CZECH TECHNICAL UNIVERSITY IN PRAGUE
FACULTY OF ELECTRICAL ENGINEERING
DEPARTMENT OF ECONOMICS, MANAGEMENT AND HUMANITIES

Designing parallel working wind power station in South Kazakhstan

MASTER'S THESIS

Study program: Electrical engineering, Power engineering and Management

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Designing parallel working wind power station in South Kazakhstan

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Designing parallel working wind power station in South Kazakhstan

Pokyny pro vypracování:

- describe technical background of possible technologies
- explain why wind power is good for investigated region
- prepare financial model for project evaluation
- compare possible project scenarios and provide sensitivity analysis

Seznam doporučené literatury:

Subhes C. - Energy Economics: Concepts, Issues, Markets and Governance, Springer, 2011, ISBN: 0857292676.
REN21. 2015. Renewables 2015 Global Status Report (Paris: REN21 Secretariat). ISBN 978-3-9815934-6-4

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Datum převzetí zadání — Podpis studenta

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"I hereby declare that this master's thesis is the product of my own independent work and that I have clearly stated all information sources used in the thesis according to Methodological Instruction No. 1/2009 – "On maintaining ethical principles when working on a university final project, CTU in Prague ".

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Abstract

Renewable energy sources have been widely implementing for the past years. Republic of Kazakhstan has a huge renewable energy sources potential and has a deep scarcity in electricity generation. The aim of the work is to design wind farm working in parallel with the National Grid and provide feasibility study.

Weibull distribution approach was applied for wind energy analysis. This includes wind data analysis, wind speed extrapolation and annual energy generation. Moreover, proper location and potential losses were considered. And last but not least, turbine selection process with several turbines comparison is provided.

Feasible study includes country’s economic situation analysis, policy and stimulation investigation. Methodology for evaluation was chosen and potential costs were calculated. Further, main financial parameters are discussed, potential risks and benefits were pointed out. Also, different scenarios were taken and researched. Finally, future changes, troubles are discussed and provided final results.

Keywords

Renewable energy sources, wind energy, Weibull distribution, financial analysis, feasibility study

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List of abbreviations

Abbreviation	Foreign meaning	English meaning
CF		Cash Flow
CIT		Corporate Income Tax
CPI		Consumer Price Index
DCF		Discounted Cash Flow
GHG		Greenhouse Emissions
GTU		Gas Turbine Unit
HPP		Hydro Power Plant
IEA		International Energy Agency
IRENA		International Renewable Energy Agency
IRR		Internal Rate of Return
JSC		Joint Stock Company
KEGOC		Kazakhstan Electricity Grid Operating Company
KZT		Kazakhstan Tenge
LCOE		Levelised Cost of Electricity
MW		Megawatt
MWh		Megawatt hour
NPV		Net Present Value
NREL		National Renewable Energy Laboratory
PI		Profitability Index
RES		Renewable Energy Sources
SPB		Simple Payback Period
SPP		Solar Power Plant
TPP		Thermal Power Plant
TPU	Tomskiy Politekhnicheskiy Universitet	Tomsk Polytechnic University
UNDP		United Nations Development Programme
USD		United States Dollar
WPP		Wind Power Plant

Introduction

Today renewable energy is the most rapidly developing energy source in the world and Kazakhstan is not an exception. Day after day alternative energy sources generate more and more electricity. However, at this moment, shares of alternative energy sources are not as huge, as their potential in Kazakhstan.

One of the biggest problem in country's energy sector is a deep scarcity of installed capacity and of generation ability. Despite some regions have mere more generation than consumption, overall energy balance lies under bottom line and covered by foreign energy grid, such as Russian Federation, Republic of Uzbekistan. It is noteworthy to comment that Republic of Kazakhstan is a member of Kyoto Protocol which was signed in 2009 [1]. Therefore, it is necessary to comply to reduce CO_2 emissions by the terms of the Protocol.

Moreover, according to researches, Kazakhstan is 20th country of overall CO_2 emissions and 19th by CO_2 per person pollution in the world [2]. This brings the crucial point: there is an extreme necessity in new capacity, especially "green" capacity. Thus, even though power plants do not supply total demand, but pollute contaminate quite enough.

Nevertheless, Republic of Kazakhstan has a tremendous renewable energy potential with the biggest share in wind and solar energy potentials. Most of this territory has favourable conditions for high wind speed [3].

It is clear that wind energy has various number of benefits. Firstly, wind energy is inexhaustible, as any renewable energy source. Furthermore, wind energy is green, meaning this is a non-fuel consuming energy source and this fact could significantly help in reducing of overall pollution level. Moreover, wind power plant does not consume water, which is also considered as a benefit. Also, building such kind of a plant there will be created new job positions which again considered as an advantage. However, there is a list of drawbacks in wind energy applying. The main drawback is reliability. Wind distribution has the fluctuating dependency, which could make troubles in the grid. While another disadvantages are not influencing so significantly, nevertheless, researches point them as noise from wind turbine, bird killing, low energy per square meter ration and etc.

This diploma thesis aims to design a wind power plant in the selected region, find out the main benefits and drawbacks. Moreover, the goal includes profitability and economic feasibility of this idea.

Throughout the work a reader will face the following structure. The thesis starts with providing information to answer to the question "Why wind energy is favourable in Kazakhstan?". This part includes some background information about current situation in Kazakh energy sector, wind energy potential and renewables stimulation in the country. Wind energy analysis will be pointed out further. This chapter was devoted to evaluate the electricity generation from wind speed data calculation to final energy output. Feasibility study will be given in the Finance model part and methodology for economic evaluation will be described next. Finally, in order to show expedience and sustainability of the work sensitivity analysis will be provided and results will be discussed.

Chapter 1

Why wind power is favourable for investigated region

1.1 Current situation in energy sector in the Republic of Kazakhstan.

Nowadays, Republic of Kazakhstan has 4 main energy subjects. Those are: South – includes Almaty, Zhambyl, South-Kazakhstan regions; Central – Karagandy region; East – Akmola region; and West – Mangistau and Atyrau regions [4]. Moreover, as it is known from several researches, there is a huge power and electricity deficit in almost whole territory [5].

The recent report "The forecast power and electricity balance of United Electrical Network of Republic of Kazakhstan in 2016 up to 2030" represented by JSC "KEGOC" shows main energy generation factories, whole electricity consumption, reserves and deficits or surpluses. According to this data, in the following figure and table, capacity and electricity balances respectively, in South Kazakhstan region provided [5].

According to this report, the following table represents how much installed capacity installed in South Kazakhstan, including future station expansions and new plants installations [5].

Table 1 – Installed capacity of power stations [5].

Title	Report	Forecast				
	2014	2015	2020	2022	2025	2030
TPP-1 JSC Yuzhpolitmetall, MW	18	18	18	18	18	18
TPP-2 JSC Yuzhpolitmetall, MW	12	12	12	12	12	12
TPP-1 JSC "3-Energoortalyk", MW	160	160	160	160	160	160
TPP-5 Kentausskaya, MW	12.5	12.5	-	-	-	-
HPP Shardarinskaya, MW	100	113	126	126	126	126
Small HPP on Keles river JSC «Kelesgidrostroi» , MW	1,3	1,3	1,3	1,3	1,3	1,3
Power station expansion, MW	***-***	***-***	***49***	***49***	***49***	***49***
TPP-5 Kentausskaya, MW	-	-	49	49	49	49
New power stations, MW	***-***	***1,4***	***1,4***	***1,4***	***1,4***	***1,4***
SPP in Shymkent city JSC «Aksu-Energo» , MW	-	1,4	1,4	1,4	1,4	1,4
Overall capacity, MW	**304**	**318**	**368**	**368**	**368**	**368**

However, installed does not mean real. Thus, it is crucial to show how much of installed power is available for operating. All necessary data is filled in following table [5].

Table 2 – Available capacity of power station[5]

Title	Report	Forecast				
	2014	2015	2020	2022	2025	2030
TPP-1 JSC Yuzhpolitmetall, MW	-	-	-	-	-	-
TPP-2 JSC Yuzhpolitmetall, MW	-	-	-	-	-	-
TPP-1 JSC “3-Energoortalyk”, MW	160	145	145	145	145	145
TPP-5 Kentausskaya, MW	5	5	-	-	-	-
HPP Shardarinskaya, MW	80	40	58	58	58	58
Small HPP on Keles river JSC «Kelesgidrostroi» , MW	1	1	1	1	1	1
Power station expansion, MW	***-***	***-***	***16***	***16***	***16***	***16***
TPP-5 Kentausskaya, MW	-	-	16	16	16	16
New power stations, MW	***-***	***-***	***-***	***-***	***-***	***-***
SPP in Shymkent city JSC «Aksu-Energo» , MW	-	-	-	-	-	-
Overall capacity, MW	**246**	**191**	**220**	**220**	**220**	**220**

As you can see from table above, not all capacity is used. Moreover, available power ratio is no more than 70%, which does not mean the best expectations, especially solar power plant in Shymkent city.

Finally, all summed up data taken from this report is presented in the following table [5].

Table 3 – Power balance in South Kazakhstan region up to 2030 [5]

Title	Report	Forecast				
	2014	2015	2020	2022	2025	2030
Maximum electrical load, MW	745	782	923	947	988	1 069
Installed capacity of power stations, MW	304	318	368	368	368	368
Available capacity of power stations, MW	246	191	220	220	220	220
Reserves, MW	-	31	36	36	36	36

Title	Report	Forecast				
	2014	2015	2020	2022	2025	2030
Power used in power balance, MW	129	159	184	184	184	184
Deficit (+), Surplus (-), MW	**616**	**623**	**739**	**763**	**804**	**885**

As this report demands, there was huge deficit in power (616 MW) in 2014. Moreover, it is increasing during the period and reached 885 MW deficit in 2030 [5].

Furthermore, to have a better imagination how it is going on, let's have a look on the next figure, which illustrates this situation. Figure was made based on data provided in report [5].

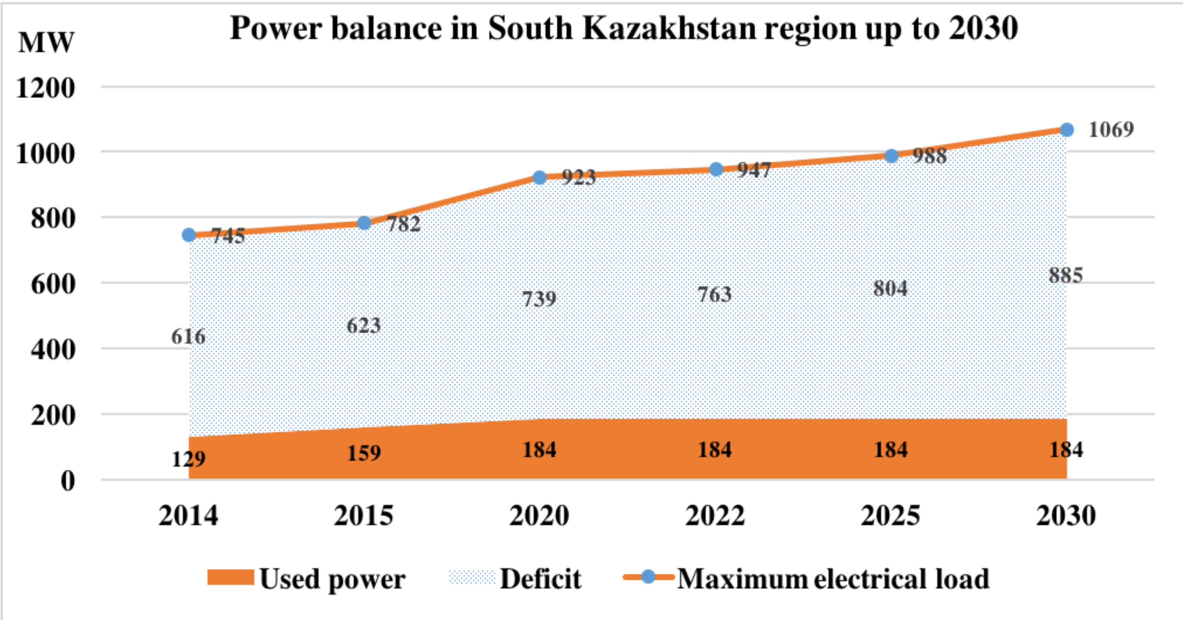

Figure 1 – Power balance in South Kazakhstan region up to 2030 [5]

Concerning to electricity generation, there is almost the same tendency. Further provided a table with main information regarding to current power plant generation [5].

Table 4 – Current power stations electricity generation [5].

Name	Report	Forecast				
	2014	2015	2020	2022	2025	2030
TPP-1 JSC Yuzhpolitmetall, GWh	-	-	-	-	-	-
TPP-2 JSC Yuzhpolitmetall, GWh	-	-	-	-	-	-
TPP-1 JSC "3-Energoortalyk" , GWh	0.76	0.71	0.71	0.71	0.71	0.71

Name	Report	Forecast				
	2014	2015	2020	2022	2025	2030
TPP-5 Kentausskaya, GWh	0.02	0.01	-	-	-	-
HPP Shardarinskaya, GWh	0.57	0.55	0.55	0.55	0.55	0.55
Small HPP on Keles river JSC «Kelesgidrostroi» , GWh	0.01	0.01	0.01	0.01	0.01	0.01
Overall , GWh	**1.34**	**1.28**	**1.27**	**1.27**	**1.27**	**1.27**

As it was predicted, there will be some changes in the future. The same situation was described above: power plants expansion and new stations inputs. Thus, total electricity balance might be obtained by adding this data [5].

Table 5 – Electricity balance in South Kazakhstan region up to 2030 [5]

Name	Report	Forecast				
	2014	2015	2020	2022	2025	2030
Electricity consumption, GWh	**4,15**	**4,16**	**4,91**	**5,06**	**5,30**	**5,72**
Electricity generation, GWh	**1.34**	**1.28**	**1.32**	**1.32**	**1.32**	**1.32**
Current power stations, GWh	**1.34**	**1.27**	**1.27**	**1.27**	**1.27**	**1.27**
Substitution, re-equipment and expansion, GWh	**-**	**-**	**0.05**	**0.05**	**0.05**	**0.05**
TPP-5 Kentauskaya (expansion) (3xGTU 16,3 MW) , GWh	-	-	0.05	0.05	0.05	0.05
New stations input, GWh	**-**	**0.002**	**0.00**	**0.00**	**0.00**	**0.00**
SPP in Shymkent city JSC, GWh «Aksu-Energo»	-	0.002	0.002	0.002	0.002	0.002
Deficit (+), Surplus (-)	**2.81**	**2.88**	**3.60**	**3.74**	**3.99**	**4.41**

According to provided information, there was huge deficit in electricity balance (2.8 GWh) in 2014. Moreover, deficit is increasing during the period and will reach about 4.4 GWh per year in 2030 [5].

