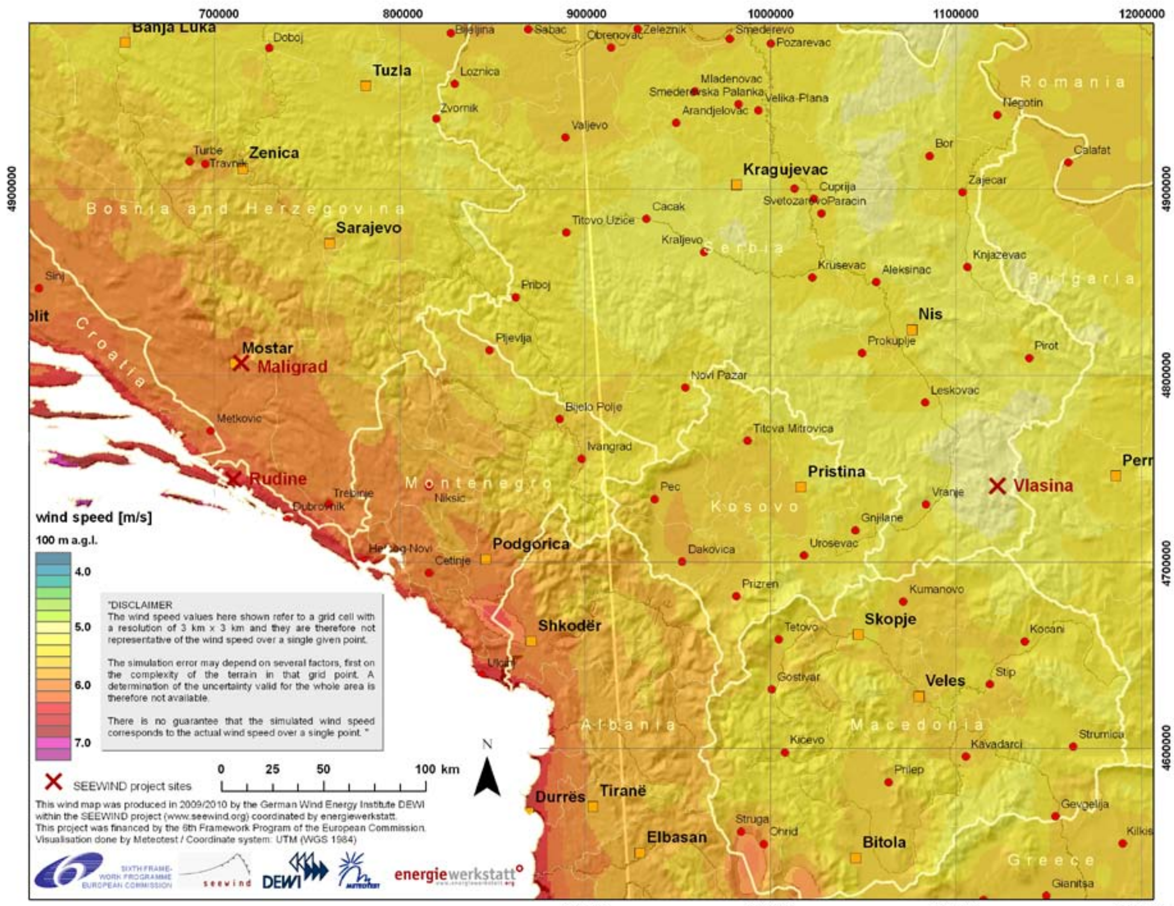


Figure 9: Computer modeling of wind distributed over SE Europe (98 m)

In this map (figure 9), can be seen the South Eastern Europe region with various wind speeds which are distributed with grid resolution of 3x3 km (http://www.seewind.org/files/element/file_download/wind_map_se_europe_98m_d6_3.jpg)

This is the map that was used lateron for realizable wind potential.

The hardest part of this thesis was to make calculations not with real on-site measurements but with modeled ones. As mentioned before there were not any on-site wind measurements done till now in Kosovo, therefore for better results the option of computer modeling had to be chosen.

This computer modeling (MM5) has shown great results, and since there were also available results for whole territory of Kosovo, it was a good approach, to have a general view on theoretical wind potential of Kosovo.

The results were collected starting from year 2000 and ending in 2008, so for this period of time there were a lot of inputs. The method used to make these results only for Kosovo was to use GIS and use the coordinates which correspond to Kosovo.

After, Kosovo was selected out from all SEE map, just then there was a clear map with corresponding wind speeds.

It is only when we have a clear picture, of how much land we have, just after that calculation of realizable wind energy potential is possible and to do this, several steps should be followed:

Then national parks, archeological parks and protected areas along with urban areas, industrial areas were also taken out by GIS.

Reason for this was to have a clear picture of how many hectares of land can be used to harvest wind energy, normally with wind speed above 5.5 m/s.

Below, the technical-spatial, environmental and later economical considerations will be described, in order to understand the steps that should be followed in theoretical wind determination.

4. Realizable Wind energy Determination

4.1 Constraints

When deciding to invest in wind energy generation there are some considerations (spatial-technical, environmental and economical) that should be taken into account.

In this section and in upcoming sections, it will be paid more attention to above mentioned constrains and combine them with the theoretical wind speed of Kosovo and therefore deciding if investing in wind energy in Kosovo, is feasible or not.

There are discussions all over the world, about what should appropriate area for wind energy generation be, and it must be known that there is not any common standard that all countries follow.

From the workshops held in different countries, and since that there was a need for the results to be more realistic, it was decided to choose a database named Corine. The reason that stands behind it, is that it is the only model that has GIS application.

4.1.1 Spatial –Technical constraints:

Slope:

As one of the main characteristics for wind turbine area selection, is slope, here are some details of how slope should be: by default slope can be up to 15 degrees, while possible range can be up to 25 degrees.

Elevation:

Elevation is another characteristic that should be checked before installation of turbines, here are the ranges: default elevation is up to 2000 m while possible ranges can extend up to 2500 m.

Corine Database:

It is the database where, land selection can be done, by checking the land types and by observing which land types have permission for turbine placement.

Below is the table of Corine database:

Land type	Setting selected	Default
1.1.1 Consistently urban character	No	-
1.1.2 Not consistently urban character	No	-
1.2.1. Industrial / Commercial Sites	No	-
1.2.2. Road / rail networks, functional associated areas	Yes	
1.2.3. Waterfronts	Yes	No
1.2.4. No airports	No	-
1.3.1. Mining areas	Yes	Yes
1.4.1. Urban green spaces	Yes	No
1.4.2. Sports / Leisure Facilities	No	-
2.1.1. Non-irrigated arable land		
2.1.3. Rice fields		
2.2.1. Vineyard		
2.3.1. Pastures	Yes	Yes
2.4.2. Complex plot structure	(Individually selectable)	(All categories)
2.4.3. Agricultural land with significant size		
3.1.1. Deciduous forests		
3.1.2. Coniferous forests		
3.1.3. Mixed forests		
3.2.1. Natural grassland	Yes	Yes
3.2.2. Moors and heath land	(Individually selectable)	(All categories)
3.2.4. Forest / shrub transition stages		
3.3.2. Rock surfaces without vegetation		
3.3.3. Sparsely vegetated areas		
3.3.5. Ice / permanent snow field	No	-
4.1.1. Swamps	Yes	Yes
4.1.2. Peat lands	(Individually selectable)	(All categories)
5.1.1. Water courses	No	-
5.1.2. No water areas	-	

Table 8: Classifications according to Corine database

Other spatial characteristics that must be taken into consideration are conservation areas of a country:

Reserve List	
Category A, B, C, D *	
National Parks	A
Conservation Areas	A
Protected Landscape Area	C
Conservation areas	C
Protected Landscape Part	B
Nature Parks	D
Plant Health Area	B
Special Protection Areas:	B
Sanctuary Park	A
Natural formations	D
Natural Monument	D
Natura 2000 Habitats Directive	B
Natura 2000 Birds Directive	B
A not * not selectable by default	
B is not selectable by default	
C uses selected by default	
D is not selected, default	

Table 9: Conservation areas and National Parks according to Corine database

Plant size and technology

Apart from spatial considerations, it is crucial to have a look at also other criteria's, like type and capacity of turbines. Reason for doing this is to determine the distance between the turbines, so that not to decrease their efficiency, it must be noted that this distance is not the only sole factor of decreased capacity, but there are other factors that contribute such as size of the turbine, which includes the rotor diameter.,

Selectable output class

Meadow, field 500 kW to 10 MW

Wald 2 MW to 10 MW

Mountain (from 1,700 m above sea level) 1.5 MW to 2.5 MW

Calculation of the hub height

Meadow, field D x 1.2

Wald D x 1.4

Berg D x 1.0

Distances between wind turbines

In plants of the same size 4.5 x D (squared)

In systems of different size 4.5 x (D1 + D2) / 2

New and old stock 4.5 x (D1 + D2) / 2

Farm efficiency

Individual plant 100%

2-5 units 97%

5-9 units 95%

From 10 plants 92%

Technical availability

Meadow, field 97%

Forest 97%

Mountain 95%

Technical losses

Electrical losses 3%

Losses due to icing altitude divided by 500 [%] .

4.1.2 Environmental constrains

When talking about wind energy, almost no one will oppose to its development, since it gives much lower pollution to environment when compared to fossil fueled energy generators.

There are small concerns on pollution during the construction, transportation phase of the turbines, or during foundation works.

During manufacturing of wind turbine the metals like aluminum, steel or other materials use energy intensive processes, generally using fossil energy sources. According to study done by Vestas-a wind turbine manufacturer, the initial carbon dioxide emissions "pay back" is within about 9 months of operation for off shore turbines[23].

Apart from small amount of emission releasing during production and transportation phase, there are also concerns that these turbines might impact wildlife, aesthetics, or make disruption to humans living nearby from noises produced, while blades are rotating.

There were seen impacts in wildlife either in onshore or offshore wind energy developments, below is a study explaining the impact in wildlife. Since the development of modern wind energy turbines does not go far back, it is obvious that impact studies for this sector are not gone into many details, except for the study shown below:

This is the study of the golden eagle in the Altamont Pass Wind Resource Area in the Coast Range Mountains of California. Here, wind energy development began in the 1970s and when the number of wind turbines peaked in 1993, 7 300 turbines were operational within an area of about 150 km^{2}. An estimated 35 000–100 000 birds, 1 500–2 300 of them golden eagles, have been killed by collision here during the past two decades (Thelander and Smallwood, 2007). Population modeling has shown that the golden eagle population in the Altamont region is declining and that at least part of this decline is due to wind farm mortality (Hunt, 2002)[24].

[23] Vestas: Life Cycle Assessments (LCA). Retrieved 2008-02-13.

[24] EEA Technical Report: Europe's onshore and offshore wind energy potential- An assessment of environmental and economic constraints

The most important thing, for development of energy park, is to be careful in land selection as mentioned above so that not to choose and protected or conserved area, and also to be as far as possible from urban and rural areas.

The figure below will show, how the protected areas, or special areas are taken into consideration with the help of GIS.