Furthermore, to have a better understanding on this picture, let’s have a look on the next figure, which illustrate the whole problem. The Figure was made based on data provided in the report [5].

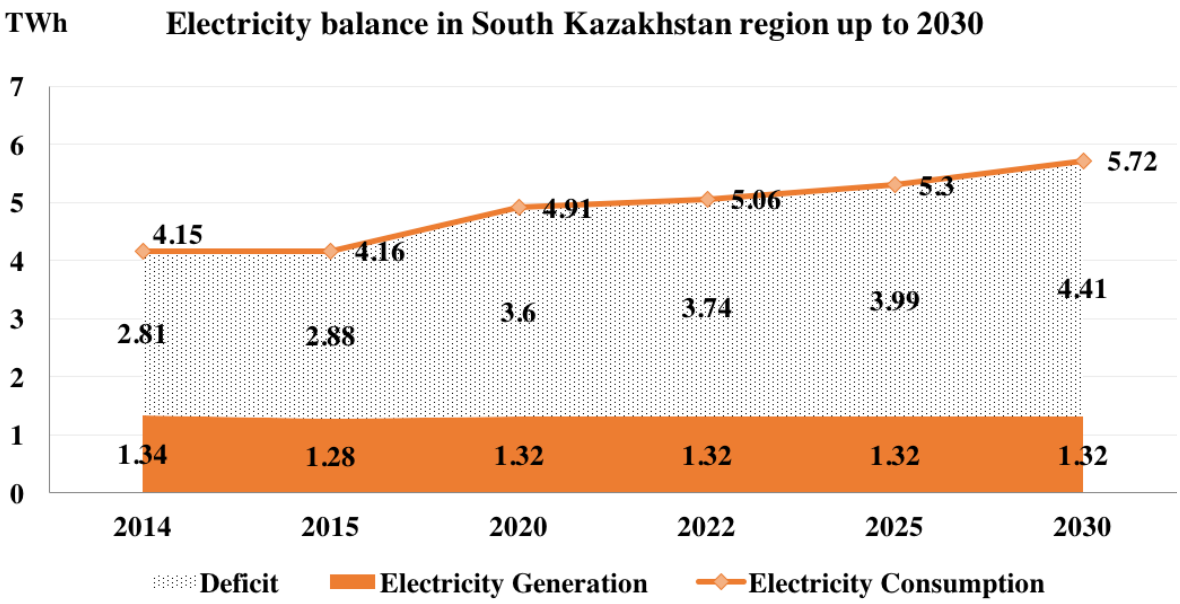

Figure 2 – Electricity balance in South Kazakhstan region up to 2030 [5]

The figures above provide main idea – a huge value of deficits are high now and will be increased in 2030. For instance, electricity and power consumption lines are raising during the whole period. Furthermore, in 2030 these values will grow by almost twice. Hence, power deficit with 885 MW and electricity deficit with 4.4 TWh are predicted in 2030.

Today, as reporters state, covering this amount of energy carried out by domestic and external generation. Domestic supply is strategic transit line North-South. While external, which carries most of deficits is energy from Central Asia countries, such Republic of Uzbekistan, Republic of Kyrgyzstan [5]. Thereby, new power entries are the priority problems in South Kazakhstan region.

1.2 Wind energy potential in South Kazakhstan

In the past 20 years, wind engineering has been rapidly extended as in developed, as in developing nations [3].

This progress has not bypassed Kazakhstan. As it is clearly known, Republic of Kazakhstan is number 9 in the world's biggest countries ranking [3], and it is mean slightly above 2.7 million square kilometres. Most of this territory has favourable conditions for high wind speed. For example, in the mountain regions there is lot of gates, on the other hand huge territory in Kazakhstan are steppes, where wind speed riches high values. Wind Speed Atlas of Republic of Kazakhstan is provided below [6].

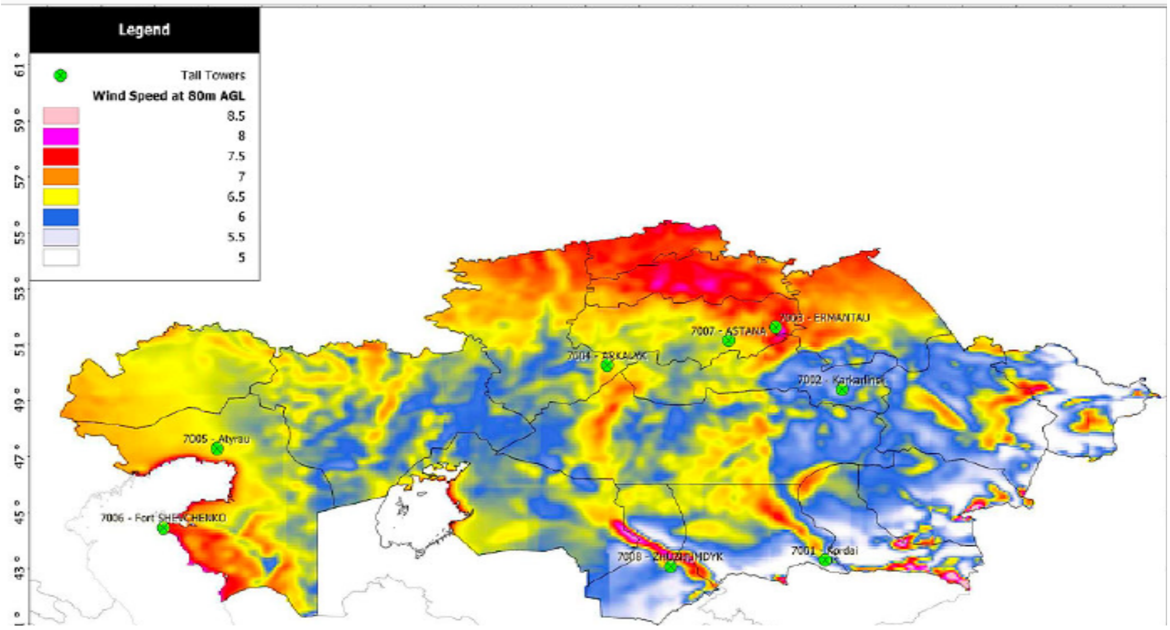

Figure 3 – Republic of Kazakhstan wind speed atlas [6]

This figure shows just a verification what were said above. According to this data, in almost whole territory average annual wind speed is about 6 and 6.5 m/s. However, in particular regions speed reaches between 7.5 and 9 m/s. The study of K.Lettice claims, the whole Kazakh territory has a great wind power resource – about 1 TWh per year. In other words, it is about 350 GW of installed power. For instance, up today near 20 GW is already installed [3].

What about South Kazakhstan. For investigated territory, situation is even better than in the rest of republic. According to Wind Atlas, published in [6], average wind speed in mountains is over 8 m/s, but in investigated place it is about 7-7.5 m/s, which sounds very good.

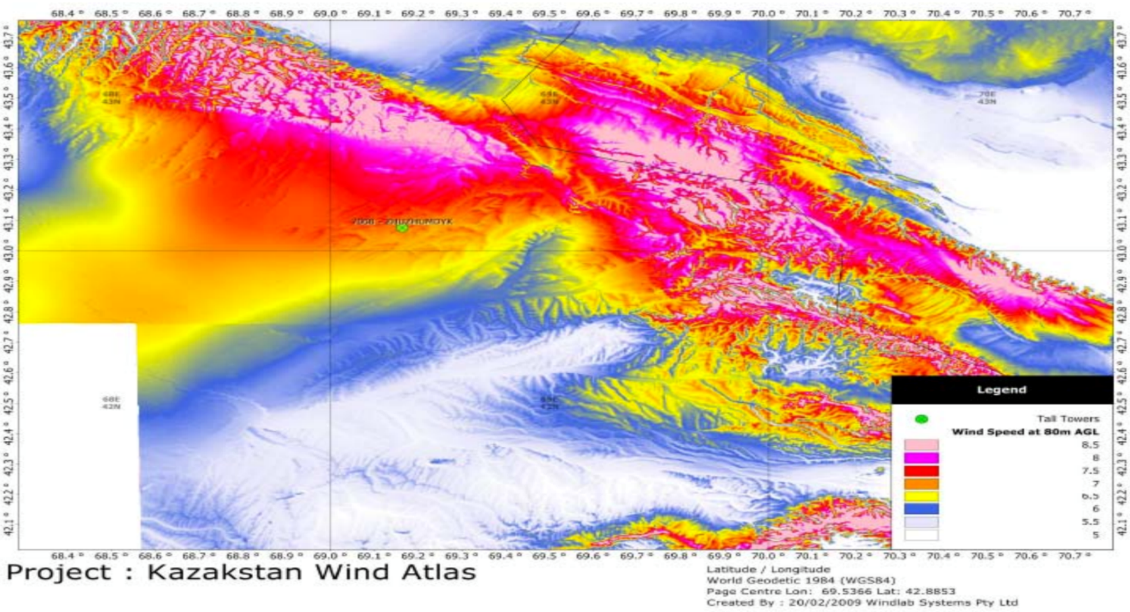

Figure 4 – South-Kazakhstan wind speed atlas [6]

1.3 National policy

Renewable energy sector in the Republic of Kazakhstan has widely progressed in the past years. And one of the supported authority is the Government [1].

First steps were made in 2004, when the Government of the Republic of Kazakhstan approved “Wind Power Market Development Initiative” project in common with United Nations Development Programme (UNDP). This document has some objectives, those are [1]:

1) Development wind energy market in Kazakhstan;
2) Prepare all necessary information in the development (including wind atlas creating, ecology factors);
3) Providing experience in the future investment in wind power plants.

The main outputs of these program are the first 5MW wind power plant in Djungar Gate and priceless experience for wind energy future [1].

However, this cooperation between United Nations Development Programme (UNDP) and the Government of the Republic of Kazakhstan was not ended. UNDP had made huge work and afterwards reported “Prospective of Wind Development in Kazakhstan” [3].

This overview consists of a range of benefits of wind energy market development in Kazakhstan, the main problems and drawbacks were also explained. For instance, wind energy potential and wind atlas were made and showed main prospective regions in Kazakhstan. Social benefits of wind energy are also being provided [3]. Ecological problems were analysed and the most optimum solutions were given, concerning to each region [1].

During this period several laws for stimulating green energy in Kazakhstan were approved (particular wind energy too) [3]. For instance, feed-in and “green” tariffs, which indicate the selling price for electricity generated by wind, solar, biomass, hydro and this kind of renewable energy sources [7]. Resolution № 645 of the government of the Republic of Kazakhstan "About approval of the fixed tariffs" dated from 12 of June 2014 claims, that all energy produced by renewable energy sources will have special price. They are: wind energy (except Astana EXPO-2017 wind power plant) – 22.68 KZT/kWh; Astana Expo-2017 wind power plant – 59.7 KZT/kWh; solar energy (based on photovoltaic modules produced in Kazakhstan) – 34.61 KZT/kWh; small hydro power plant – 16,71 KZT/kWh; biomass plant – 32.23 KZT/kWh [7]. Full descriptions and calculations of green tariffs are provided in the official web site of Settlement and Financial Centre of electric power [8]. Moreover, all buying and selling rules by Settlement and Financial Centre of electric power of the Republic of Kazakhstan are explained in the Resolution № 876 of the government of the Republic of Kazakhstan [9]. There were explained main rules about energy generation, connection to the KEGOC (Kazakh Electricity Grid Operating Company) and National Grid, operating mode’s monitoring.

In 28th of June 2014 the Parliament of the Republic of Kazakhstan approved the Resolution № 724 [10], which assume the development conception of fuel and energy complex of the Republic of Kazakhstan till 2030. This report demands to extend renewables share in whole energy complex. Moreover, the plan is at least 3% of renewables in Kazakhstan until 2020, 30% until 2030 and 50% of green energy in 2050 [10], [11].

1.4 Ecology problems

Renewables also can help Kazakhstan with ecology problems. For instance, reducing CO_2 emissions [1]. As it widely known, the Republic of Kazakhstan has signed the Kyoto Protocol in 2009 [1]. This document is a guarantee that Kazakhstan is obligatory must diminish greenhouse emissions in the atmosphere. This document claims that during the past 15 year CO_2 has been significantly raised from almost 100 million tonnes of CO_2 to about 150 million tonnes. All necessary information provided in the figure below [1].

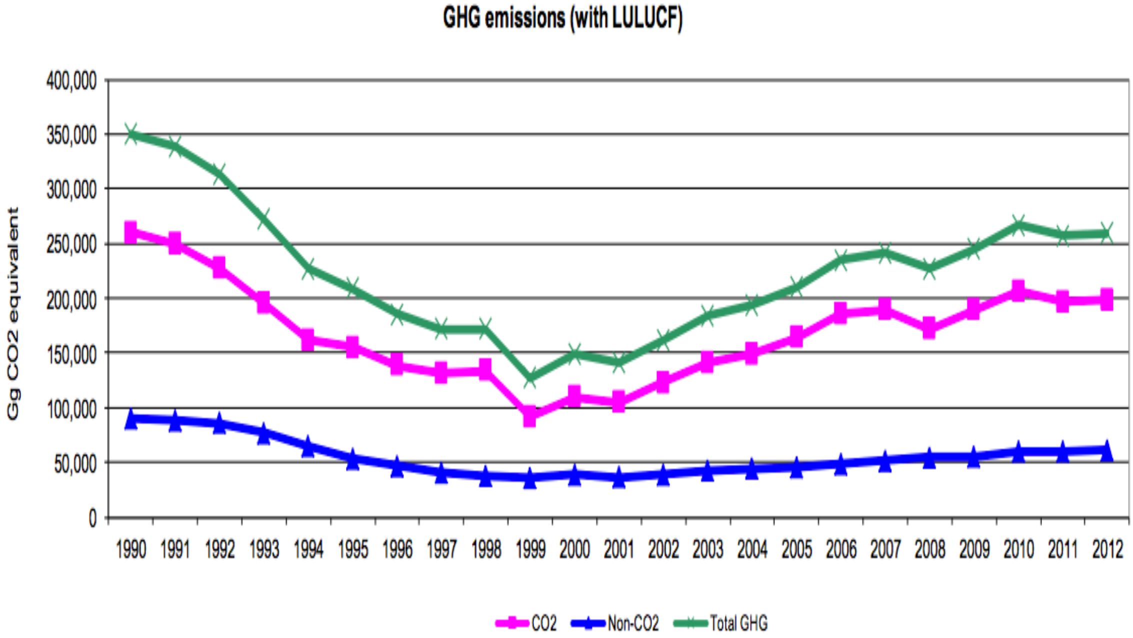

Figure 5 – Greenhouse gases emissions in Republic of Kazakhstan [12]

On the other hand, this protocol can have a positive impact – applying new technologies reduces greenhouse gases, which means a good effect than bad. So, according to this report, it can be seen that with renewables Kazakhstan can extremely decrease the level of emissions. For instance, according to researcher's predictions CO_2 gas emissions will have level off trade at about 90 million tonnes of CO_2 and will continue up to 2024 [1]. Compare to the first scenario, it means reducing emission more than double level. In the following figure gas emissions reducing forecast is illustrated.

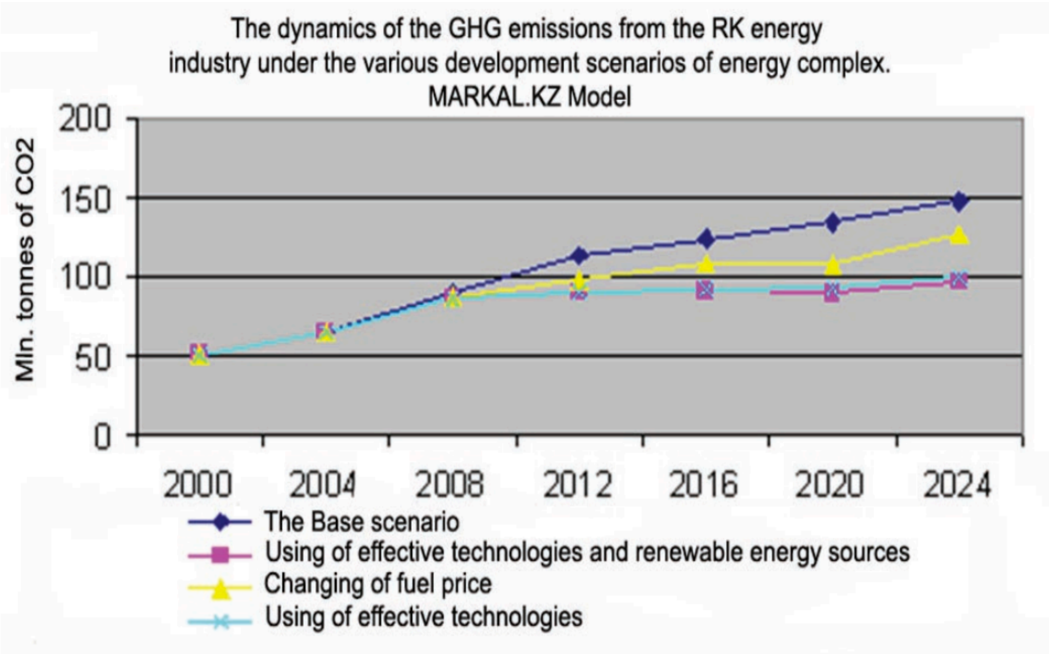

Figure 6 – Greenhouse emissions dynamic in Republic of Kazakhstan [1]

1.5 Social advantages

Wind power plants have another great benefit: increasing employment in the country. Thus, according to the International Renewable Energy Agency (IRENA) 2016 annual report, new wind power stations have created over 1 million vacancies for employers [13]. The next figure illustrates amount of created space for employers by each source of renewables.

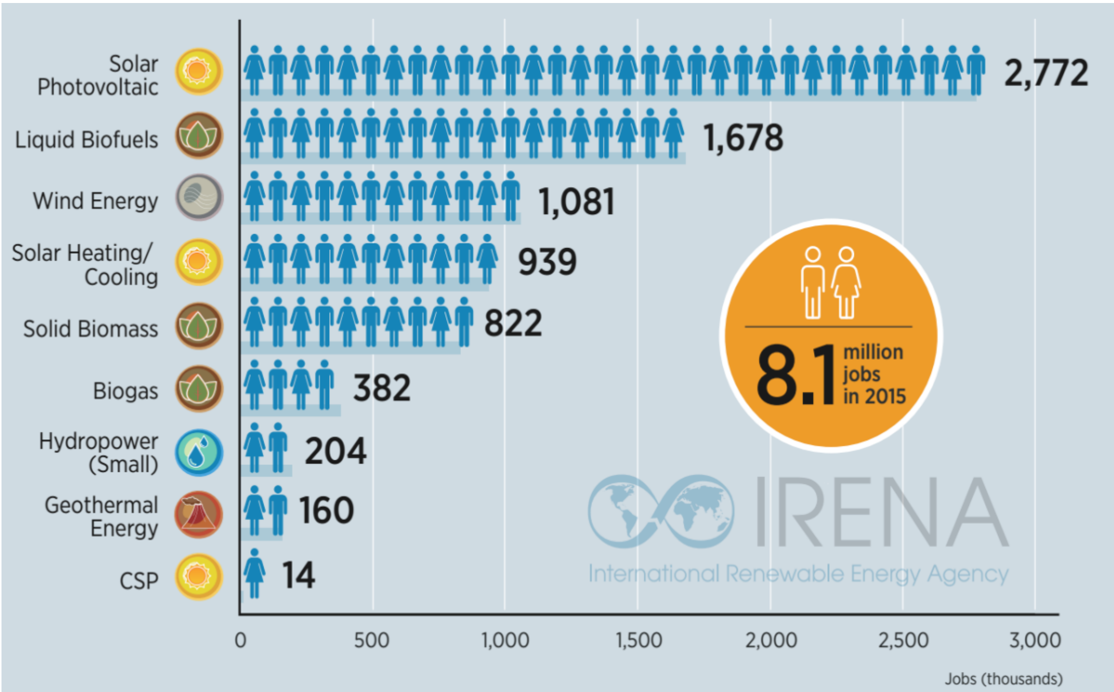

Figure 7 – New job vacations in wind industry [13]

Chapter 2

Technical background

2.1 Wind power potential calculating

In accordance with the agreements between the the Government of the South Kazakhstan region and UNDP under the UNDP Wind Energy Project meteorological mast (with maximum height of 50 m) has been established at the area near Zhuzimdik village and were made thousands measurements (with 10 minutes' gap) of wind speed and direction [4]. It should be noticed; all of those measurements were completed in agreement with international IEA/IEC standards in the field of wind speed measurements to evaluate the potential of wind energy [14], [15]. Wind speed data in the given area was measured in accodrdance with the international standarts and shown in Figure 8.

Figure 8 – Meteorogical mast [4]

Moreover, location, operation and support configurations, included in mast, are also corresponded with international standards (IEA/IEC) [4].

2.2 Meteorogical mast's data processing

According to several researches, wind speed increases with height at a certain dependence. Based on more detailed description of the calculation the extrapolation of wind speed on an approximate height of the wind turbine tower is known as a Hellman's extrapolation [14]:

$$v_{extr} = v_{nom} \cdot \left(\frac{h_{extr}}{h_{nom}}\right)^{e} \qquad \text{Equation 1}$$

where v_{nom} – initial wind speed, m/s;

v_{extr} – extrapolated wind speed, m/s;

h_{nom} – meteorogical mast height, m;

h_{extr} – extrapolated height, m.

However, there's also widely applied method which uses logarithmic law of height dependency. The formula is presented below [16].

$$v_{extr} = v_{nom} \cdot \frac{\ln(\frac{h_{extr}}{z_0})}{\ln(\frac{h_{nom}}{z_0})} \qquad \text{Equation 2}$$

where v_{nom} – initial wind speed, m/s;

v_{extr} – extrapolated wind speed, m/s;

h_{nom} – meteorogical mast height, m;

h_{extr} – extrapolated height, m.

z_0 – roughless length, m.

Roughless length assumed at 0.03 m, regarding to site spesification. In this case it is open area with rare small houses (probably). And it is the 1st roughless class [16].

For example, if mast's height is equal 51.2 meter and wind speed is approximately equal 6,739 m/s, then wind speed at 90-meter height is getting be:

$$v_{extr} = 6.74 \cdot \frac{\ln(\frac{90}{0.03})}{\ln(\frac{51.2}{0.03})} = 7.25 \ m/s$$

All extrapolated wind speeds are provided below in Table 6.

Table 6 – Extrapolated wind speed data

Metrological mast in South Kazakhstan	Average speed (51.2m), m/s	Average speed (90m), m/s
	6.74	7.25
Date and time	Average speed on 50 m, m/s	Average speed on 90 m, m/s
26.10.2006 17:40	5.41	5.82
26.10.2006 17:50	4.95	5.32
26.10.2006 18:00	6.58	7.08
26.10.2006 18:10	6.89	7.41
26.10.2006 18:20	6.66	7.16
26.10.2006 18:30	6.73	7.24
26.10.2006 18:40	7.04	7.58
26.10.2006 18:50	7.20	7.75
26.10.2006 19:00	7.90	8.50

Metrological mast in South Kazakhstan	Average speed (51.2m), m/s	Average speed (90m), m/s
	6.74	7.25
Date and time	Average speed on 50 m, m/s	Average speed on 90 m, m/s
26.10.2006 19:10	7.74	8.33
26.10.2006 19:20	7.36	7.91
26.10.2006 19:30	7.90	8.50
26.10.2006 19:40	7.98	8.58
26.10.2006 19:50	7.74	8.33
26.10.2006 20:00	8.44	9.08

As it can be seen on the Table 3, average annual wind speed at 90-meter height is about of 7.2 m/s, while at the height of 51.2 meters it just 6.7 m/s.

After similar calculations for each month separately, it is possible to make an analytical comparison of wind speed distribution by a monthly basis. Average monthly wind speeds are illustrated on the graph in Figure 9.

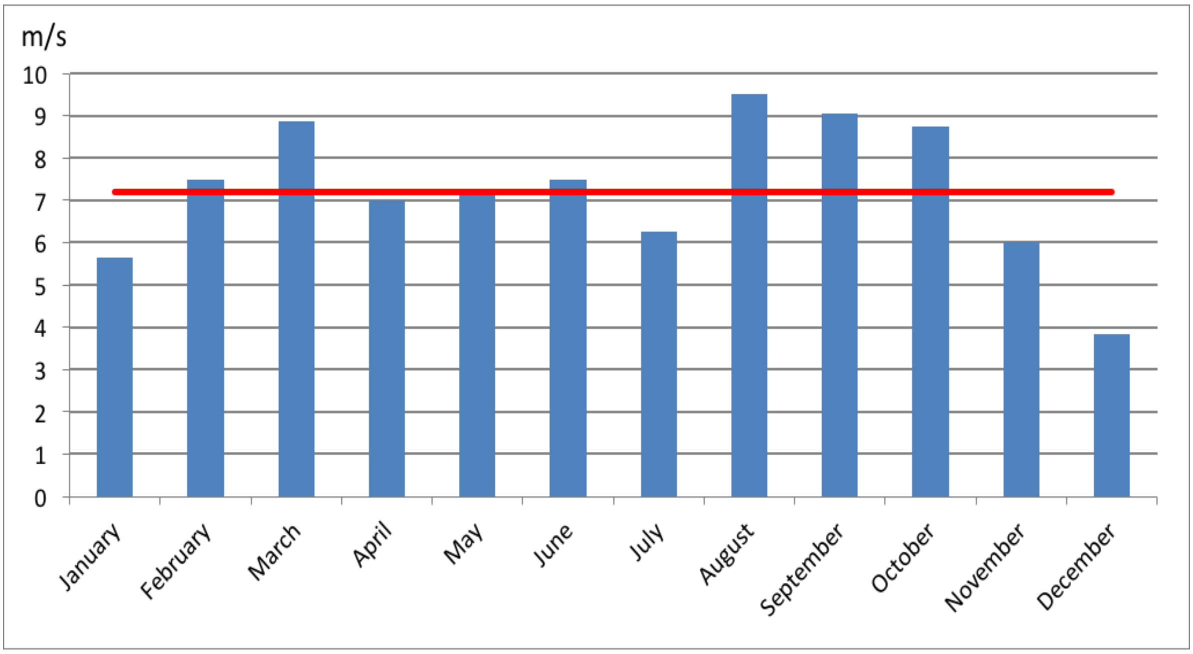

Figure 9 – Average month and annual wind speeds

It is clear, that wind speed has a good potential in this region. Despite of picks from August to October when wind speed is more than 9 m/s, monthly average wind speed does not have a big gap during the year. The minimum of wind speed – about 4 m/s, could be expected in December.

Further, wind speed data about average summer and winter and their comparison with average year wind speed were illustrated in the following figures (Figure 10 and Figure 11).