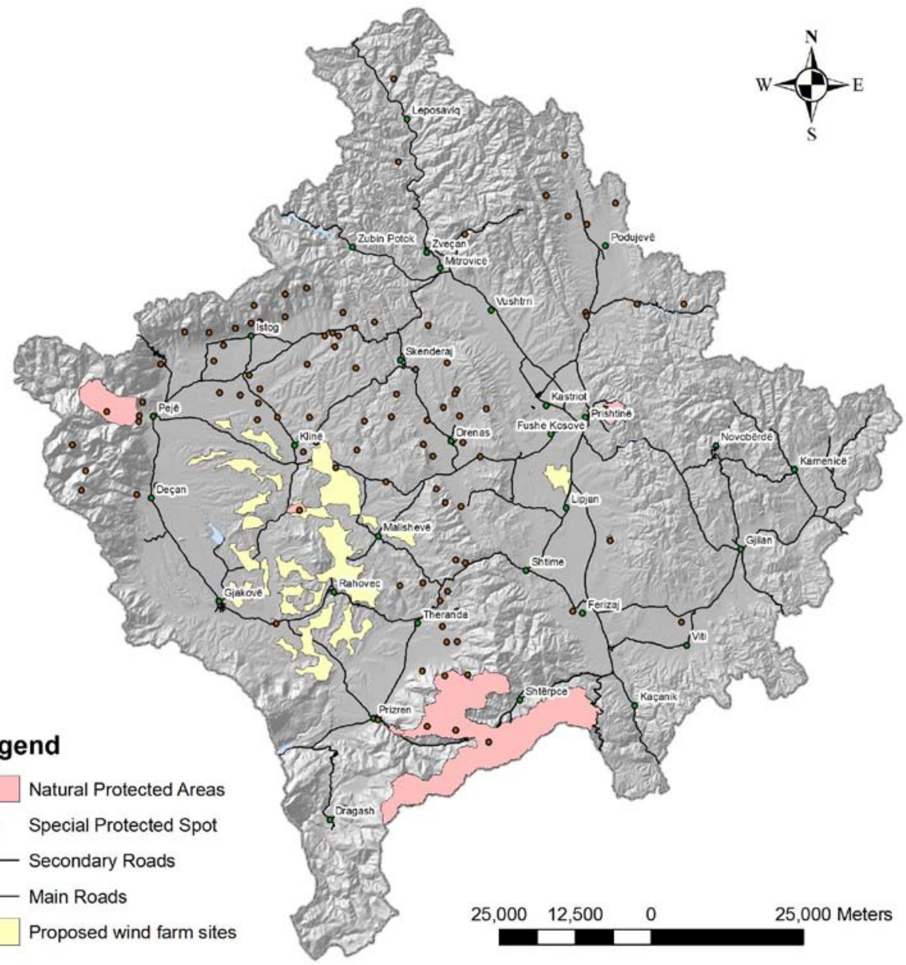


Figure 10: Kosovo’s map with natural and special protected areas

Land use for operation

In order to reduce losses caused from interference of turbines, the distance as mentioned above should be 400-500 m. wind energy has another advantage since as investor you don't need to buy land, instead you can pay yearly rent/turbine to the lender, while he/she can still use that land (e.g. farming).

Prevention of possible impacts

Prevention of possible impact in wild life can occur, by identifying and proper mapping of sensitive area, especially where these birds are of conservation concern. By identifying these areas, we actually will prevent any development of wind farms (parks), therefore protecting also the endangered species.

High risk of impact might be the habitats like: woodlands, wet lands, mountain ridges which are used by raptors and other species, also zones with dense migration and important sites for sensitive non-breeding birds.

It is needed prior to construction, a detailed analysis of area, so that there will not be any risk caused to wildlife.

4.1.3 Economical Constraints

In this section it is discussed for economical constrains and possible difficulties that may occur during, or after the investment including also maintenance costs.

According to American Wind Energy Association (AWEA) the cost of electricity from utility-scale wind systems has dropped by more than 80%. In the early 1980s, when the first utility-scale turbines were installed, wind-generated electricity cost as much as 30 cents per kilowatt-hour. Now, state-of-the-art wind power plants can generate electricity for less than 5 cents/kWh.

Also by the help of government incentives and also by keeping feed-in tariffs higher than fossil fuel fired power plant, makes wind energy price competitive with new coal- or gas-fired power plants.

It is obvious that there is a progress in development of wind energy sector, but still we can’t say that this sector is in the place where it should be, therefore it would not be wrong to say that wind energy’s costs will continue to decline as the industry grows and matures since the factors affecting the cost of wind energy are still rapidly changing.

Wind Speed’s importance

Whenever there is a project about wind energy generation, the most common question of a possible investor would be, to ask the average wind speed.

If we look back again, in every case where there is a serious investor it is suggested that there should be daily, monthly and yearly measurements of wind speed and direction. Wind speed will tell us how much electricity our turbines will be able to produce, while wind direction, will tell us from which side wind is blowing more

Why the wind speed is important someone may ask? It is important, because from the fact that the energy that can be tapped from the wind is proportional to the cube of the wind speed, so having a slight increase in wind speed results in a large increase in electricity generation and this would be better understood if it is explained by taking two examples, So we have two different sites with same wind power generators, same hub heights: one with an average wind speed of 6 m/s and the other with average winds of 7 m/s. All other things being equal, a wind turbine at the second site will generate nearly 50% more electricity.

Another important factor is the improvements in design of turbines that were done till now, and this can be from the fact that taller the turbine tower and the larger the area swept by the blades, the more powerful and productive the turbine.

The swept area of a turbine rotor (a circle) is a function of the square of the blade length (the circle's radius). Therefore, a fivefold increase in rotor diameter (from 10 meters on a 25-kW turbine like those built in the 1980s to 50 meters on a 750-kW turbine common today) yields a 55-fold increase in yearly electricity output, partly because the swept area is 25 times larger and partly because the tower height has increased substantially, and wind speeds increase with distance from the ground.

Advances in electronic monitoring and controls, blade design, and other features have also contributed to a drop in cost. The following table shows how a modern 1.65-MW turbine generates 120 times the electricity at one-sixth the cost of an older 25-kW turbine[25]:

Source: The Economics of Wind Energy,p.2; AWEA

Year of installation	1981	2000
Rated Capacity	25 kW	1,650 kW
Rotor Diameter	10 meters	71 meters
Total Cost ($000)	$65	$1,300
Cost per kW	$790	$2,600
Output, kWh/year	45,000	5.6 million

Table 10: Change in price and generation capacity over years

From the table above we see how technology improved over years and how it reflected in wind energy sector also. The prices of wind turbines can also vary between different turbine designs.

Besides the cost of wind turbine, planning, installation, foundation, transport and connections should be included in investment costs.

[25]The Economics of Wind Energy
http://www.awea.org/pubs/factsheets/EconomicsOfWind-Feb2005.pdf p.2

These incidental expenses are on average 34.5 per cent of the wind turbine sale price, but can be much higher for smaller systems. Operating cost consists of land rent, maintenance, repair and insurance costs[26].

A large wind farm is always cheaper then the smaller one, when assuming the same average wind speed of 8 m/s and identical wind turbine sizes, a 3–MW wind project delivers electricity at a cost of $0.059 per kWh and a 51-MW project delivers electricity at $0.036 per kWh—a drop in costs of $0.023, or nearly 40%. Any project has transaction costs that can be spread over more kilowatt-hours with a larger project. Similarly, a larger project has lower O&M (operations and maintenance) costs per kilowatt-hour because of the efficiencies of managing a larger wind farm[27].

Source: Understanding Renewable Energy Systems, p.257; Quaschning Volker

System size		Annual energy gain in MWhel/a				
Rotor	Power (kW)	vhub = 5 m/s	6 m/s	7 m/s	8 m/s	9 m/s
30 m	200	320	500	670	820	950
40 m	500	610	970	1360	1730	2050
55 m	1000	1150	1840	2570	3280	3920
65 m	1500	1520	2600	3750	4860	5860
80 m	2500	2380	4030	5830	7600	9220
120 m	5000	5300	9000	13,000	17,000	20,000

Table 11: Annual Energy Gain for Wind Power Plants of Different Sizes and Different Wind Speeds vhub

Since the wind energy is capital-intensive, it should be noted that the cost of financing constitutes a large variable in a wind energy project's economics.

There are different reasons, explaining that other types of electricity generation are financed more easily then wind projects.

One of the main reasons is also the project ownership, if it is done according to independent ownership, so that the project is invested by private owner, is more expensive than utility owned financing.

---

[26] Understanding Renewable Energy Systems, p.256; Quaschning Volker
[27] The Economics of Wind Energy
http://www.awea.org/pubs/factsheets/EconomicsOfWind-Feb2005.pdf p.2

According to a study by Lawrence Berkeley National Laboratory, utility ownership of a wind facility results in a significantly lower estimated levelized cost of energy, because lower-cost financing available to large electric utilities (IOUs, or investor-owned utilities) is not available for non-IOU wind projects. IOU ownership reduces levelized costs by approximately 30%, the study found[28].

Apart from that, compared to other energy technologies, wind energy is still considered as “risky” investment, although wind turbine technology has progressed steadily to the point where it is now.

Other expenses that would increase the investment are as follows:

Transmission and market access constraints should be considered as possible constrain that would significantly affect the cost of wind energy. Wind speeds vary, thus causing wind plant operators to not predict the amount of electricity they will be delivering to transmission lines in a given hour. These unpredicted results would lead to deviations from schedule which in some cases may be penalized without regard to whether they increase or decrease system costs. Investors usually chose to build their own lines since there is no standardization on procedures of interconnection and since utilities have no occasion imposed such difficult and burdensome requirement. From the fact that electricity markets are restructured in such way to allow long-term power purchase agreements and thus leading to trade on power exchanges, transmission and market access conditions would play important role in economics of wind power project.

Last but least factor that plays role in final price of wind project, would be environmental impact which according to AWEA (American Wind Energy Association) states that *Wind power’s environmental impact per unit of electricity generated is much lower than that of mainstream forms of electricity generation, as wind energy neither emits pollutants, wastes, or greenhouse gases, nor damages the environment through resource extraction. The higher the air quality and other environmental standards adopted in a country, the more competitive wind energy therefore becomes in the*

[28]The Economics of Wind Energy
http://www.awea.org/pubs/factsheets/EconomicsOfWind-Feb2005.pdf p.3

marketplace. Conversely, a relaxation of standards or failure to internalize environmental costs through pollution charges or other processes makes polluting forms of electricity generation appear deceptively cheap. This is an important economic issue, because the hidden "subsidy" that governments and markets give to polluting energy sources by partially or fully ignoring their health and environmental costs is typically much larger than direct subsidies to such energy sources[29].

[29] The Economics of Wind Energy
http://www.awea.org/pubs/factsheets/EconomicsOfWind-Feb2005.pdf p.5

4.2 Realizable Wind Energy Potential of Kosovo

4.2.1 Realizable wind potential through computer modeling

Till now it was discussed about the steps, which should be followed in order to have an idea about realizable wind energy potential of Kosovo.

It was discussed that lack of data, was most important obstacle of this thesis, therefore the option of computer modeling (MM5) had to be chosen first to determine the theoretical wind data. Just after having theoretical wind data, it is possible to check the realizable wind potential.

With these modeling methods there, wind speeds can be described while taking also into account the effects on wind parameters, such as ground surface cover topography and elevation. *It must be noted that, not necessarily the values of this software correspond to the values that could be taken from on-site measurements*.

For improved quality of the results this kind of modeling needs to be prepared with values from local meteorological station measurements or other weather data., it still doesn't mean that without those data, there cannot be any good results.

Typically, this wind-mapping software's will derive a graphical representation of mean wind speed (for a specified height) across an area. This may take the form of a 'wind atlas,' which represents the wind speed in entire territory, and requires adjustments to provide a site-specific wind speed prediction to be made with due consideration of the local topography. In some areas, 'wind maps' may be available which include the effects of the terrain and ground cover. Wind atlases and wind maps have been produced in a very wide range of scales, from the world level down to the local government region, and represent the best estimate of the wind resource across a large area. They do not substitute for anemometry measurements – rather they serve to focus investigations and indicate where on-site measurements would be merited[30].

---

[30] http://www.wind-energy-the-facts.org/en/part-i-technology/chapter-2-wind-resource-estimation/regional-wind-resources.html

The figure below shows how measurements are done, more specifically how they are modeled, where each cross represents a value, by saying value it must be understood that each value represents a wind speed. Each cross is defined by altitude and longitude values.

In this figure there can be seen area surrounding Pristina, the capital city of Kosovo.

First of all the values that were given from Austrian company Energiewerksttat and their German partners DEWI in a form of collected data starting from year 2000 till 2008, where all data was presented with their corresponding coordinates.