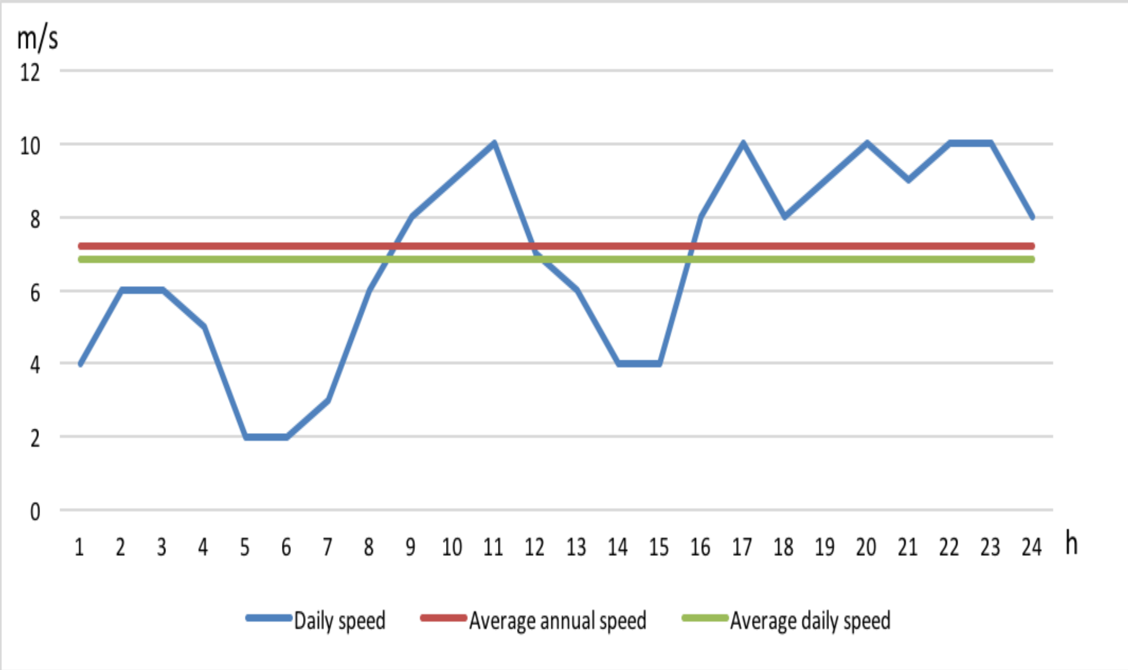

Figure 10 – Wind speed comparison in average winter day

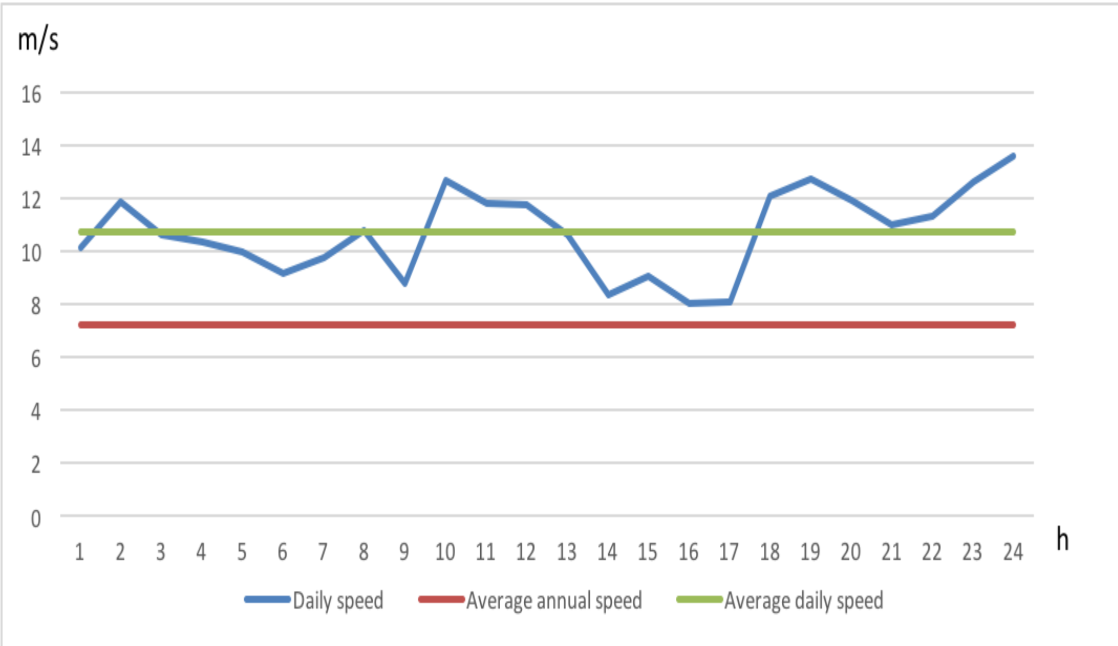

Figure 11 – Wind speed comparison in average summer day

All information given above illustrates the following: on the one hand wind speed reaches the pick and average wind about is about 10 m/s in summer, but on the other hand there are some declines in winter, nevertheless, average wind speed is more than 7 m/s.

According to researches, wind and energy distribution roses in this region looks like in Figure 12 [4].

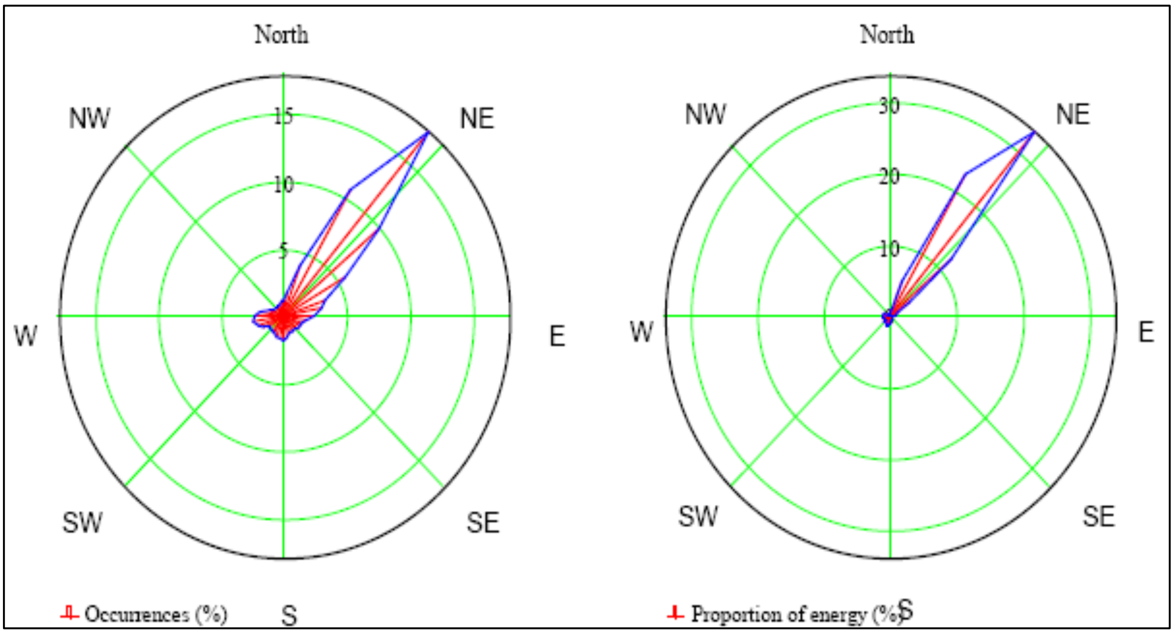

Figure 12 – Wind (on the left) and energy (on the right) distribution roses [4]

Figure 12 shows, that wind speed's direction and energy distribution are mostly from South-West to North-East as well [4].

2.3 Energy production evaluation

2.3.1 Wind turbine selection

It's clear, that turbines with bigger capacity will produce more energy. Even turbines with the same installed power have different power curves, meaning some turbines have bigger rotor diameter or generator specifics. However, the process of wind turbine selection does not regard only to power, in other words "more power" does not always mean better.

First of all, turbine should meet specific wind turbine classes conditions. Wind turbines divide on several classes and must satisfy the internatinal standards IEA/IEC [15]. So, before strating possible wind energy production and many other calculations, wind turbine's classes should be already known. Wind turbine classes and wind speed dependance are shown in the next Table.

Table 7 – IEA/IEC classes and wind speed dependence (based on report [15])

Wind turbine class		I	II	III	S
V_{ave} (m/s)		10	8.5	7.5	User defined
V_{ref} (m/s)		50	42.5	37.5	
$V_{50, gust}$ (m/s)		70	59.5	52.5	
I_{ref}	A	0.16			
	B	0.14			
	C	0.12			

According to Table 7, with the average wind speed of no more 7.5 m/s application of wind tubibes with IEC III class certification are recommended. IEC III class is considered as low speed [16].

Eventually, crucial thing gained from the table, regarding to chosen methodology, is - only IEC III turbines ared required, which means not all turbines can be used.

Moreover, wind speeds research at the supposed working place showed, that mostly wind speed ranges between 4-12 m/s. Which means to be more efficient wind turbines should have as much as lower cut on and rated power speeds.

According to reporters, TOP-5 of wind turbine producers in the world are: Vestas (Denmark), General Electric (USA), Enercon and Siemens (Germany) and Suzlon (India) [17]–[19].

However, after small research the following information was found out: Enercon and Siemens companies' turbines, especially large ones, are considered as IEC I and II class turbines, which means they are intended for high speed, more than 8.5 m/s [20].

Finally, to find out the probability to use at supposed place other turbine classes requires deeper site investigation, probably more detailed site assessment will be needed.

For now, there were assumed three different products, which requires as to class IEC III standards, as to power output (higher) and they are: Vestas V100 2MW, GE 1.7-100 and Suzlon S97.

Technical charachteristics of GE 1.7-100 wind turbine was taken from official web site and represented in the next table [6]:

Table 8 – GE 1.7-100 technical data [18]

Model	GE-1.7-100
Manufactory	General Electric
Tower height (m)	96
Rotor diameter (m)	100
Class IEC	III S
Noise level (dB(A))	Max 107

Power curve was plotted from data given in the official web site of GE company [21]. All data was represented in the following turbine.

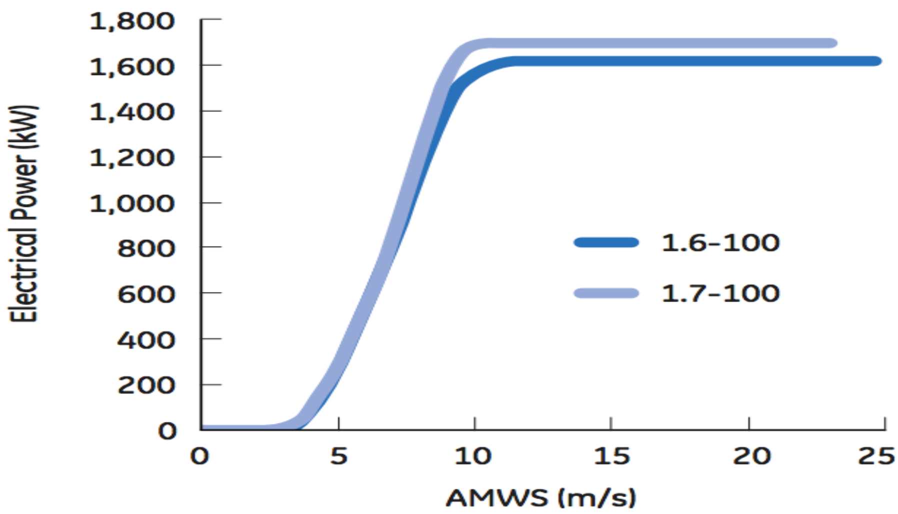

Figure 13 – GE-1.7-100 power curve [21]

Technical charachteristics of V100-2MW wind turbine of Vestas company is provided in Table 9 and power curve in Figure 15 were taken from the official web site of company[22]:

Table 9 – V100-2MW technical data [23]

Model	V100-2MW
Producer	Vestas
Tower height (m)	96
Rotor diameter (m)	100
Class IEC	III S
Noise level (dB(A))	Max 107

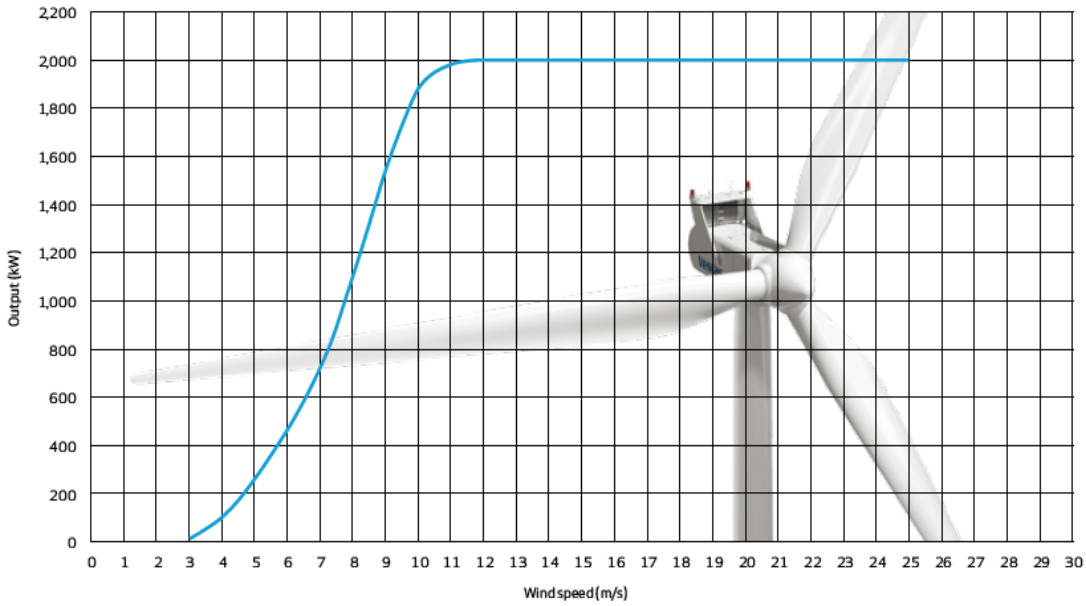

Figure 14 – V100-2MW power curve [23]

Technical charachteristics of S97-2.1 MW wind turbine, illustrated in Table 4, and power curve, showed in Figure 16, were taken from official web site [24]:

Table 10 – S97-2.1 MW wind turbine's technical data [24]

Model	S97-2.1MW
Producer	Suzlon
Tower height (m)	90
Rotor diameter (m)	82
Class IEC	III A
Noise level (dB(A))	Max 105