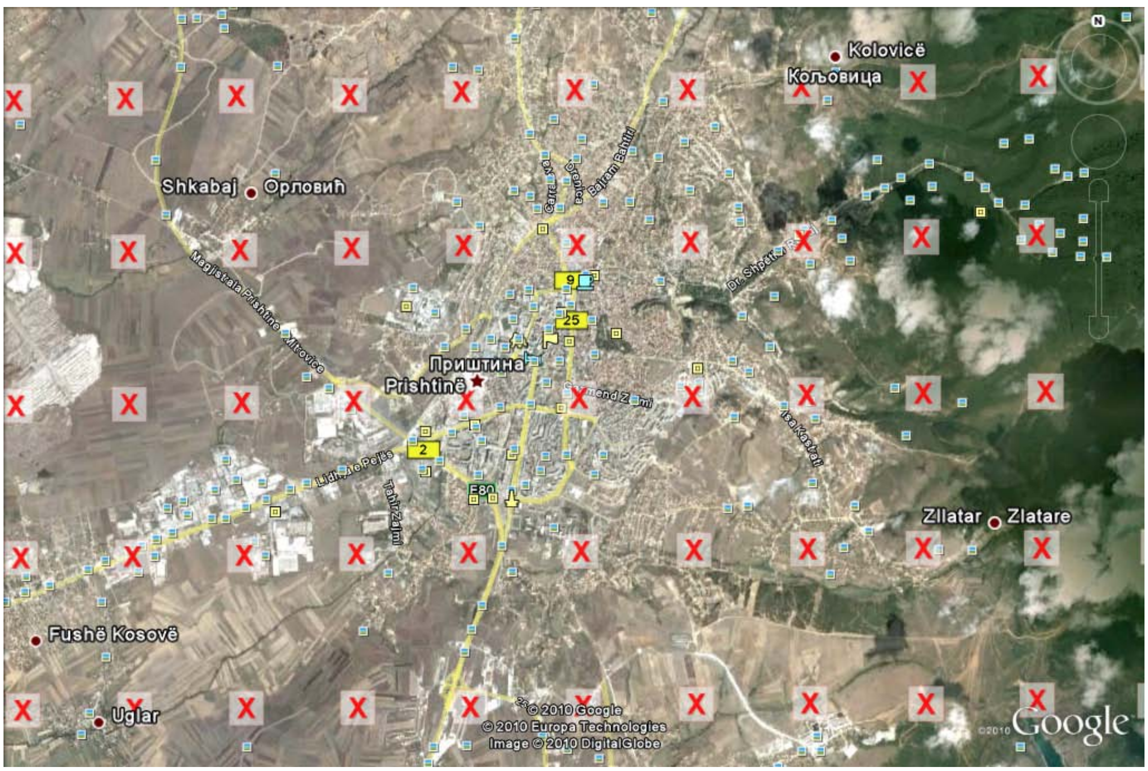


Figure 11: Positioning of modeled measurements in the "Google Earth"

According to the source "Wind Energy- the Facts" most wind energy resource studies start with a top-level theoretical resource, which is progressively reduced through consideration of so-called constraints. These are considerations which tend to reduce the area that in reality will be available to the wind energy producer. For instance, they can be geographically-delineated conservation areas, areas where the wind speed is not economically viable, or areas of unsuitable terrain. Areas potentially available for development are sequentially removed from the area over which the energy resource is summed.

The disadvantage of using GIS and computer modeling, is that it cannot be applied for a concrete project, it can only help to have estimates for wider areas

It is common when deciding for realizable wind energy potential to go through some stages; those stages were explained also in sections above. By the help of these stages we would finally have a realizable wind potential.

The paragraph below, explains very well how process should take place:

Different estimates of the potential energy resource can be calculated according to assumptions on the area that will be available for development. The resource without constraints is often called the "theoretical" resource; consideration of technical constraints results in an estimation of a 'technical' resource; and consideration of planning, environmental and social issues results in the estimation of a so-called "practical" resource. Such studies were common in the 1980s and 1990s, when wind energy penetration was relatively low, but have been overtaken somewhat by events, as penetrations of wind energy are now substantial in many European countries[31].

[31] http://www.wind-energy-the-facts.org/en/part-i-technology/chapter-2-wind-resource-estimation/regional-wind-resources.html

4.2.2 Classification of possible installment sites

4.2.2.1 Spatial-Technical constraints

In previous sections it was discussed about, the possible site selection for wind turbine installment and the constraints that investor should go through.

In this section, we will go a bit more in details, and check how much land is available for wind energy generation in whole Kosovo.

To do this we should also define the turbine type that will be used in this calculation. The turbine type that will be used in this evaluation is Vestas V-80, where the details for it will be given in following sub-chapter.

Also, after selection of turbine there, is a Kosovo's GIS database, which was used, in order to define these places easily. In GIS database there are all inputs that would be needed for our project, starting from protected area, national parks, archeological parks, cities – villages, interconnection lines and all other spatial and social inputs.

All needed inputs were included according to Corine database, where by the help of GIS, there were National Parks, Conservation Areas and other cultural and historical sites taken out of the possible areas, since it is not allowed to build anything nearby (including wind turbines).

All wind speed areas having results, below 5.5 m/s were taken out, since it might not be feasible for wind turbines to work below that speed with the current feed-in tariff of 8.4 c/kWh.

Since the speed of 5.5 m/s and above was considered to be feasible for wind energy development, it must be noted that there were two areas in whole Kosovo, which were identified as possible sites.

It should be considered that these areas are the most suitable ones, let it be either of their suitable elevation or distance to overhead lines.

There were two possible zones identified (Lipjan zone and Dukagjini zone), which will be explained in details in chapters below.

The series of figures below will show how the possible wind energy sites were defined by GIS.

Figure 12: Defining the contours of Kosovo

After the contours were defined, then from already modeled data from SEEWIND web-page, the corresponding results for Kosovo were fitted into the map by the help of GIS.

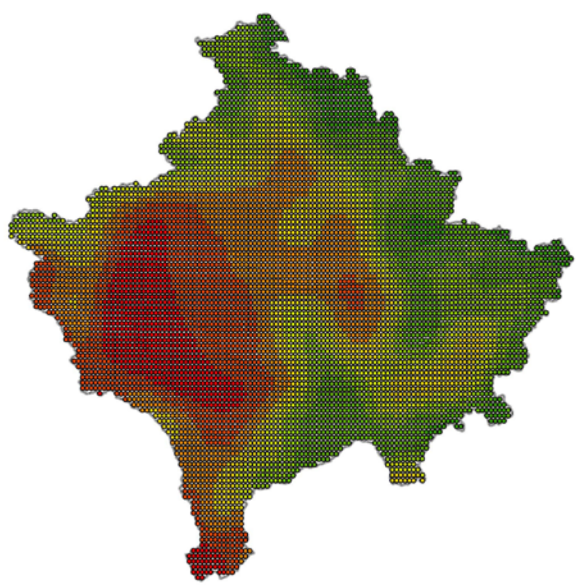


Figure 13: Inserted wind data from SEEWIND

The values of a wind speed resulting for Kosovo from 2000-2008 period measurements were from min. 5.24 to max. 5.85 m/s. Since there were too many data and since we were interested only for data above 5.5 m/s we had to go with this option.

While the figure below shows the already included data, but which were limited. The range starts from 5.6-5.85 m/s, it must be noted that those data are for modeled measurements at 98 m height 3x3 km grid.

In this map also slopes are added, since they are needed in identification of land, due to Corine database.

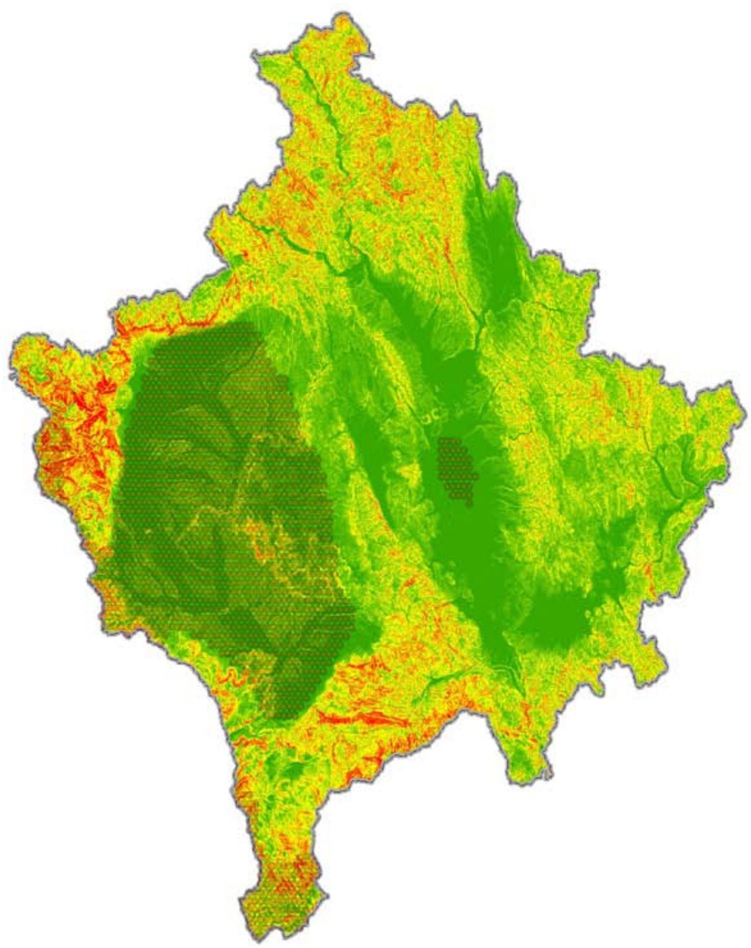


Figure 14: Wind speed data ranging only from 5.6-5.85 m/s

Two identified zones are darker; the larger one is Dukagjini zone, while smaller one is zone of Lipjan.

Just after a clear picture of possible sites, it was done a detailed GIS analysis, where settlements, main roads and railroads, airports and also other components of Corine database were added, so that possible land for development of wind energy could be chosen.

The main reason behind it, stands that with the help of Corine database and GIS, it will be easier to calculate the possible sites, since by these two components and of course by having wind speeds, we will see and calculate which land is only available for wind energy generation.

Lipjan zone will be the first to be discussed its total suitable area for wind energy generation.

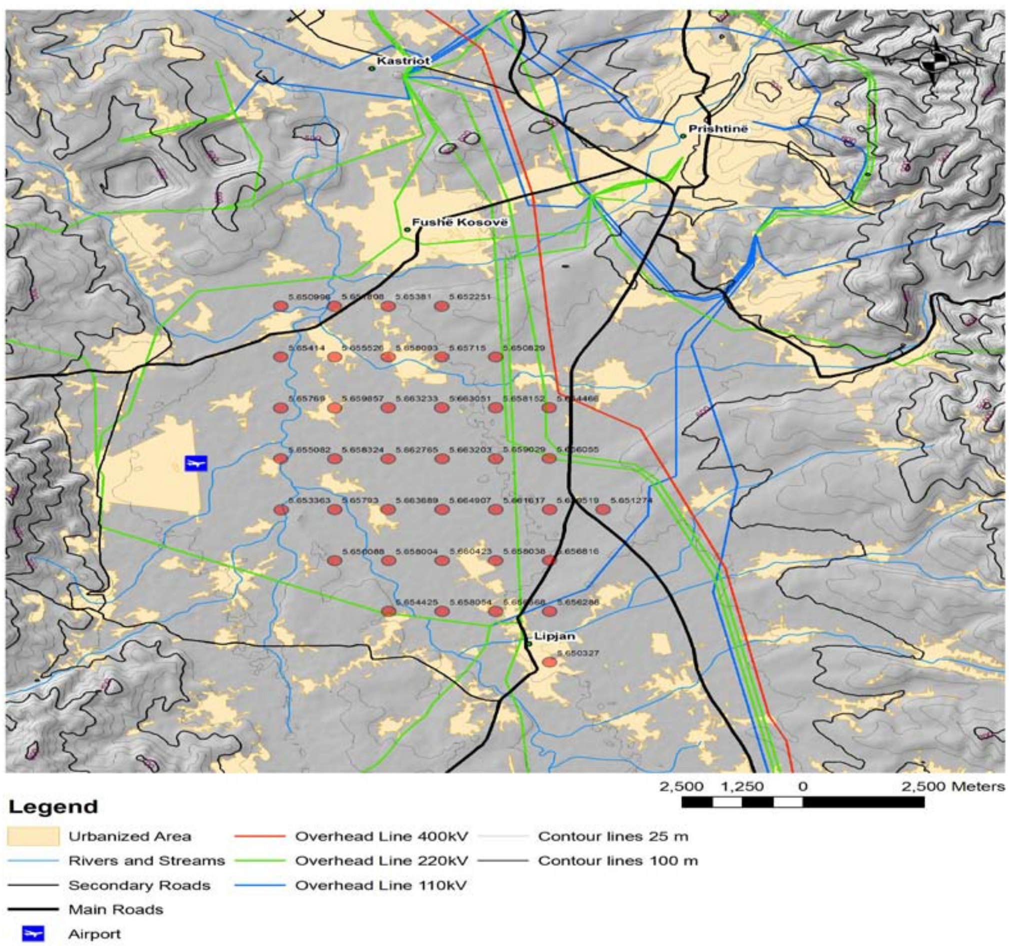


Figure 15: Detailed (Lipjan) possible site

The figure above shows a possible site, for wind energy generation, which is located near capital city Pristina, and also to Lipjan Municipality.