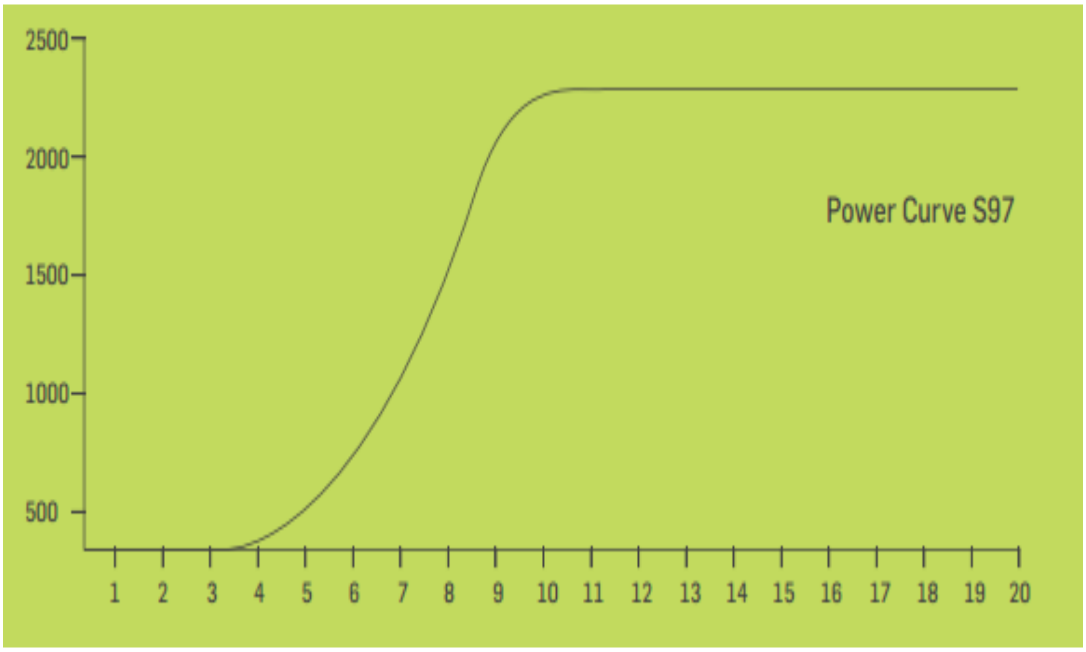

Figure 15 – S97-2.1 MW power curve [24]

2.3.2 Electricity production overview

Evaluation of wind power plant electricity generation

According to researches [25]–[30], the most correct method for wind speed records analysis is Weibull distribution. Weibull distribution made for careful model, rather than Gauss or Rayleigh models [28]. Simply, there are two types of wind power generation forecasting, which called physical and statistical. The first one: physical - means conditions, including geography position, temperature, air pressure. In spite of this types, the last one: statistical – applied for providing a correlation between wind power potential and another data, for instance wind speed [25]–[27].

However, because of a lack of information it was unable to compare data in different years. In other words, there is no many wind speed data during longer period of time. This drawback will be covered in sensitivity analysis with reducing of energy generation caused by wind speed dropping. Because, of course, there might be lower wind distribution after 5 years, for example, or it will be decreased year by year. Finally, wind power distribution fluctuations over the years will be examined in further sensitivity analysis.

Firstly, should start with big data of wind speed. According to Committee on Renewable Energy Sources of Republic Kazakhstan [6], there was taken a various number of bins of wind speed measurements in given region. After that, in MS Excel this amount of wind speed frequency was estimated relative and cumulative value by each wind speed. In the graph below there are all data provided.

Table 11 – Wind speed frequency

Wind speed, m/s	Number of bins	Relative, %	Cumulative, %
1	1005	1.47%	1.47%
2	4213	6.16%	7.63%
3	6294	9.20%	16.83%
4	6726	9.83%	26.66%
5	6580	9.62%	36.28%
6	5427	7.93%	44.22%
7	5196	7.60%	51.82%
8	5198	7.60%	59.41%
9	4989	7.29%	66.71%
10	4852	7.09%	73.80%
11	4461	6.52%	80.32%
12	3741	5.47%	85.79%
13	2832	4.14%	89.93%
14	2051	3.00%	92.93%
15	1462	2.14%	95.07%
16	1072	1.57%	96.64%
17	839	1.23%	97.86%
18	552	0.81%	98.67%
19	310	0.45%	99.12%
20	212	0.31%	99.43%
21	173	0.25%	99.69%
22	109	0.16%	99.85%
23	51	0.07%	99.92%
24	34	0.05%	99.97%
25	16	0.02%	99.99%
26	3	0.00%	100%
Overall	52474	100%	

As it can be seen at the table above, during the year most common wind speeds were from 3 up to 11 m/s. Furthermore, each of these speeds equal almost 9% of overall data.

Weibull distribution for wind speed might be represented by the following formula [29]:

$$f(v) = \frac{k}{c} \cdot (\frac{v}{c})^{k-1} \cdot \exp[-(\frac{v}{c})^{k}].$$ Equation 3

After double logarithm the equation above by graphical method of calculating Weibull parameters [14], cumulative description of Weibull distribution is getting be:

$$\ln\{-\ln[1 - F(v)]\} = k \cdot \ln(v) - k \cdot \ln C.$$ Equation 4

Where Weibull distribution is going to be a straight line, but k coefficient, called shape factor, shows declining this line [25]. After making similar calculations all number are filled up and provided in the further table.

Table 12 – Weibull distribution on graphical method

v, m/s	ln(v)	ln(-ln(F(v-v_i)))
1	0.00	-4.21
2	0.69	-2.53
3	1.10	-1.69
4	1.39	-1.17
5	1.61	-0.80
6	1.79	-0.54
7	1.95	-0.31
8	2.08	-0.10
9	2.20	0.10
10	2.30	0.29
11	2.40	0.49
12	2.48	0.67
13	2.56	0.83
14	2.64	0.97
15	2.71	1.10
16	2.77	1.22
17	2.83	1.35
18	2.89	1.46
19	2.94	1.56
20	3.00	1.64
21	3.04	1.75
22	3.09	1.87
23	3.14	1.97
24	3.18	2.10

v, m/s	ln(v)	ln(-ln(F(v-v_i)))
25	3.22	2.28
Intersection		-3.98
k		1.894
A		8.154

Let's plot a graph using the latest number and get graphical illustration.

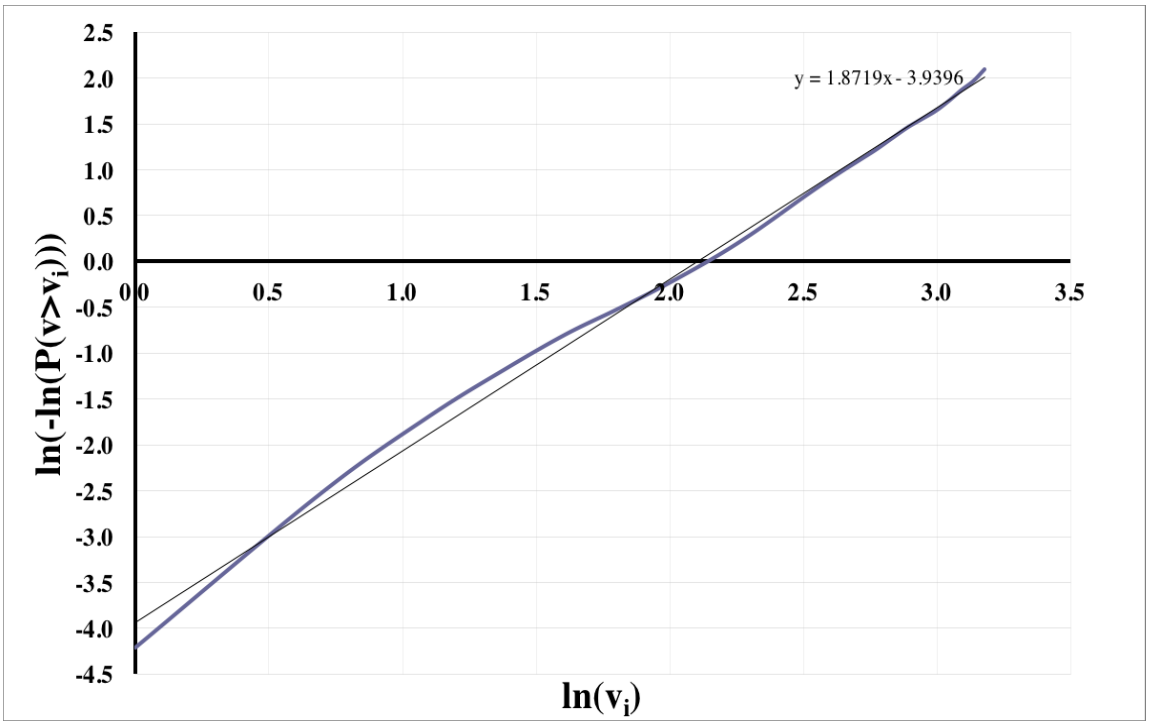

Figure 16 – Graphical illustration of Weibull distribution

Further, having the Weibull distribution's equation and data from the previous table it is necessary to just take appropriate numbers for each turbine had chosen before these calculations. Moreover, there also will be needed initial data of chosen turbines were taken from previous chapters.

Using equation 4 annual wind power distribution was obtained, thus how much energy will be generated at each speed separately can be calculated. All necessary calculations are provided in Appendix A. Further, graphical description of provided numbers is showed below.

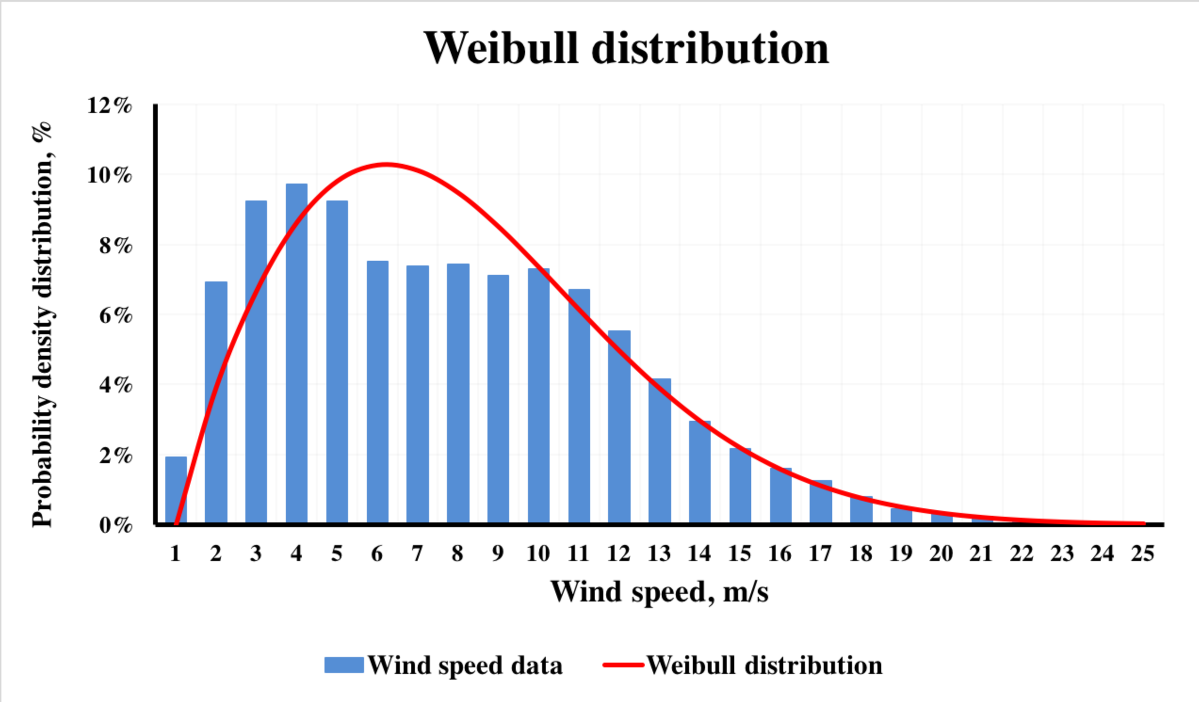

Figure 17 – Weibull distribution of wind speeds

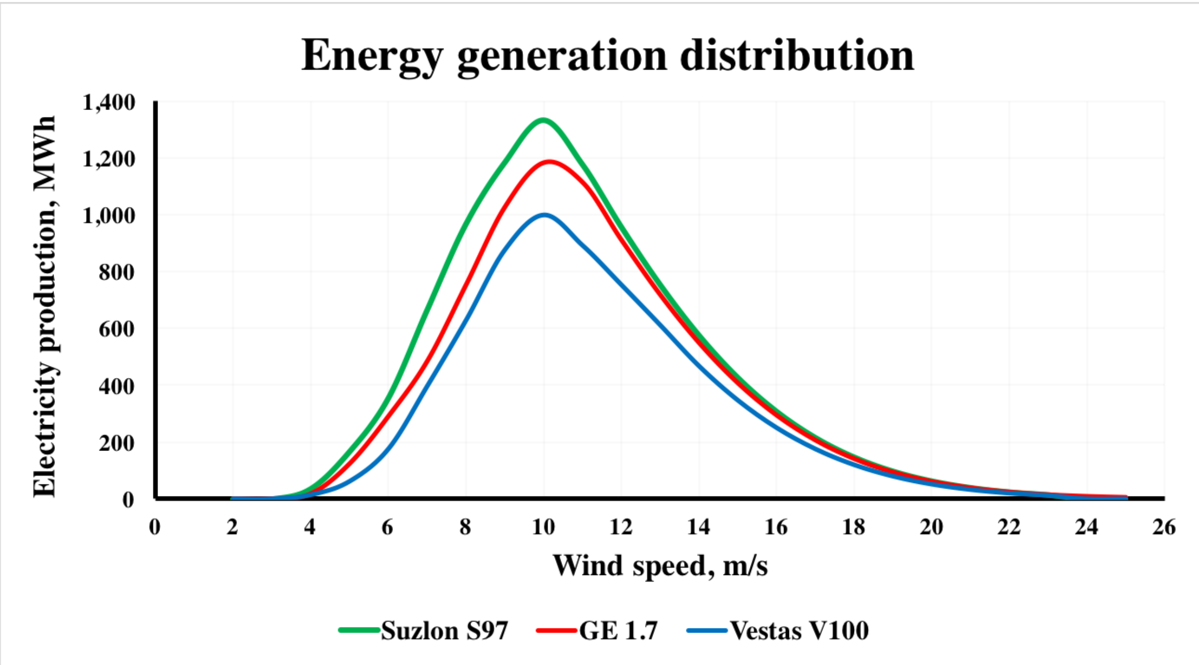

Figure 18 – Energy generation distribution

Thus, accoridng to the graph above, it is clear, that Suzlon's wind trubine will produce more energy than others. So, it seems it is a better option compared to Vestas or General Electric.