It can be observed that, there are also, slopes, elevation, urban areas, main roads and rail roads added to the below shown figure, using GIS. Apart from those data, there are also included the overhead lines (440 kV, 220 kV and 110 kV).

Reason for adding overhead lines, was to see how close they could be, in case there would be a development of Wind Park, and since being far from the overhead lines just increases the investment cost.

As it is seen the location is very suitable, and also it is situated in a flat are, making the development of wind energy even more advantageous.

The terrain roughness in this region is taken as open or open to rough according to terrain classifications, and it can be given a value of $z0 = 0.1$ m.

Following the next figure, shows the buffer zones created in urban areas, these buffer zones were calculated as 500 m and the zone left in between is considered as suitable zone for wind energy.

The reason to take 500 m as enough distance, is that there is no a common standard followed for this, each country, including the EU countries has specified different distances between wind turbines and urban areas, these distances start from 350 m (Belgium) and it goes up to 1500 m (Germany, only for quiet regions).

Since there is not a common standard followed and since in Kosovo there is no any restriction specified till now, it was found suitable to go with 6 x rotor diameter (80 m) which is 480 m and it is considered suitable, later it was decided to round it up to 500 m.

Reason why the turbines should be located in considerable distance from urban areas, are mainly due to the noise and aesthetic disturbance that they may cause in nearby areas.

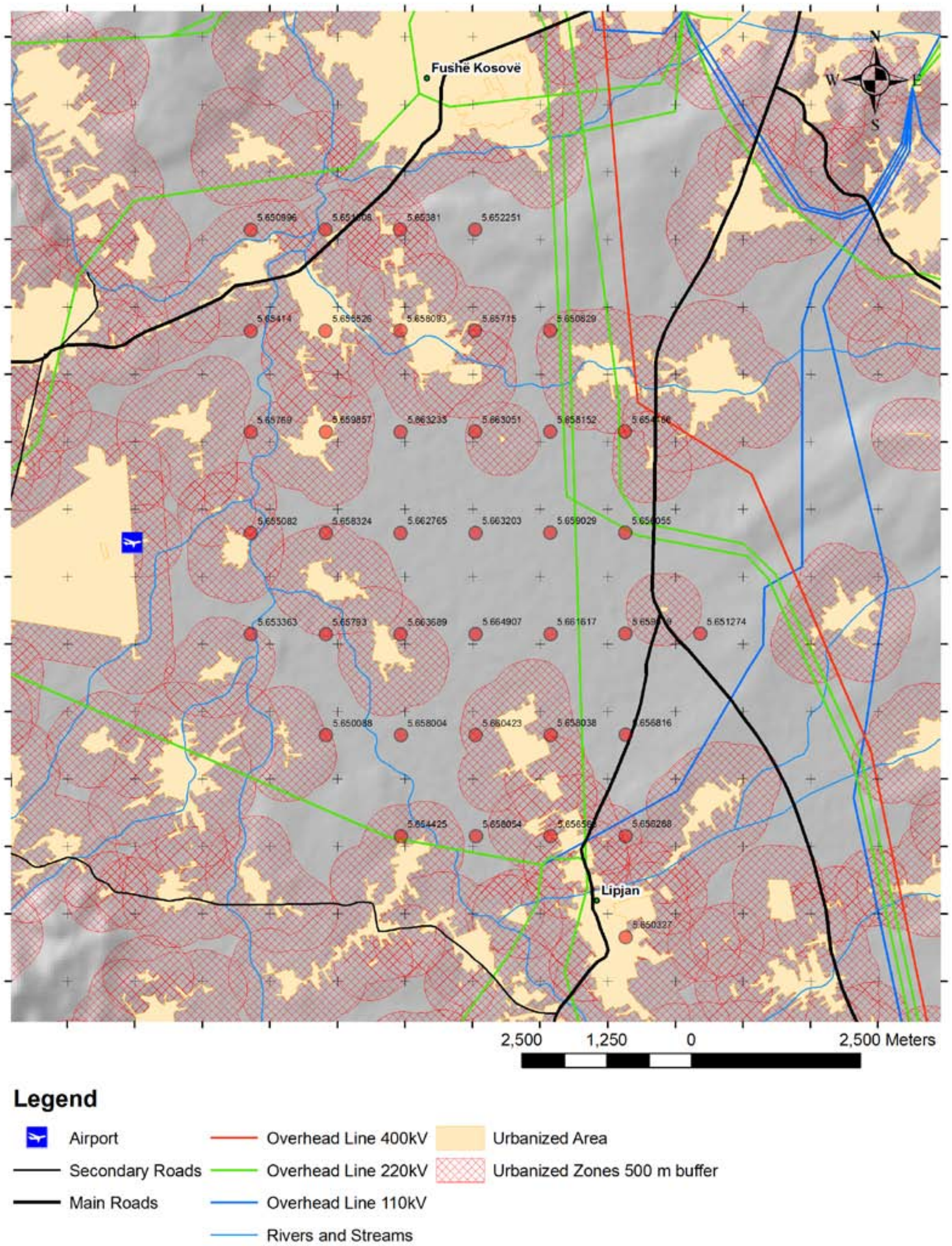


Figure 16: Detailed (Lipjan) possible site with buffer zones

After possible site was classified including the buffer zones, then they were made in Google Earth format and its remaining “suitable land” was calculated.

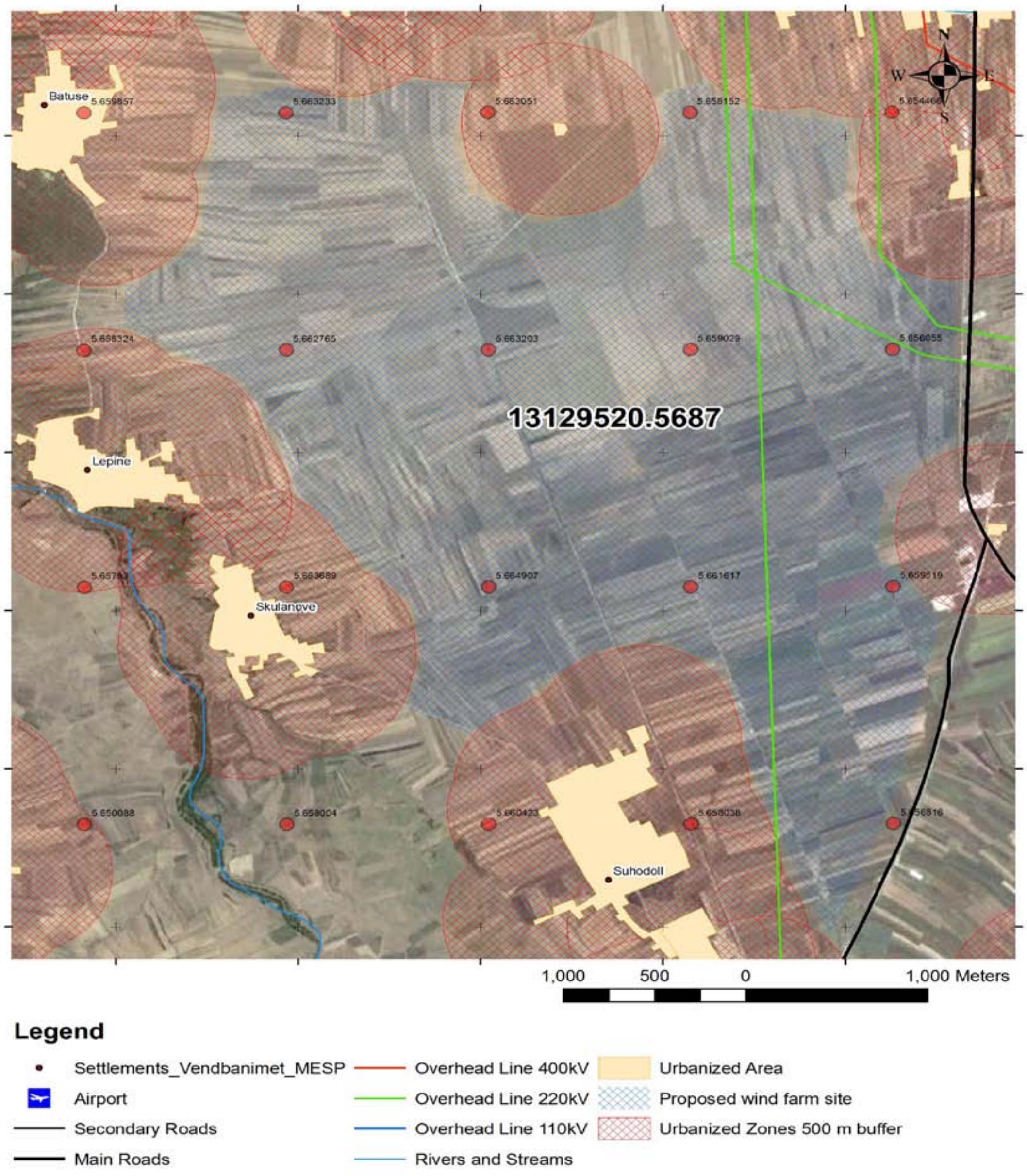


Figure 17: Google earth version of the possible site and its area in m^2

From the figure above it is seen the available land and its area that are possible for development of wind turbines, in area of Lipjan Municipality, consists of total land of 1313 ha.

The detailed calculation of wind energy yield/ha will be calculated in upcoming chapters

The upcoming figures will be explaining the Dukagjini zone, and its possible sites.

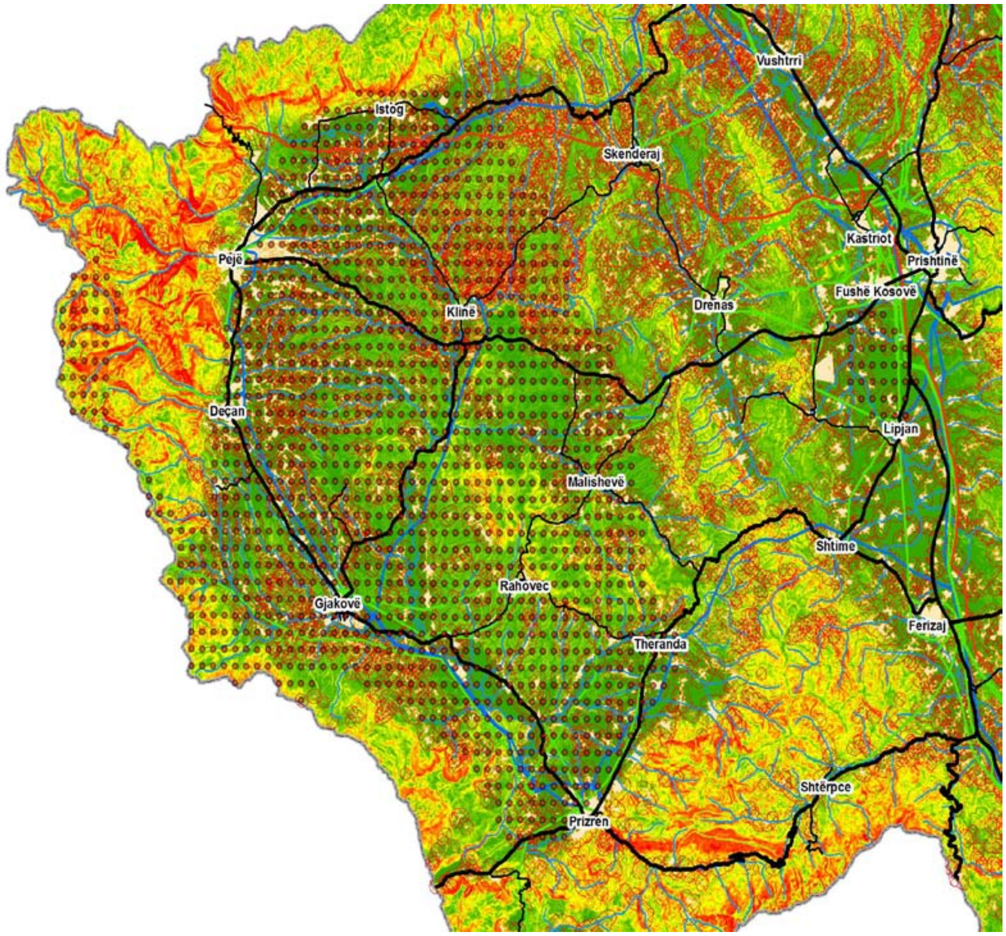


Figure 18: Dukagjini zone with possible sites

Figure above describes the possible sites, with the elevation and slopes included.

Red points indicate the areas where the modeled measurements showed values of more than 5.6 m/s and it was observed that some areas in this zone have reached 5.85 m/s at 98 m.

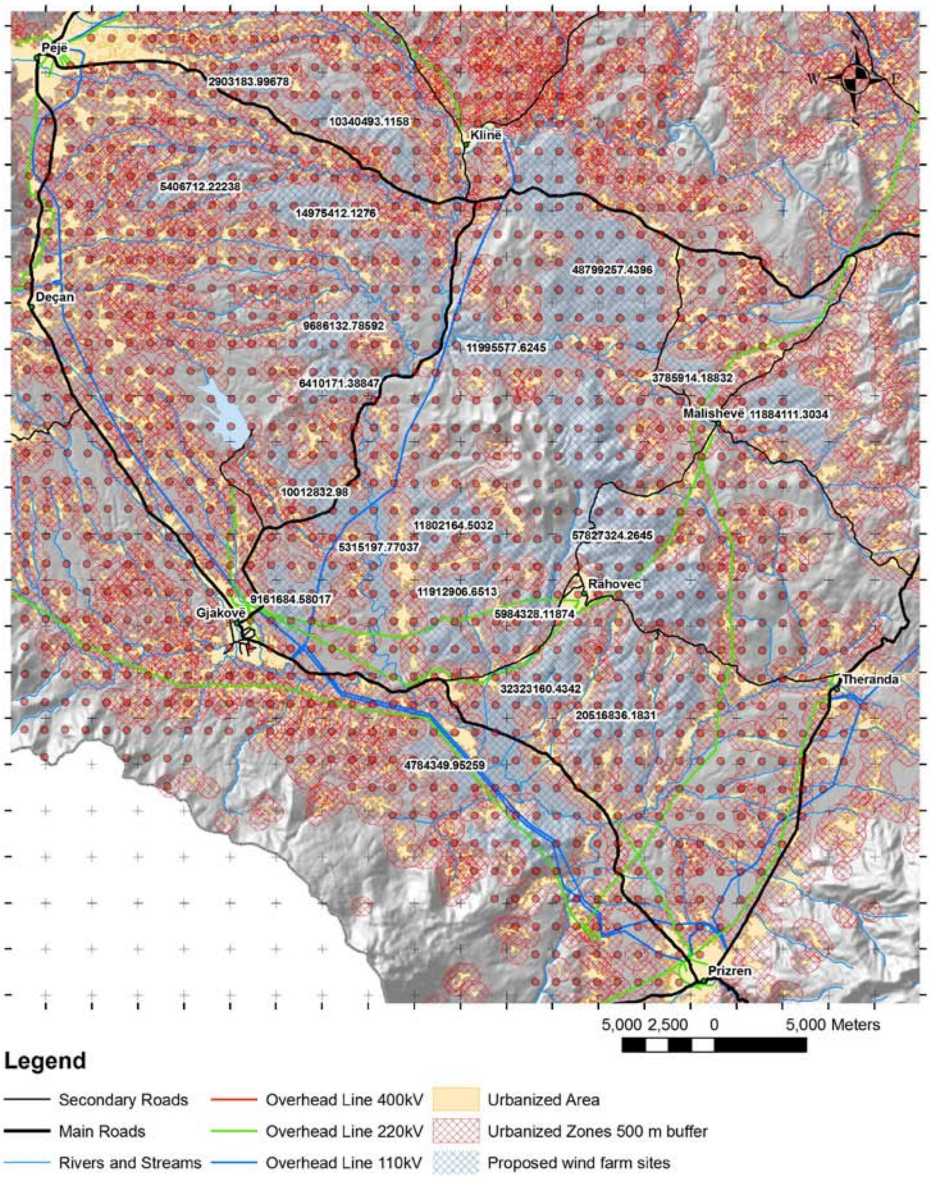


Figure 19: Possible (Dukagjini) sites with buffer zones included

As in previous zone also this zone went through the same procedures, of land selection. There were added the urban areas, roads, rail roads, overhead lines and also water bodies for better approach, since this area is richer in water sources, a special attention was paid to rivers, streams and lakes.

It must be noted that area is also close to the possible site of national park, whose decision on declaration of the national park, at the moment is pending.

During the calculation of possible land, within the territory there were found two zones, which according to Corine database, are not allowed for development of wind energy generation.

From these two sites, one was a Radoniqi lake in Municipality of Gjakova and a mine near Municipality of Klina.

Since the terrain of this zone is different from the Lipjan’s terrain, makes also its surface roughness different.

Roughness of this zone will be classified as very rough with z0 = 0.5 m and will be described as park landscape with bushes and trees.

As it was described in above chapters, the roughness of the land is important, in order to precisely calculate the wind energy yield.

So it should be considered the roughness of the land, which also for Kosovo changes from place to place, as you may recall in Lipjan zone, there was a land roughness of z0 = 0.1 m which means, more flat land with little portion of obstacles.

The two figures below will show the same procedures that also zone of Dukagjini went through.

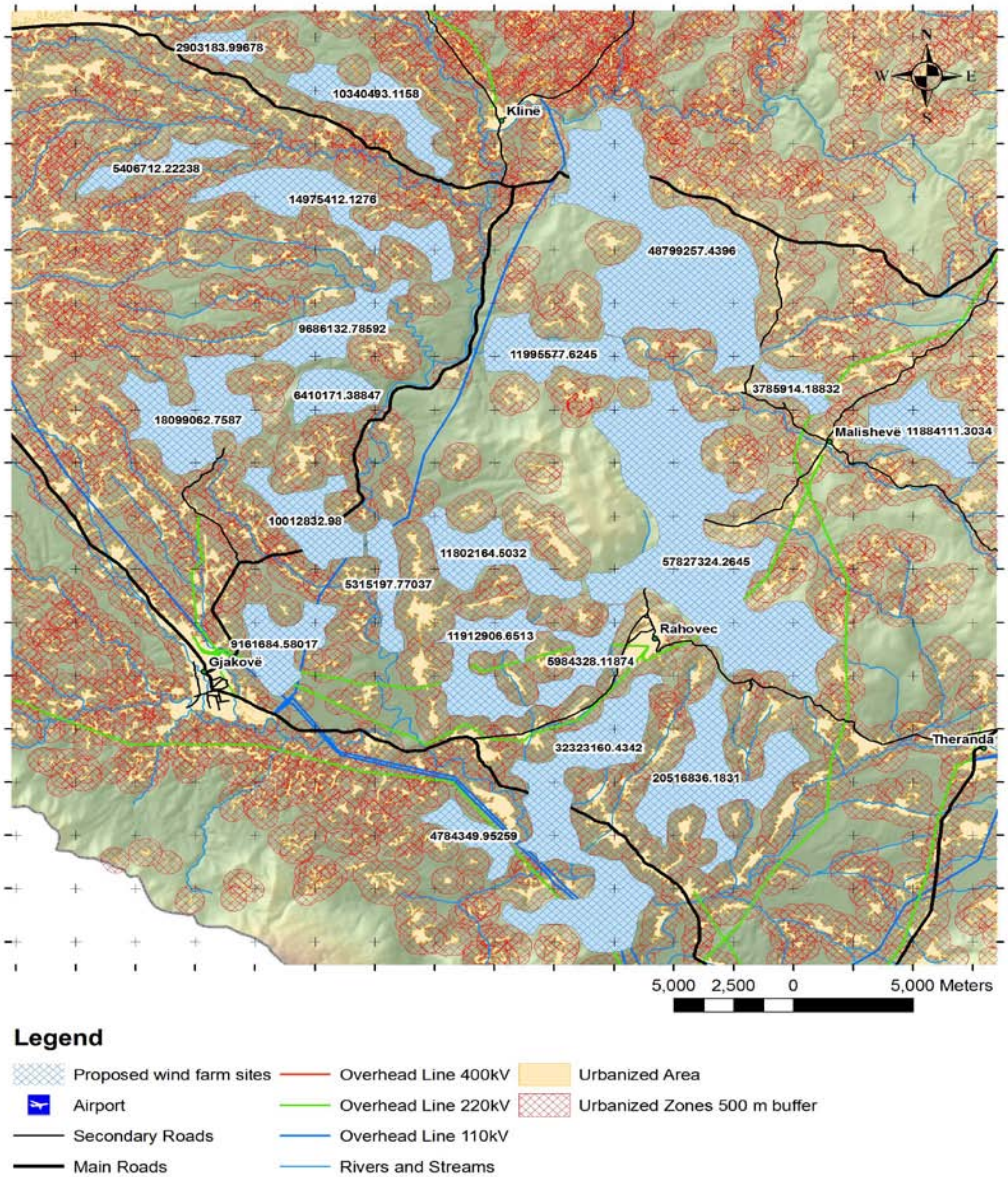


Figure 20: Possible sites (blue)

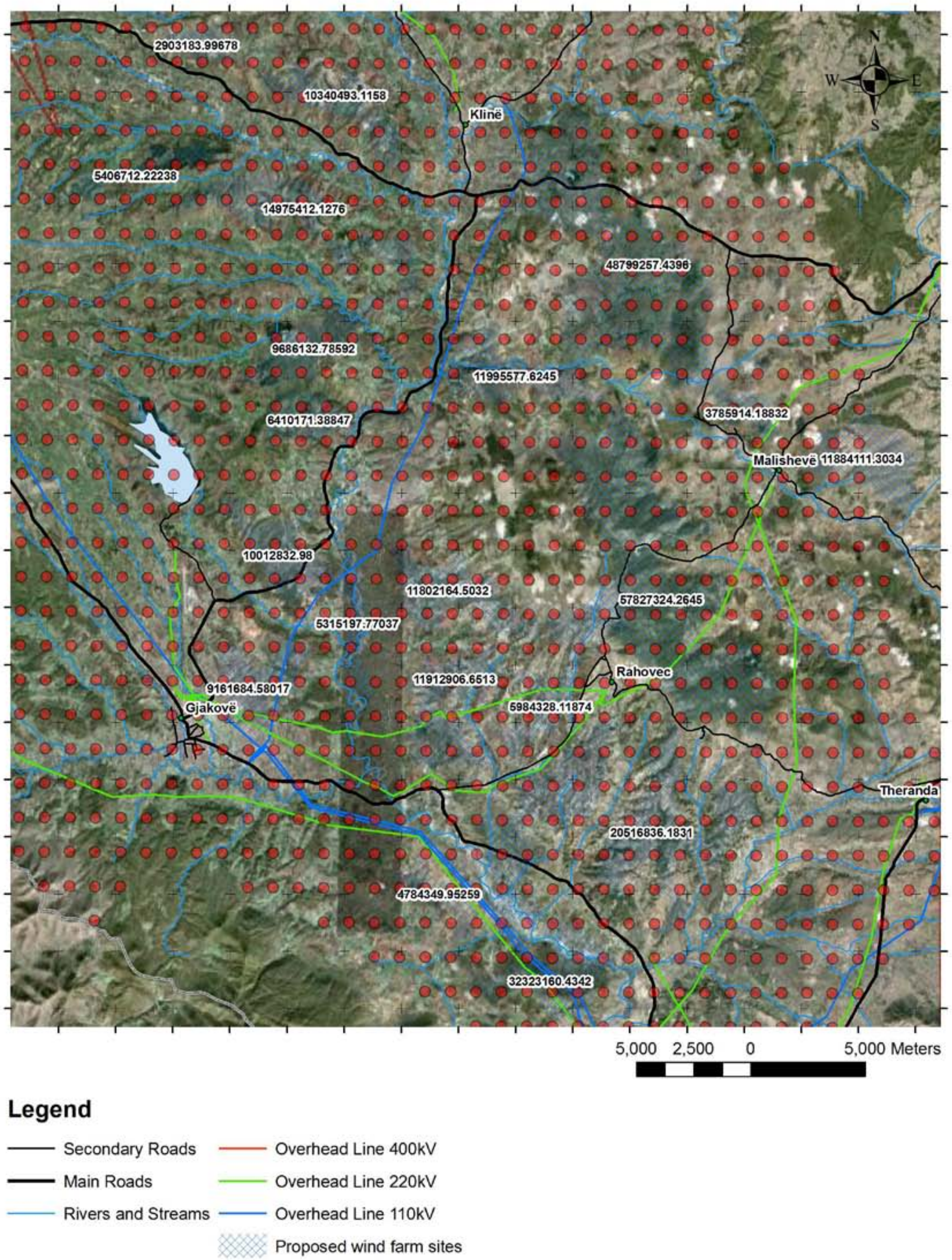


Figure 21: Possible sites in Google Earth format with corresponding areas in ha

Classified sites and their total area

As noted before the most suitable sites for whole Kosovo were chosen, and doing this, elevation, slope, urban areas surrounding these sites etc. were taken into consideration.
All sites were calculated not including the before created buffer zones of 500 m, and from two locations it resulted an area of approximately 31000 ha.
The results will be presented in table below, while calculation of wind energy yield/ha will be calculated separately for two zones, since they have different roughness values and wind speeds.