After analysing the given turbines it can be concluded, that most common wind speeds are betwen 3 and 9 m/s, but at the same time more effective wind speed are between 9 and 14 m/s with a good energy production predictions: each speed guarantee about 10-15 % of annual generation.

Before speaking about final generation result, it is necessary to describe what kind of electrcity losses were assumed. It was mentioned above, that main susbstation is located in 1-1.5 km from investigated region, which could be an advantage. Even though, some losses must be included.

According to United Nations Development Programm, different companies have been doing several assumptions regarding to wind energy development. Hence, Australian company "PB Power" calculated their expectations about electricity losses in potential wind power plants (several regions). Moreveover, several projects which works nowadays in Kazakhstan used their assumptions. Thus, based on their opinion, there was assumed the level of losses in projected wind power plant. All necessary data is presented in the table below [4], [31].

Table 13 – Losses in wind farm [30].

Item	Loss	Source
Power curve degradation	0.5 %	Opinion of "PB Power"
Turbine shutdown hysteresis	Minimum impact	Opinion of "PB Power"
WTG miscellaneous loss	0.5 %	Estimated by "PB Power"
On-site electrical losses	3 %	Estimated by "PB Power"
Long-term WTG availability loss	3 %	Estimated by "PB Power"
Grid outage loss	Not included	-

Further, it could be summed up, that overall losses are estimated at 7% value. However, there's no losses in grid. This drawback will covered in sesnsitivity analysis, with increasing overall losses.

Finally, available information allows to estimate power coefficient. Power coeffient is a value characterized the efficiency of your wind turbine [30]. Also, this coefficient helps with chosing amount of turbines, if value of output power is necessary for a project. All needed information about power coefficient (or Cp) is provided in the table below.

Table 14 – Power coefficient and energy producing

GE-1.7MW	Annual energy producing (including loses), MWh year	6478
	Total energy producing (including loses), MWh year	51825
	Working hours, hours	3109.8
	Power coefficient	35.5%
Vestas V010-2MW	Annual energy producing (including loses), MWh year	7885

	Total energy producing (including loses), MWh year	63082
	Working hours, hours	3242.1
	Power coefficient	37.01%
Suzlon S97-2,1MW	Annual energy producing (including loses), MWh year	8842
	Total energy producing (including loses), MWh year	70735
	Working hours, hours	3488.2
	Power coefficient	38.82%

As it can be clear from the table above, the biggest power coefficient has S97 wind turbine with about 3500 working hours per year, and, obviously, with the highest electricity generation. At the end, it means, that most effective turbine in this case is S97.

2.4 Wind power plant intergation to the grid

2.4.1 Locationg planning

As it was noted above, there is 35/10 kV substation placed near investigated region [4]. As researches from Tomsk Polytechnic University reported [32], optimized load for 35 kV high-voltage lines is about 15 MW. Concerning this information, taken Suzlon turbines with 2.1 MW power, only 8 wind turbines could be taken with the maximum capacity of 16.8 MW. Therefore, the location of wind turbines should be designed according to the standarts.

As researches reported, wind turbines should not be placed close to each other [33]. There are a lot of reasons to have a poor impact for the operation process. This study explained aerodynamic inferences [34].

According to Patel's work, the distance between wind turbines in a wind power plant must be from 8 rotor diameters up to 12 diameters [35].

However, researches from University of Aalborg, reported a new proposal where the best distance for a more productive operation is from 4 to 6 rotor diameters [36]. According to this data, it was planned to use 6 rotor diameters.

Suggested wind turbines location is illustrated in the following Figure 20.

Figure 19 – WPP locations [4].

As it can be seen from the figure above, wind power turbines will be constructed in checkboard pattern, four turbines in the first line and the other four turbines in the second one. This location was chosen according to the chapter 1.2, where energy and wind directions were described.

Chapter 3

Financial model

3.1 Theoretical background

Net present value

Net present value (NPV), as claimed in [37], is the total sum of overall future cash inflows and outflows, represented into present value. Moreover, all cash flows must be discounted at some discount rate, corresponded to the project. The following expression shows how NPV is getting on [37]:

$$NPV = -INV + \sum_{i=1}^{T} \frac{CF_i}{(1+r)^i} \quad \text{Equation 5}$$

where CF – sum of cash flow at different periods of time;

i – discount rate;

N – lifetime.

It should be noted, that CF_0, at the beginning of period, is frequently in negative form. Hence, this value is estimated as cash outflow or investments [38].

According to Oliveira and Fernandes, different energy projects have different revenue flow. For example, for wind speed distribution mainly considered as the same each year, so it means that annual revenue will remain at almost the same numbers [39]. Further, NPV formula with unified revenue showed below:

$$NPV = -INV + ACF \left[\frac{(1+r)^T - 1}{r \cdot (1+r)^T} \right] \quad \text{Equation 6}$$

where ARR – average annual revenue;

INV – initial capital cost;

N – lifetime period;

i – discount rate.

As it was mentioned by Ivo Welch, the most elementary, but the best description of NPV is: if NPV equals zero – it does not bother; if NPV is lower than zero – it must be discarded, but if NPV higher than zero – it is better to accept this project. It also called "capital budgeting rule" [40].

However, as any method NPV has some drawbacks, which related to renewables, such as wind or solar energy [39]:

1) Since it is difficult to calculate all project risks, measuring of proper number project's capital costs seems to be not an easy ask.

2) Values, like discount rate, depend on economic situation in each country, financial market actions. Nevertheless, in such project they remain constant, which of course has a bad affect.

3) Some people claim, that percentage NPV would be better that monetary.

Despite of NPV is very crucial value for evaluation, there are several values which can be also useful to see full picture.

Internal rate of return

Internal rate of return, or commonly called IRR, is one of the investment evaluation methods. This technique usually illustrates a superb insight on how project is going on [40]. IRR is a value that leads all cash flows (both inflows and outflows) to zero. In other words, Net Present Value (NPV) will be equal to zero at the discount rate equals IRR [39]. As it was explained in [38], the acceptable value of IRR is when the discount rate is lower than IRR [38]. In other words, in investment project IRR should be higher than discount rate. It also calls "Internal rate of return rule" [38].

So, as it was mentioned above IRR is a value making NPV equal zero. The next equation shows how to calculate this value:

$$NPV = -INV + \sum_{i=1}^{T} \frac{CF_i}{(1+IRR)^i} = 0 \qquad \text{Equation 7}$$

where CF – cash flows (both inflow and outflow);

INV – investments;

NPV – net present value.

According to researches, in investment projects, related to wind energy, revenue is calculated by unified expression, since expected revenue is estimated annually. So, in this kind of case for wind energy projects IRR will be calculated by the following formula [39]:

$$NPV = -INV + ACF\left[\frac{(1+IRR)^T - 1}{IRR\cdot(1+IRR)^T}\right] = 0 \qquad \text{Equation 8}$$

where IRR – internal rate of return;

ACF – annual cash flow;

INV – investments;

N – lifetime period.

Moreover, this equation can be modified [39]:

$$\left[\frac{(1+IRR)^T-1}{IRR\cdot(1+IRR)^T}\right]=\frac{INV}{ACF}=SPB \qquad \text{Equation 9}$$

where IRR – internal rate of return;

ACF – annual cash flow;

INV – investments;

SPB – Simple payback period;

N – lifetime period.

It can be clearly seen from this equation: no matter value of N, when IRR rises SPB declines. What was proved in [39] article.

However, the internal rate of return method has several disadvantages, which are showed below [39]:

1) Despite of cash flows structure, there might be several IRR values. It means that there are several solutions in one project. Finally, there is no one decent answer.

2) IRR value expects, that cash inflows and outflows might be reinvested into IRR. Compare to NPV, which doesn't have this drawback.

3) The IRR forget about the amount of investments. Small size projects could have IRR higher than projects with great investments. Again, NPV doesn't have such drawbacks.

Profitability Index

Profitability index is the value which illustrates the ratio of project's future cash flows in the present value over investments. The formula is showed below [38]:

$$PI=\frac{\sum_{i=1}^{T}DCF_i\cdot(1+r)^i}{INV} \qquad \text{Equation 10}$$

where DCF – discounted cash flow;

r – discount rate;

INV – investments;

T – lifetime period.

According to several studies, PI describes relation between Net Present Value and Investments in a monetary unit. Also it can be rewritten by the following expression [41]:

$$PI=1+\frac{NPV}{INV} \qquad \text{Equation 11}$$

where NPV – net present value;

INV – investments;

Projects with Net Present Value greater that one usually means that Profitability Index is also has a positive value. So, "the rule of profitability index" claims: if a project has profitability index higher that one, it should have a green light to be accepted, otherwise – the better way is to avoid it [40].

As it was described in some works, profitability index has some drawback, as any other methods [41]:

1) Profitability index could not give, sometimes, the correct answer, because of different types of cash flow. In other words, there might be a situation when profitable index is higher, while NPV is much lower comparing to another project. Hence, it leads to make a wrong decision when you need choose one project among three another.

Levelised Cost of Electricity

Levelised Cost of Electricity is the price that describes the ratio between expenditures (including investments, operation and maintenance costs, fuel costs) on produced electricity, including discount rate. Value of LCOE ranges due to the following factors: different sources (traditional or alternative); the location where the project is going on (in each country prices various); technology (what quality and type of technology was used) and other aspects. According to experts from IRENA, levelised cost of electricity for renewables (including wind power) can be calculated by the following formula [42]:

$$LCOE = \frac{\sum_{i=1}^{T} \frac{INV + OMC + FC}{(1+r)^i}}{\sum_{i=1}^{T} \frac{E_t}{(1+r)^i}} \qquad \text{Equation 12}$$

where INV – investment;

OMC – operation and maintenance costs;

FC – fuel costs (for wind energy ignored);

E – annual electricity producing;

r – discount rate;

T – lifetime period.

In other words, levelised cost of electricity nothing else annual total costs per generated energy. A fully described meaning of LCOE is illustrated in the figure below.

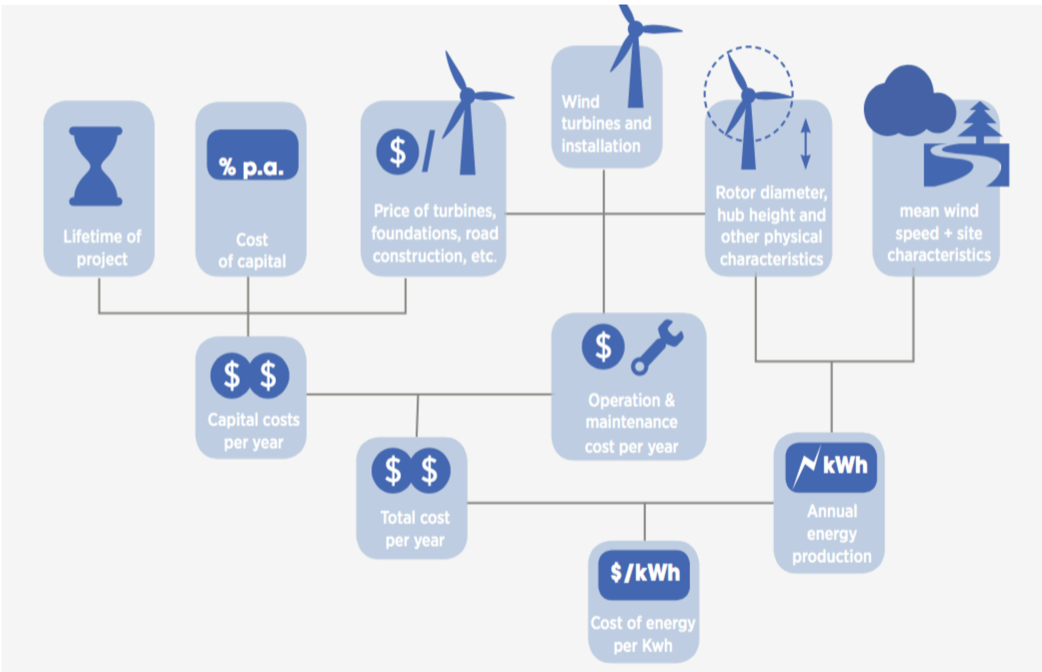

Figure 20 – Levelised cost of electricity assumption in wind energy [42]

Payback Period

Scientists in some studies demands, that in capital-budgeting methods the more "practical", rather than "theoretical" is payback rule [40]. It is also the most frequent operated technique after internal rate of return and net present value.

According to investigator, the payback rule means: if payback period is lower than stoppage period, in this case the project should be adopted, if it higher – not or if close to cut off period, it might have more projects risks [38].

As it was reported, simple payback period is the period of time which is needed to return the investments. The simple description is represented below:

$$(C_i - C_0)_1 + (C_i - C_0)_2 + \ldots + (C_i - C_0)_T = \sum_{i=1}^{T} (C_i - C_0)_t \geq C_0 \qquad \text{Equation 13}$$

where C_o – cash outflow;

C_i – cash inflow;

As it was mentioned above in renewable energy project, like wind, annual electricity production is assumed as identical from year to year. It means, that annual revenue from electricity selling will be the same. So, based on this knowledge SPB will be determined likewise in the next formula [39]:

$$SPB = \frac{INV}{ACF} \qquad \text{Equation 14}$$

where INV – investments;

ACF – annual cash flow;

Though, this method also has some drawbacks, which was described in [39]:

1) Simple Payback Period does not take into account cash flow which might be obtained after payback period in the following future and has impact for this value;

3.2 Wind power plan economic evaluation methodology

For the past 20 years' basic methodology for wind power projects evaluation almost has not been changed. Several institutions, like National Renewable Energy Laboratory (NREL) or International Energy Agency (IEA), made dozens researches on this question and the principle was almost the same.

According to International Energy Agency, main inputs and outputs were considered in this report [39]. Crucial recommendations were made and shown in the next figure.