	Total area presented in ha for two zones	
	Dukagjini (ha) 5.8 m/s	Lipjan (ha) 5.6 m/s
Total	**29581.3**	**1313**

Table 12: Total area of possible sites in (ha)

Wind turbine Selection

Till now it was discussed about Kosovo's economical, energy situation, current trends in renewable energy. It was discussed about the feed-in tariffs that are applied in Kosovo, wind energy in general and how it should be measured, what measurement methods were used etc.

It is this section where, it will be discussed more in details about the wind generator that will be chosen for the calculations.

In selection of this generator it was taken into consideration the most common one as for the generation capacity, while the brand shouldn't be considered in any case as a suggestion or preference, in future developments of wind parks.

The generator that was selected is the VESTAS V-80 with capacity of 2 MW and hub height of 100 m.

Source: www.vestas.com

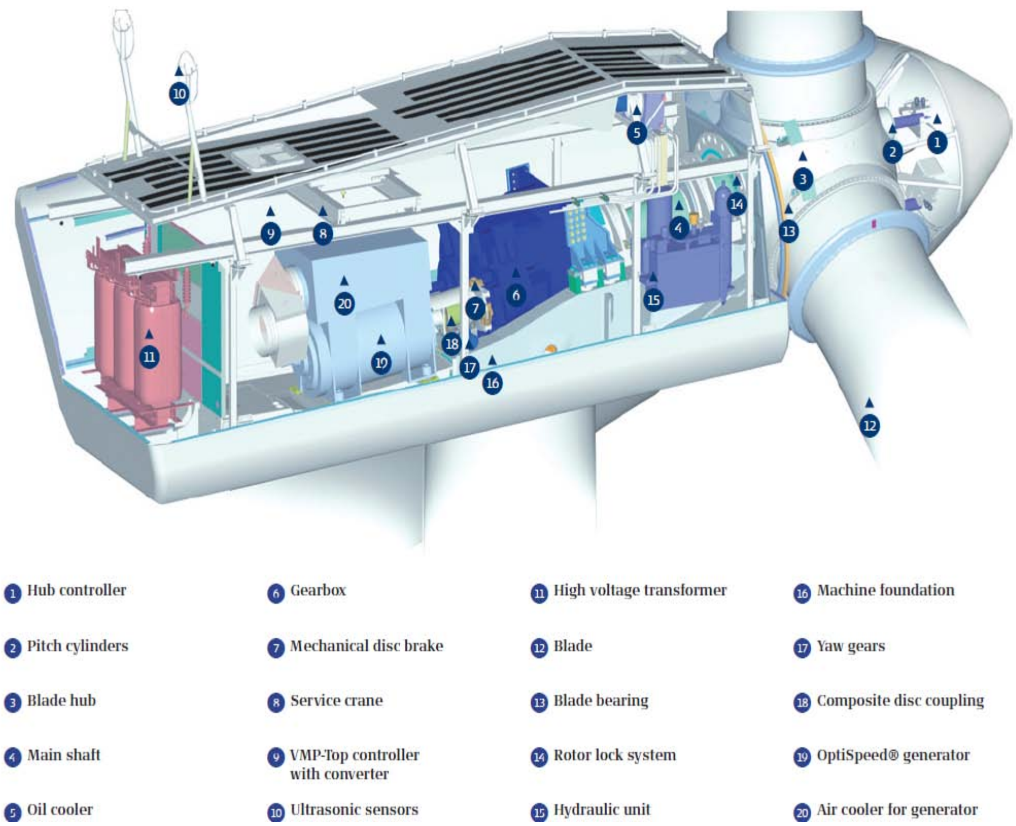
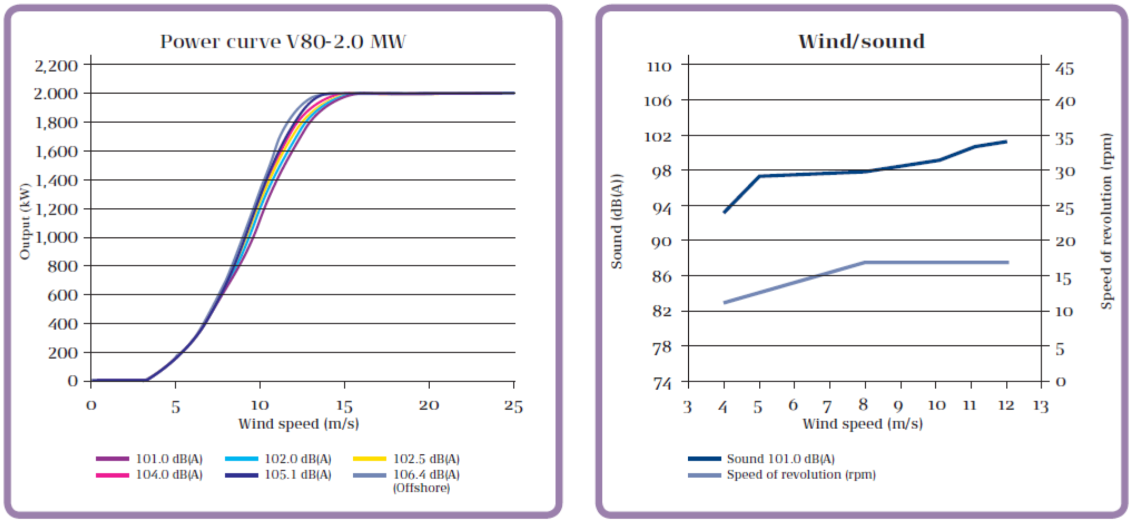


Figure 22: Vestas V-80 turbine

The power curve of this type of the turbine will be showed below, also the sound that is produced from the wind generation.

Source: www.vestas.com



The figure above illustrates the power curves at different sound levels for the V80-2.0 MW turbine, which is equipped with OptiSpeed®[32].

Figure 23: Power curve and wind/speed ratio of Vestas V-80

Other important parameters include:
Rotor Diameter: 80 m
Area swept: 5,027 m2
Number of blades: 3
Air brake: Full blade pitch by three separate hydraulic pitch cylinders.
Hub height (approx): 100 m
Cut-in wind speed: 4 m/s
Nominal wind speed (2,000 kW): 15 m/s
Cut-out wind speed: 25 m/s
Weight: Nacelle: 67 t
Rotor: 37 t
Towers Hub height: 100 m – 225 t[33]
t = metric tonnes
.
Roughly the calculated price for this type of the turbine, including transport and installation cost/turbine is calculated to be 2,5 million Eur.

[32] *Product Brochure Vestas V-80, www.vestas.com*
[33] *Product Brochure Vestas V-80, www.vestas.com*

Energy yield calculation

Energy yield calculation will be done with software named ALWIN which was developed from a German company named Ammonit GmbH-Berlin.

This software as a working principle is not complicated, but produces reliable results.

The inputs that are given are: the place name, the sea level, measurement years, average mean temperature, the roughness, and wind generator data, including power curve, hub height etc.

The following examples will show the calculated wind energy yield/annum of a single wind turbine, for two locations (Lipjan and Dukagjini).

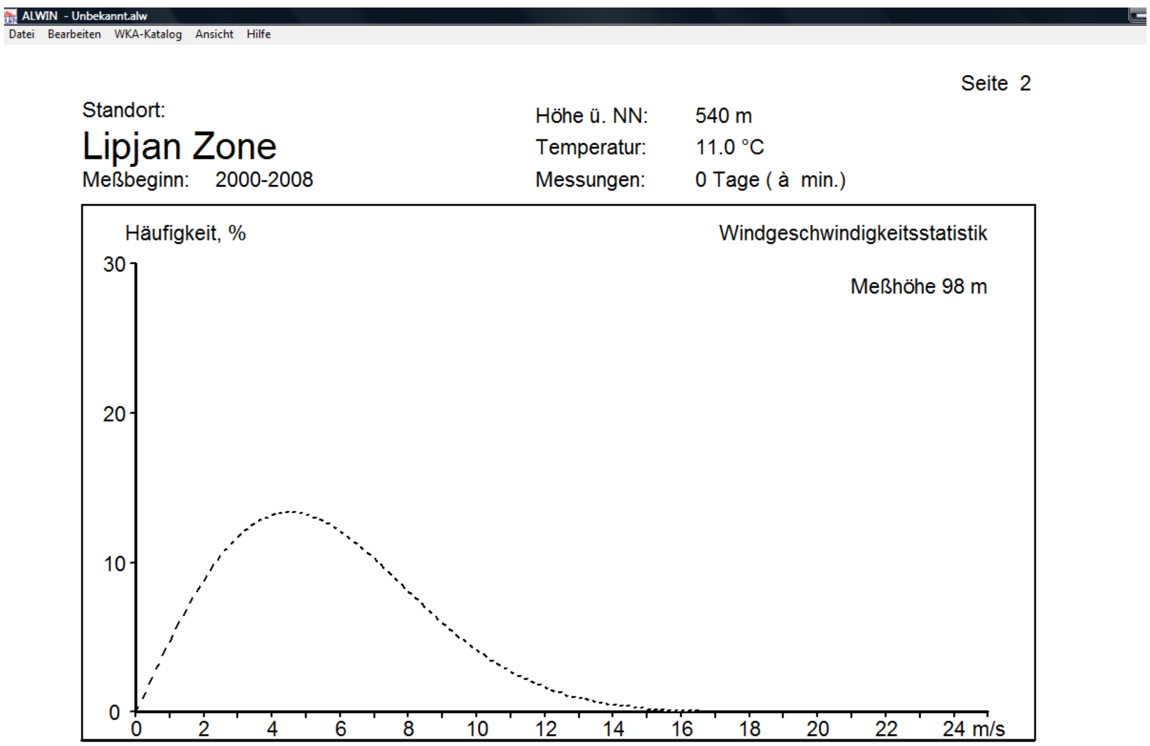


Figure 24: Shows the wind speed curve for the Lipjan zone measured at 98 m

In the figure above there are seen the inputs, such as the measurement period which is 2000-2008, the sea level of that specific area, the average yearly temperature and also the measurement height which in this case is the modeled measurement height at 98 m.

In the figure 26, it is shown the power curve of the turbine while in figure 27 the annual energy yield that a turbine can produce, under specified circumstances.