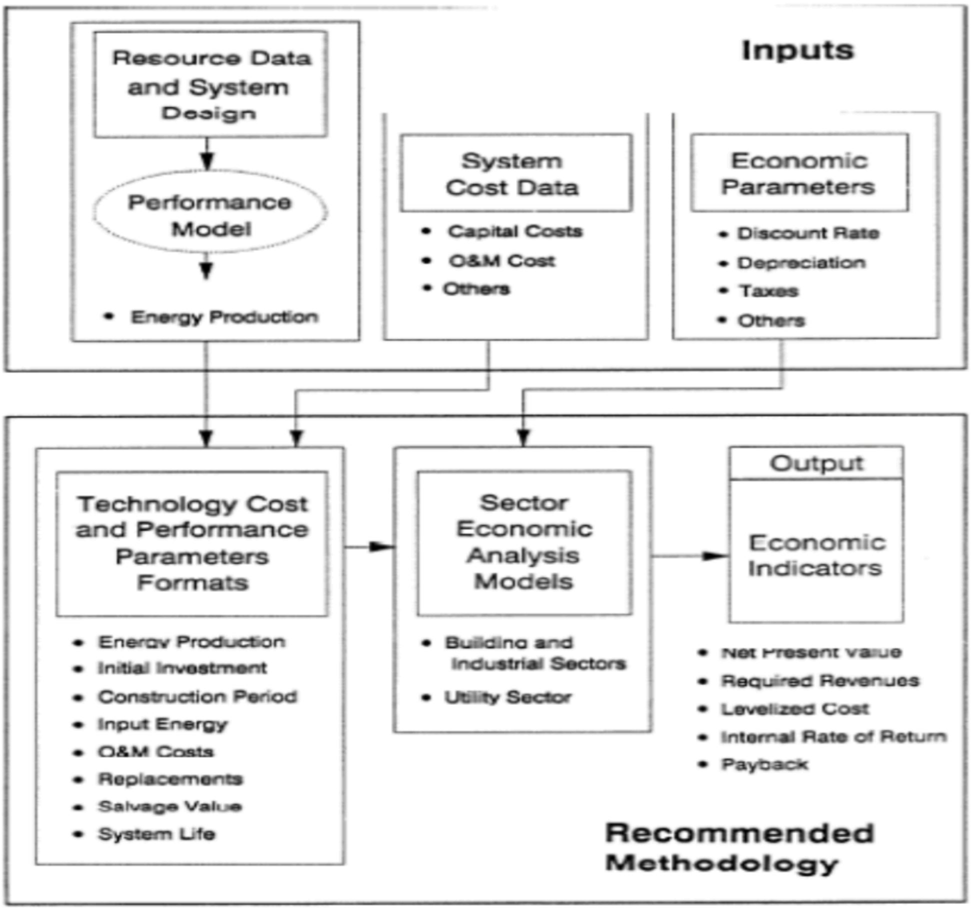

Figure 21 – Wind power plant economic evaluation methodology [39]

According to National Renewable Energy Laboratory's research, capital expenditures and operational expenditures were considered as main costs in wind power projects evaluation. Capital Expenditures, in turn, [43].

In some works, researchers based on NREL's work made a proper investigation in the wind power economic evaluation. As they claim, all cost should be classified in several groups in such projects. So they proposed to divide all costs to: investments costs, operating costs, O&M costs and financial costs [39], [44].

Experts from International Renewable Energy Agency (IRENA) pointed out that the key criteria for renewables such as wind power are: investment costs, operation and maintenance costs and cost of capital. Moreover, investment costs include any expenditures concerning to project financing, and O&M cost have two types: variable and fixed [42].

For IRENA expert's investment costs look like in the next figure.

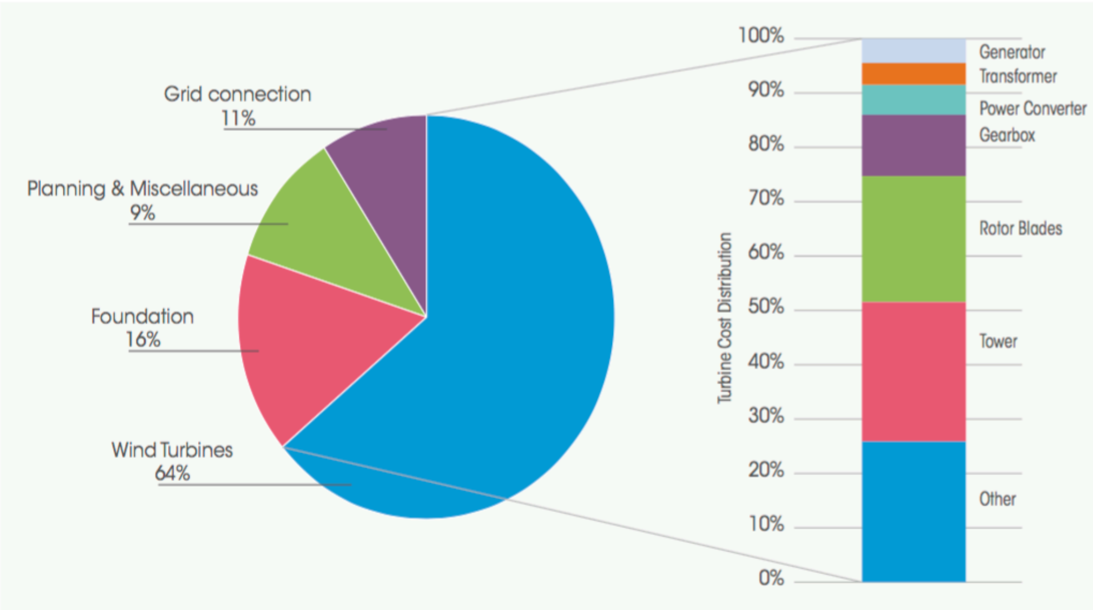

Figure 22 – Investment costs [42]

In particular, each part of given pie chart above has another parts [42]. For instance:

1) Wind turbines costs include purchasing rotor blades, nacelle, power converter, gearbox, tower, transformer (may be installed in nacelle or tower) and other parts of turbine (up to producer);
2) Planning and Miscellaneous – construction work expenses (turbine installation), for planning (including transportation, road planning) and others for future work;
3) Foundation – costs for land preparation (road design and construction) and found making (mostly from concrete);
4) Grid connection – costs for transformer substation building, connection to the grid (includes all electrical part, high voltage line construction).
5) Other – other costs appear during the project progressing.

As it was mentioned above, operation and maintenance costs might be divided into two types: fixed and variable. According to Deloitte publications, typical cost list might looks like [42], [45]:

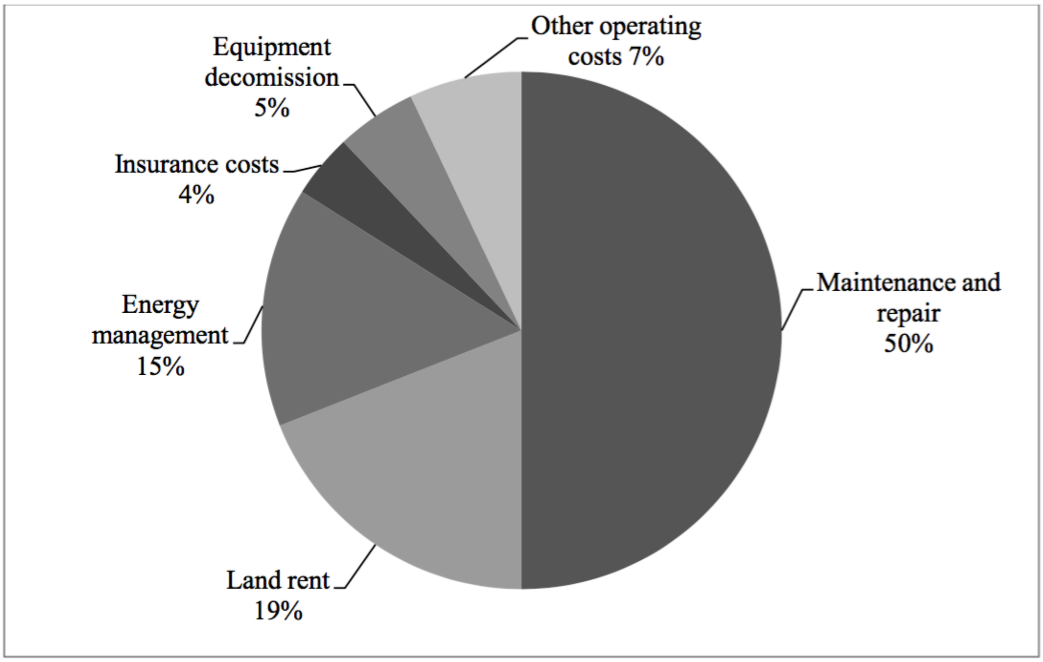

Figure 23 – Operation and maintenance costs [42]

According to the pie chart on the Figure above, the main contents in operation and maintenance cost are [42]:

1) Maintenance and repair - around 50%;
2) Land rent – 19%;
3) Energy management – 15%;
4) Insurance costs – 4%;
5) Equipment decommission – 5%;
6) Other operating costs – 7%;

Maintenance and repair, it is obviously, includes full maintenance; minor and major repairs; details replacements and repair; any details upgrade.

Land rent mostly is land leasing. It is all territory of wind farm which will be taken for the project.

Energy management, generally, could be divided into two components: technical management and commercial management. Technical management includes:

a) monitoring (including technical reports about the current situation on the site, faults, problems and their solution), management of repair works etc.;
b) environment issues (monitoring of wind farm influence on the environment, conformity to today's requirements, noise measurements);
c) Performance analysis (power efficiency data analysis, optimisation at the whole stations working process).

While, commercial management includes:

a) Business issues (control of current contracts, negotiation works, leading energy selling process);

b) Commercial issues (accounting, bookkeeping, cost estimation, optimisation, refinancing, audits, reports to banks or top management).

However, shares of this cost range significantly and in each country it ranges, it is clear. For instance, land rent might be much lower, comparing to this data, while maintenance and repair, energy management – higher, because of a lack of qualified employees, and probably external specialists will be needed. Further sensitivity analysis will show how the projects stay alive with this changes [31], [45].

Moreover, these costs might be divided on fixed and variable. For example, land rent could be assumed as fixed cost, because payment almost doesn't influence from wind power generation. As a fixed cost, also, can be considered energy management, insurance, equipment decommissions (both selects and depends on capacity). Nevertheless, there are costs, which depend on energy production, such as, maintenance and repair and other operating costs. Besides, maintenance and repair can be divided on scheduled and unscheduled, long term service repair (had to be agreed before) [43].

Risks

Experts from Deloitte in their report, which includes dozens of journals, like IEA, IRENA and etc., published the overview of general risk, occurred in wind projects [45]. Investment stage-specific risks in wind power projects are shown in the following Figure.

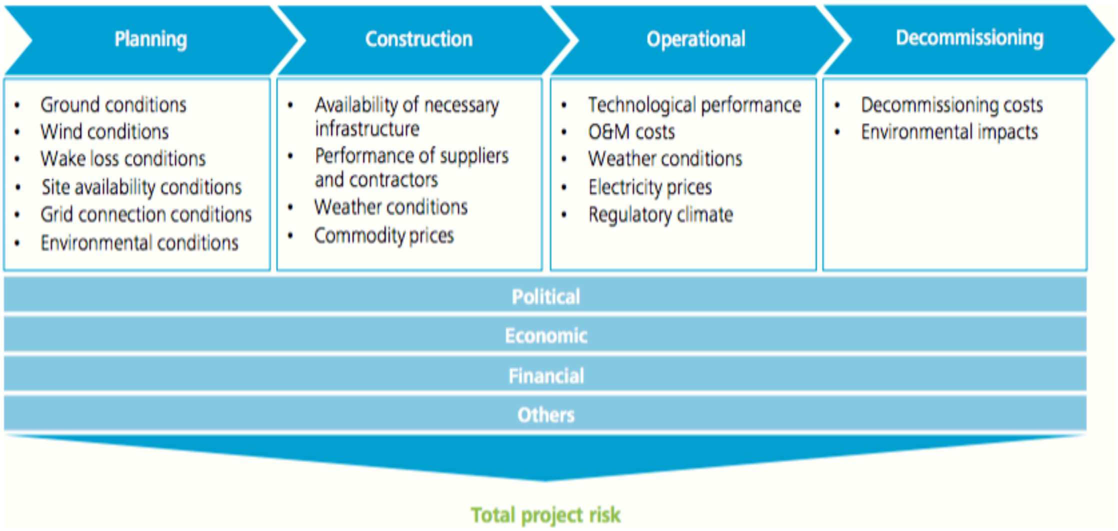

Figure 24 – Risks in wind power projects [45]

However, there is no clever understanding in each part. Therefore, experts form Deloitte explained each stage of these troubles [45]. Explanation are shown in the next Figure 25 below.

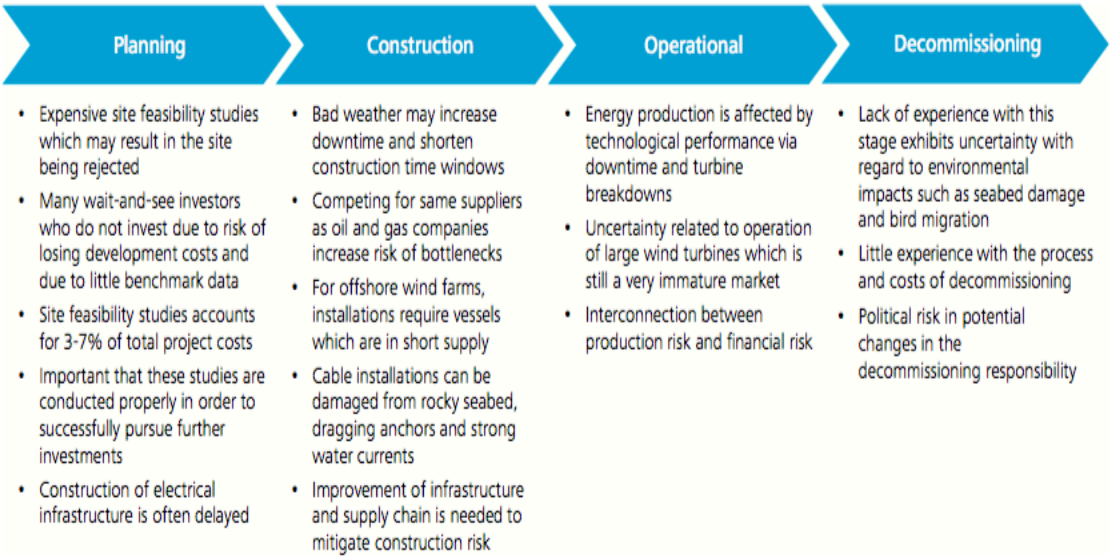

Figure 25 – Risk stages description [45]

Thus, there should not be ignored the facts that project risk uncertainties in particular area should be investigated. Some aspects from various areas, maybe, has much bigger affect. According to Deloitte's report, there is a list of uncertainties which investors could face in such projects [45].