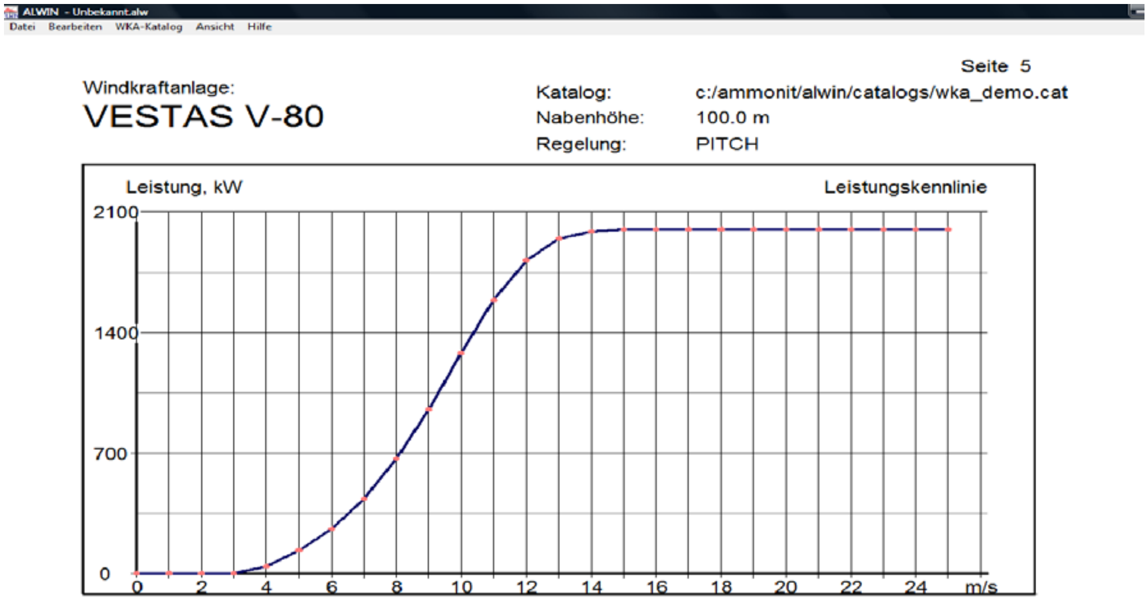


Figure 25: Power curve of selected turbine

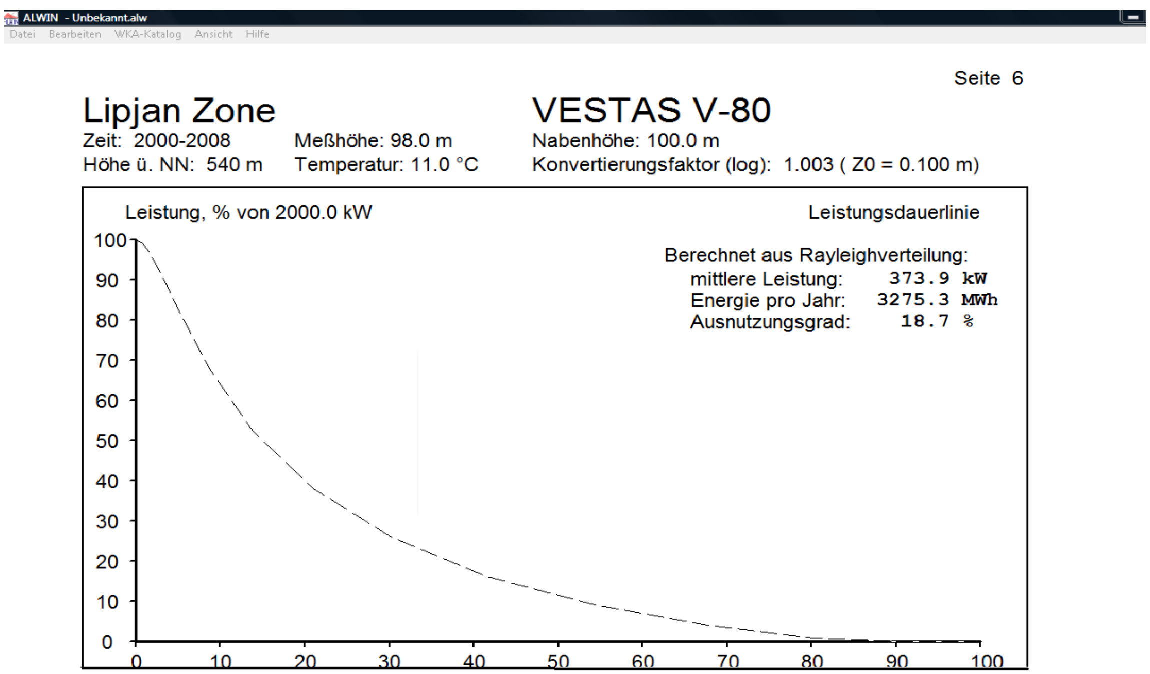


Figure 26: annual energy yield of Vestas V-80, in Lipjan zone with calculated mean wind speed of 5.66 m/s.

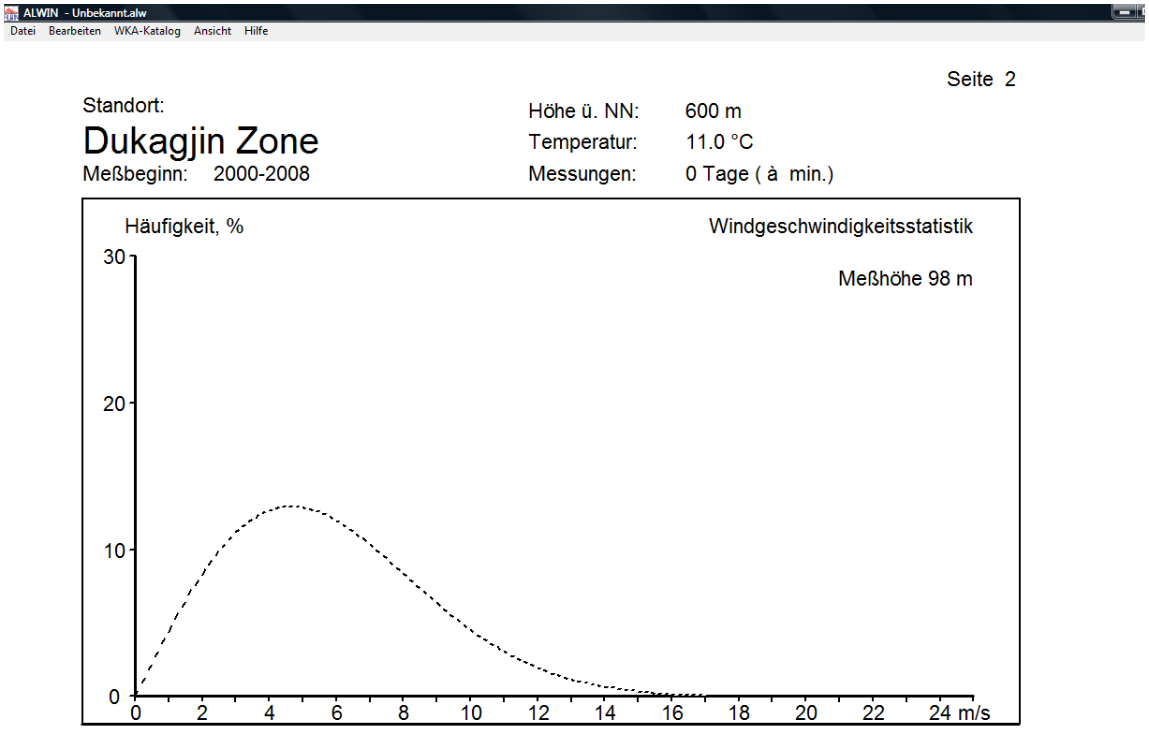


Figure 27: Shows the wind speed curve for the Dukagjini zone measured at 98 m

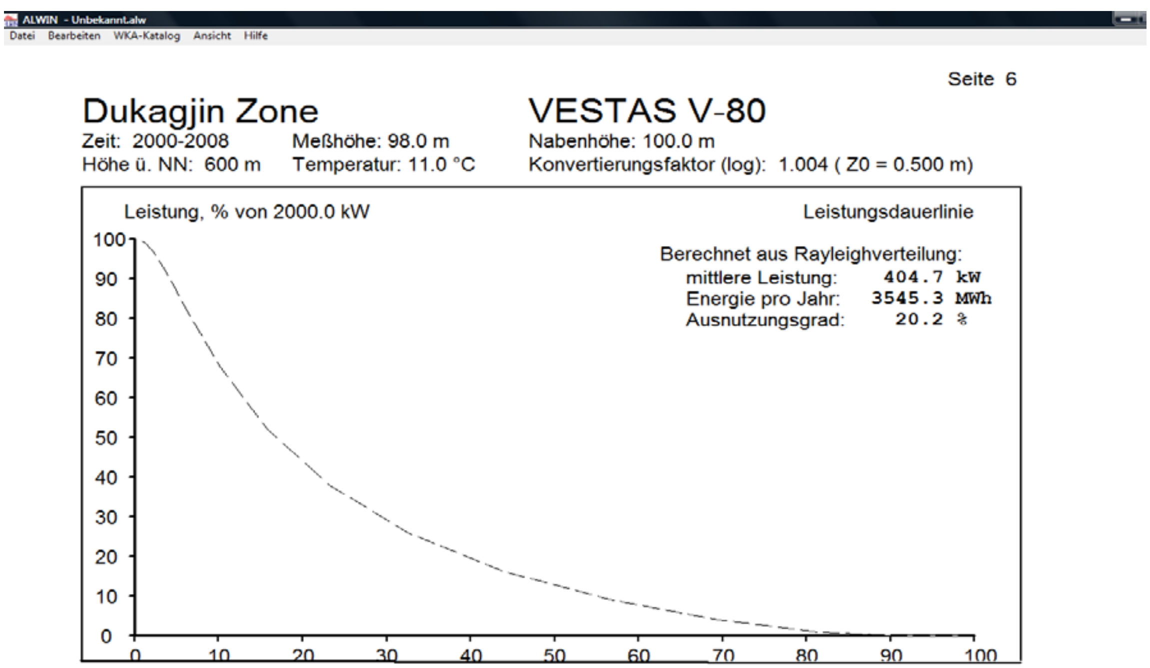


Figure 28: annual energy yield of Vestas V-80, in Dukagjini zone with calculated mean wind speed of 5.85 m/s.

In this section, it will be calculated the total energy production from specific types of turbines (Vestas V-80, 2MW) in yearly bases.

From the data that is necessary to have, we have the data of total possible site which is approx. 31000 ha and we have two different energy yields per annum for two different sites, which is normal, since we have two different wind speeds for two different zones.

What will be done next simply is that the two zones will be divided and then multiplied with corresponding energy yield/turbine.

For better approach, also the distance between turbines should be calculated, which in this case, it is calculated as follows:

5 x rotor diameter (80 m) = 400 m should be the distance between the turbines.

If we think that there should be perpendicular distance from each side, and then it results that one turbine can be placed at an area of 400x400 m which results in 160000 m^2.

When the area of 160000 m^2 was divided to corresponding areas of two zones, it resulted that zone of Lipjan can have 82 turbines more or less, while the biggest number of turbines can be installed in zone of Dukagjini with total of 1865 turbines.

Zones	Avg.wind speed (m/s)	Total area in (ha)	Energy yield of corresponding zone in MWh/a	Number of turbines	Total energy from wind in GWh/a
Lipjan	5.66	1313	3275.3	82	268.6
Dukagjin	5.85	29851.3	3543.3	1865	6608.2

Table 13: Total energy yield from wind (two zones) energy/annum

4.2.2.2Environmental Constraints

As stated in above chapters, environmental approach of project such as wind energy generation, always need to be taken into consideration.

What was done also for analysis done for Kosovo is that, the real situation was analyzed through GIS. The data of the available, nature or archeological sites were taken from respective institutions and included in Kosovo's map, where it was observed the layout of these inputs (see figure 10).

In above chapter it was mentioned about benefits that wind energy would bring to a country and how harmless is this type of energy to nature when compared with fossil fueled ones. Like everything in nature, also this process has its carbon footprints, as stated in the chapter above, the most harm to the environment in this process is during the production and transportation of these turbines.

Other impacts are also possible but they will be opened for discussion only when there is an investment opportunity in those areas.

Another thing that was studied during this phase was to check if there is any protected area for the birds and mammals that are endangered and therefore protected from the institutions, but luckily there was not such area nearby.

Again it is worth to say that this analysis of environmental constraints, was to have a general knowledge about the possible sites, and it must be noted that for specific project, detailed environmental studies must be prepared in cooperation with Ministry of Environment and Spatial Planning.

4.2.2.3 Economical constraints

This is the section where it will be discussed, whether this type of turbine can generate enough electricity from the wind so that it would be feasible with the current feed-in tariffs that are guaranteed for period of 10 years through PPA (Power Purchase Agreement). Also the procedures of taking a power production license will be discussed briefly.

License Procedure:

In Kosovo there is an Energy Regulatory Office (ERO), which is responsible in defining feed-in tariffs and also has the right to give or not the license to the companies willing to produce energy and later selling to the market.

If we summarize the license procedure:

There are 4 steps that should be followed,

1) Authorization for building
2) If the capacity is above 5 MW then there is a need for License
3) Certificate of origin
4) Application for feed-in

So from the above steps, it is clear that first an investor has to apply to have authorization for building, then after having this authorization and defining how much capacity will the plant be, it will be the need to get the License for energy production.

After getting this license, the certificate of origin (for generator) is asked from the ERO, and after having a proof of this certificate that it is compatible with standards, then investor may apply for feed-in tariffs, which basically is the last step before the start-up of energy production.

Economical analysis:

It was mentioned that if investor wants to invest in wind energy, then among the things that are of greatest importance are the feed-in tariffs and their lasting period, and also the wind speed. In the graph below, it will be shown how feed-in may change when wind speed changes:

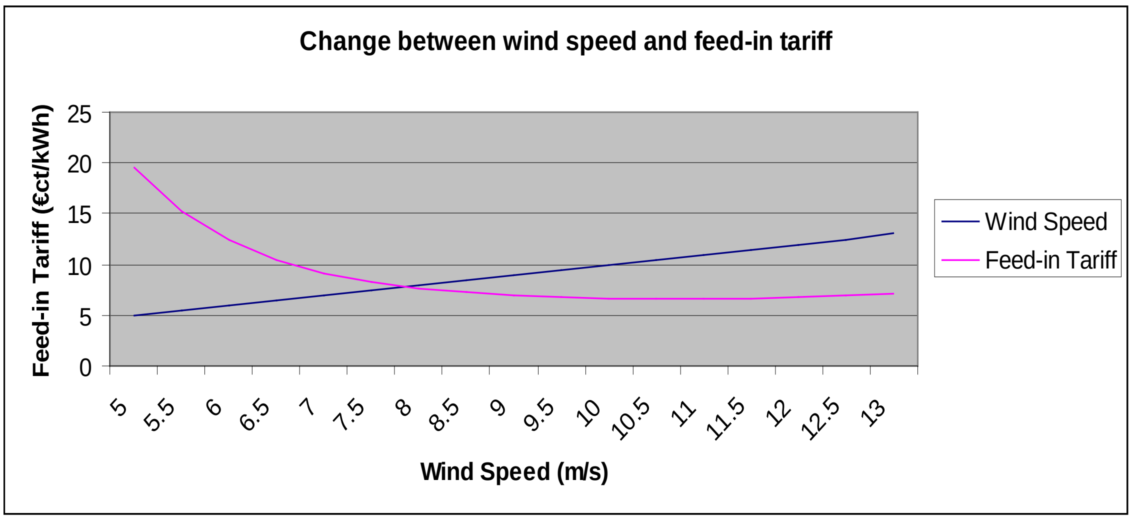


Figure 29: Change between wind speed and feed-in tariff

It must be understood from the figure above that the higher the wind speed, the lower feed-in tariff we need, for our project to be feasible.

The formulas below, helped to have a look at our project if feasible or not. The formula shown below is known as Gerrad formula and is used in energy projects. By the help of these formula, it is calculated the return on investment on how many year it is going to occur, operation costs, construction costs, inflation rate etc, and combining these all gives a result of how much would be the cost for KWh.

$g = CxR/E + O$ where;

g – Cost per KWh

O – Operation and Maintenance costs

R – Return of investment

C - Construction cost

E – Annual return of m^2 of rotor diameter

Also the other formula,

$R = r / 1\text{-}(1+r)^{-r}$ where;

r - Inflation-adjusted effective interest rate

n - Number of annual payments

Using these two formulas, produced the tables below, which for the sake of simplicity were produced in this way.

Annual Energy Yield	**[kWh/*Year]**	3,275,300
Construction cost/turbine	**[€]**	2,500,000
Operating costs as% of plant costs	**[%]**	4.00
Internal Rate of Return	**[%]**	7.00
Depreciation period	**[Years]**	10
Redemption Factor		0.14
Electricity Production Cost	**[€ct/kWh]**	**13.92**

Table 14: Costs of single turbine and its electricity production cost (Lipjan zone)

Annual Energy Yield	**[kWh/*Year]**	3,543,300
Construction cost/turbine	**[€]**	2,500,000
Operating costs as% of plant costs	**[%]**	4.00
Internal Rate of Return	**[%]**	7.00
Depreciation period	**[Years]**	10
Redemption Factor		0.14
Electricity Production Cost	**[€ct/kWh]**	**12.87**

Table 15: Costs of single turbine and its electricity production cost (Dukagjini zone)

In these calculations, the price for wind turbine roughly was calculated to be 2.5 million Euro including transport and installation.

As observed from the tables above, the feed-in tariff of 8.4 €ct/kWh which is currently the tariff for wind energy generation for Kosovo, is really low for this case and it is not feasible to invest in wind energy in both locations at least with these modeled wind speeds.

As stated above, the computer modeling is not so precise in determination, therefore it doesn’t mean that the average wind speeds, reflect the real wind speed, it can be said that there is always a deviation and errors that should be taken into account.

There is a need to have on-site measurements for a better economical approach.

5. Conclusion and Recommendations

Throughout the thesis it was discussed about the wind energy, let it be theoretical or realizable, the constraints, and possibilities to install wind turbines.

When deciding about this topic, author couldn't imagine that it would be this hard, reason for it is that there were not any wind measurement data, and without those data it was a very difficult situation for author to come up with acceptable results.

It was discussed about the economical situation of this country, since it is a need to have clear picture of investment environment. Other statistical data and electricity consumption as well plays an important role from this aspect. In order to have a more complete thesis author tried to combine all above mentioned data, and also adding the results that came out from the research.

For professionals who are interested in renewables, wind energy is one of the top interesting topics, although wind energy is nothing new, it has passed through different stages to be as perfect as possible, and by perfection author definitely means high efficiency. Wind energy has different components that should be studied before going into production. It is a fact that after "global warming" has emerged, countries has started to give more importance to renewables, mainly because they are clean energy sources and doesn't harm environment. Thus in considerable numbers of countries feed-in tariffs were introduced, in order to motivate the investors to produce energy and make incomes by selling it to the grid.

When it is discussed about feed-in tariffs, it is clear that they can be changed, either be increased or decreased, but one thing that remain un-certain is the wind speed, which makes wind energy investment, highly to be investigated. By this investigation author states the need to have serious on-site measurements for at leas one year and to have an idea of the wind that blows in that certain area.

The process that author went through in this thesis was that, first of all the available wind measurement results were analyzed, although they were not enough, and therefore there was a need to study the theoretical part of wind energy of Kosovo.

After it there was a need to go more into details, in order to have more compact work, so it was studied the realizable wind energy potential.

By realizable wind energy potential we understand, when all constraints (spatial-technical, environmental, economical) are taken into considerations.

Reason to have realizable wind potential study is that, theoretical wind is available in general but when there is need to go for details, you should consider the spatial criteria, environmental impacts that certain project might have, and finally economical constrains such as feed-in tariffs as discussed above.

The reason why author have stopped in two factors (feed-in and wind speed) is that, the most difficult part of this thesis was to predict the wind energy of a certain place, without having on-site measurements. Since in Kosovo, there were not any wind measurements done before and after considering all possibilities, it came out that for a “pioneer” study as this it might be a good idea to go for modeled studies of wind.

Therefore in continuous consultations with thesis advisor, it was decided to use the result that came out from computer modeling named MM5. These were the results from a German company named DEWI for whole SEE Balkans namely for the periods between 2000 and 2008.

These results have advantages, because they help to have a general idea, without going into many details they help to describe the effects on the wind of parameters such as elevation, topography and ground surface cover.

Disadvantage of computer modeling is that, they are not exact as in on-site measurements case; therefore they cannot be used for specific projects.

After having the results from DEWI and SEEWIND webpage they were simultaneously transferred into GIS where, corresponding wind speeds for each coordinate within the boundary of Kosovo appeared.

The places where the wind speed was higher than 5.5 m/s were selected for the sake of simplicity. After determining these places than selection of spatial criteria according to Corine database took place, which led to technical-spatial constraints, after analyzing it the next was to analyze the environmental constraints where all natural, archeological and special protected areas helped to get a better approach, last but not least also the economical constraints were taken into account.

In economical constraints, it was investigated if it is feasible to invest in wind energy with given wind speeds of certain areas and with specific type of wind turbine.

By the help of ALWIN which is wind energy modeling software, it was calculated the energy yield that selected turbines may produce annually by taking into account mean wind speed, roughness, average mean temperature and elevation of a location.

After having an annual energy yield, by the help of the Gerrad formula, it was calculated the cost per kWh of a turbine and they were presented in a simplified table.

These results presented in table took into account the cost of a single turbine to be a 2.5 million Euro which would be considered as turnkey so including everything, also inflation rate was calculated together with maintenance and operation cost which would finally lead to the results, describing if the feed-in tariff of 8.4 eurocent/kWh would be enough so that a given project would be feasible.

Unfortunately what was observed from the study appeared that with the wind of more than 5.5 m/s but not more than 6 m/s wouldn’t be feasible since it requires feed-in tariff of more than 10 eurocent/kWh, which at the present is lower for Kosovo.

As stated above results from computer modeling are not always as certain and exact as on-site measurements, but they definitely contribute to have a general picture about where wind blows more or less.

The last part of this section will be dedicated to some recommendations that may assist to have a better approach to wind energy.

The strategy for Energy of Republic of Kosovo exists, which foresees the usage of renewables including wind, there is also an Energy regulatory office, which has clear procedures of application and energy production, by this it can be concluded the there is a good environment to invest.

What remains as a main handicap, is that absence of on-site wind measurements would make investment more difficult, therefore it is recommended that as soon as possible measurements take place, and to have a general wind atlas of Kosovo.

It is obvious that this may not occur without a help from EU, therefore it is highly recommended the development of wind atlas as soon as possible.

Acknowledgement

Writing the acknowledgment is a very hard part, since I cannot differ anyone who helped me in preparing this thesis. I would like to start first of all with my father Dr. Talat Gjinolli, who made this master degree achievable for me, he as well as my mother, siblings and my grand mother were the ones to give me high support and encourage.

I have to thank my fiancé Blerina Zeneli, who never hesitated to support me, even in the hardest times and also her family to be by my side whenever it was needed.

A special place for me, who I consider contributed in professional means of this thesis are: Mr. Andreas Krenn, as the advisor and mentor of my thesis, Prof. Sabri Limari for his valuable information regarding energy situation of Kosovo, Lorik Haxhiu PhD for his contributions with GIS, Mr. Ramadan Gagica, Mr. Ardian Berisha and many others whose names are not here, for their valuable information regarding legal and procedural steps of wind energy generation.

Finally, last but not least I would like also to thank my friends and my extended family for trusting me in this project.

References

AWEA publications, “The Economics of Wind Energy”, February 2005

BELHOMME Régine, ROYE Daniel and LAVERDURE Nicolas, “Renewable energies, wind energy systems”2009

Commission of the European Communities, “Kosovo Under UNSCR 1244/99 2009 Progress Report” 2009.

Danish Wind Industry Association, Measurement in Practice, 19 September 2003

EEA Technical Report, No 6/2009, “Europe's onshore and offshore wind energy potential- An assessment of environmental and economic constraints” 2009.

Erebara Gjergj, “Kosovo has highest GDP growth in Balkans,” Balkan Insight, 2 October 2009,

EWEA, “Wind Energy-The facts”, March 2009

Lecture notes “Energy situation in Kosovo” by Besim Islami, from Energy audit training program April-May2010

Ministry of energy and Mining of Republic of Kosovo (MEM), “Energy Strategy of the Republic of Kosovo for the Period 2009 – 2018”, 2010

N. Schink, “Wind Power Systems”, Wind System Components, Wind Energy II

Ngô Christian, Natowitz Joseph B. “Our Energy Future, Resources, Alternatives, and the Environment”, 2009

Quaschning Volker,
“Understanding Renewable Energy Systems” 2005

The Statistical Office of Kosovo (SOK) has published nominal GDP figures for the years 2004-2007, stressing at the same time that the number and the quality of existing statistical surveys are insufficient for successful implementation of national accounts according to ESA 95 standards.

Youth initiative for human rights, “State of construction Governance and Free Expression in Kosovo”, May 2010

Vestas: Life Cycle Assessments (LCA). Retrieved 2008-02-13.

Vestas, “Product Brochure Vestas V-80” 1/08 UK

World Bank, “Kosovo Powerty Assessment”, October 3, 2007,