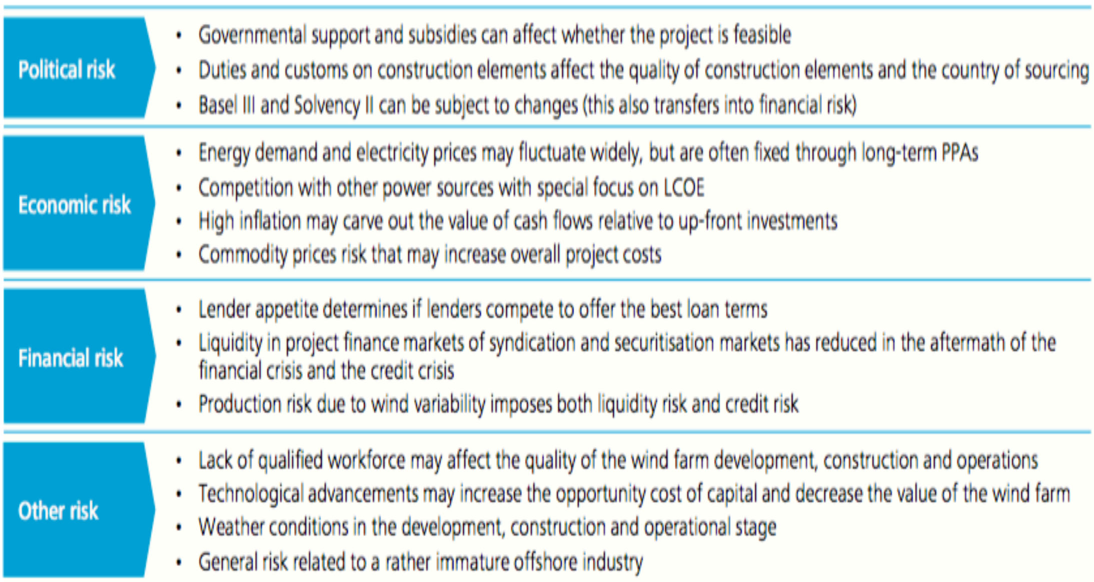

Figure 26 – List of risks [45]

3.3 Economic parameters

3.3.1 Inflation

According to the National Bank of Kazakhstan, in the Republic of Kazakhstan inflation is rising of the price for goods and services [46]. Thus, if inflation will increase during some time period, you are going to spend more money for the amount of goods or services in the past and vice-versa.

As other rates, inflation suffers from different causes. They might be as external, as internal. Experts from National Bank of Kazakhstan claims that main factors impact on the level of inflation are [46]:

Business development in the Republic. That means how domestic business is going on, how it acts in the market;

Output gap. Which means how the real number of growth domestic product (GDP) differs its potential level;

1) Employments rate;
2) Labour or working productivity;
3) Overall market competition;
4) Population's income;
5) Worldwide price in different markets and etc.

For inflation calculation they use Consumer Price Index (CPI). Consumer Price Index is a value, which indicates any price variations in stock markets [46].

Any country in the world makes an inflation targeting, as Kazakhstan does it. So, basically, targeting is an assumption of average level, taking into account government priorities, monetary policies and etc. Moreover, this calculation process demands to notice population expectations. For instance, if this expectations are high, then market will try to invest money into investment projects, financial projects and etc., however, if they are lower, then market will put money in business which does not depend on the currency value [46].

According to the National Bank of Kazakhstan, the main target for the nearest future is between 5% and 6% up to 2018 and 3% and 4% in 2020. The inflation forecast till 2018 is illustrated in the following figure [46].

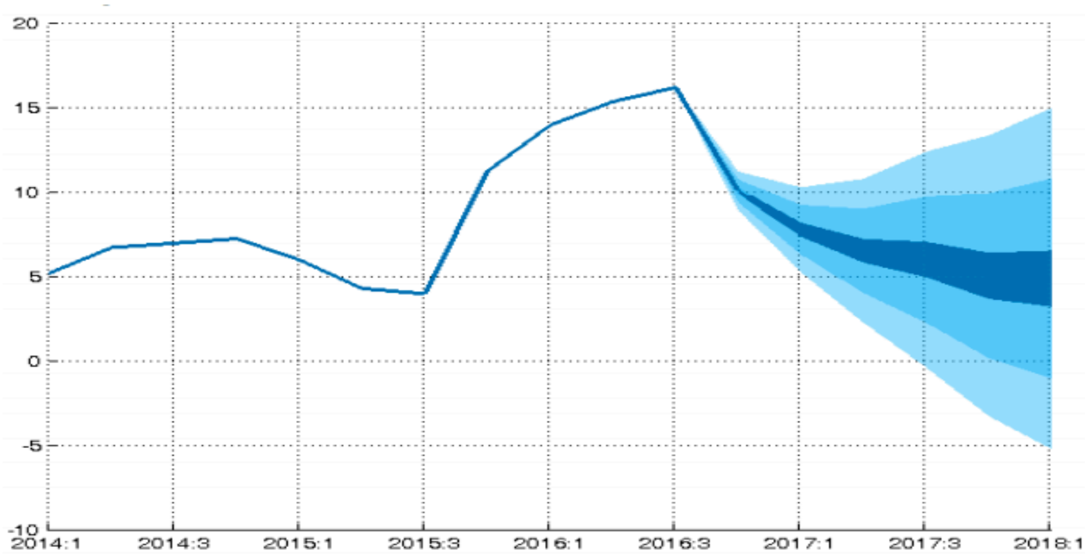

Figure 27 – Inflation forecast in Republic of Kazakhstan [46].

3.3.2 Tax shield

According to The Tax Code of the Republic of Kazakhstan, in the Republic of Kazakhstan there are different types of taxes. To make investments in such a big project, investors should know, what they can and must expect [47].

Corporate Income Tax

Corporate income tax is payment applied for payers' earned income. As The Tax Code of the Republic of Kazakhstan claims, corporate income tax payers in this case are [47]:

Resident or non-resident, legal persons of The Republic of Kazakhstan.

Moreover, non-residents should make their business through a permanent establishment of The Republic of Kazakhstan [47].

In Kazakhstan, corporate income tax (CIT), according to Kazakhstani and international researches, from 2009 to present day it equals 20%. It should be noted, that up to 2009 CIT was equal 30% [47], [48]. The following figure shows how CIT has been changing during past 15 years.

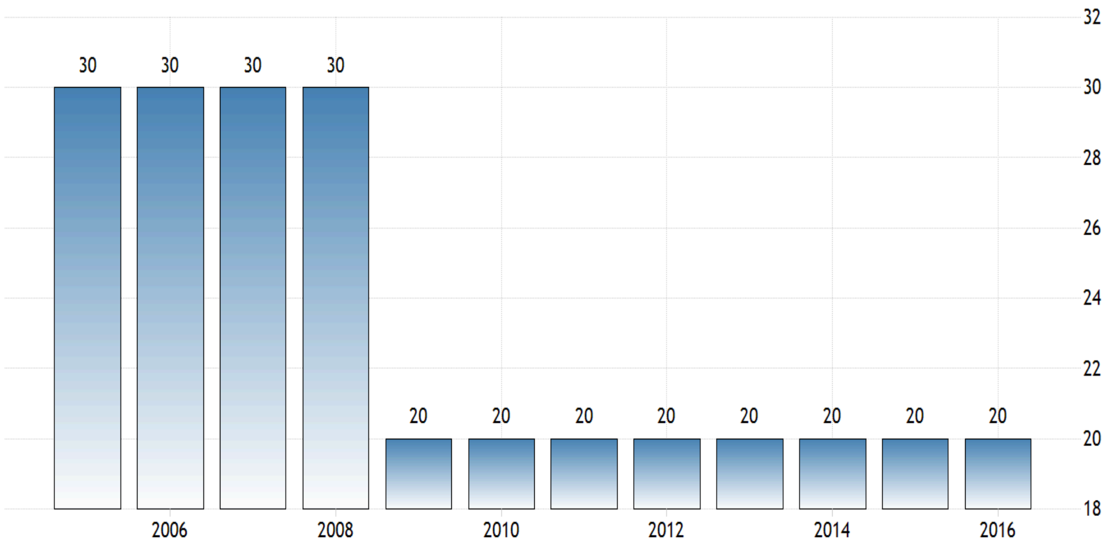

Figure 28 – Corporate income tax in Kazakhstan [48]

3.3.3 Depreciation

There are several methods of depreciation in financial management. Most common of them are:

1. Straight-Line Method;
2. Accelerated Method. Might be in various interpretation:
   a) Sum of years;
   b) Declining.

The Straight Line Method is the simplest method. This amortization method based on the basic equation:

$$D = \frac{INV}{T}$$ Equation 15

where INV – investments of each item,

T – item's lifetime.

Accelerated methods used in accounting for higher values of depreciation in the beginning of the lifetime period [51]. So, these methods had good impact on cash flow if the project would have a few amount of money in the earlier years. Double-declining depreciation method is based on the straight line depreciation, but with double declining [51]. Sum of years method based on the method with similar like double declining, but using sum of lifetime period [51].

However, selection of depreciation calculation types depends on the law and various in each country.

According to Article 120 of the Tax Code of the Republic of Kazakhstan, depreciation should not be above than given amortization rate [47].

Table 15 – Depreciation rates

№	№ of group	Description of fixed assets	Maximum rate of depreciation (%)
1	2	3	4
1.	I	Buildings, structures, except for oil, gas wells and transmission facilities	10
2.	II	Machines and equipment, except for machines and equipment for oil and gas production, and also computers and equipment for information processing	25
3.	III	Computers, software and equipment for information processing	40
4.	IV	Fixed assets not included into other groups, including oil, gas wells, transmission facilities, machines and equipment for oil and gas production	15

Based on the information described above, it can be concluded, that in the Republic of Kazakhstan accelerated depreciation is used for calculations.

3.3.4 Discount rate

Currently, there are a lot of formulas to calculate discount rate for different projects. But, most of them demand several coefficients which could not be found because of a lack of initial data and, moreover, they are could not be used for each project. In other words, even if it is the projects on the same topic, conditions could vary significantly. In that case, there is a necessity in comparison of this rate in several methodologies.

Weighted Average Cost of Capital (WACC)

Weighted Average Cost of Capital or WACC of any project, as several studies claims, it is an average rate of return of all financing types (both debt and equity). Moreover, it is evaluated by engaging on project. The formula is given below [40], [49]:

$$WACC = \frac{E}{E+D} \cdot r_e + \frac{D}{E+D} \cdot r_d \cdot (1-t)$$ Equation 16

where E – value of equity;

D – value of debt;

r_e – cost of equity;

r_d – cost of debt;

t – corporate tax rate.

Speaking more about each value of WACC, it is better to describe them, referencing to several studies.

According to one study, cost of debt, as they claim, mostly conform to funding company's interest rate. Usually, debt is: bank loan, leases, corporate warranties and etc. It is clear that, if paying company has high risk, probably has interest rate and finally projecting company has bigger cost of debt. Moreover, corporate income tax rate might be concerned and has an effect on tax contraction [50].

The same researches pointed out, that cost of equity may be acknowledged as an expected return rate of funding corporate's equity. In other word, if investors will see no return, it is obvious they will decline to purchase their shares [50].

Nevertheless, there are various methods which are applied to determine the cost of equity. Today, the most well-known methodologies are: the Capital Assets Pricing Model (CAPM) and the Build-Up Methodology [50]. Let's figure out what do they mean.

Capital Assets Pricing Model (CAPM)

Capital Assets Pricing Model or CAPM, according to Ivo Welch's work, is a model which calculates a convenient value of cost of capital, with project's risks consideration. In other words, if you know project's market beta, risk-free rate and forecasting rate of return, Capital Assets Pricing Model will give you more correct value of your project's rate of return. The following equation illustrates how to calculate it [40]:

$$r = r_f + \beta \cdot (r_m - r_f)$$ Equation 17

where r_f – risk-free rate;

β_a – market beta;

r_m – expecting rate of return.

According to Baker and Powell, managers, basically, as a risk-free rate assume the profitability on the government bonds. Moreover, to define a convenient value of the risk-free rate means the following: to estimate such risk-free rate, when the yield on state securities with a maturity duration is the same of the project's lifetime [51].

Expecting market return determining is not easier than risk-free rate, because it means that managers assessing what investors suppose that return will be, not it has been. So, as it was claimed, generally speaking, historical medium bond returns over a long period is assumed as a market return. Knowing both rates, risk-free and market risk, it is possible to solve out the market risk premium, which equals to their difference. As it was investigated, historically, average market risk premium ranges between five and six percent, but this value is not stable [51].

Project's beta shows project's return affectability on market's return fluctuations. As several studies suggested, there are some determining approaches of project's beta. One of them is calculated by changing the historical returns compared to market's returns. The second one is an estimating way of comparison of different companies. It is also called pure-play method. The meaning is to find several companies in the same business field (can be founded in Bloomberg, S&P and etc.). After that, responsible person can equate all betas and provide calculations [51].

However, to find appropriate value of, for instance, market beta is quite challenging since for countries like Kazakhstan every value changes rapidly even in each working sector. Because these values are given for the whole country, particularly in the Republic of Kazakhstan, it is too risky to use it.

Build-Up Methodology

Several publications, such as Ibboston Associates, described this approach. However, according to [50], cost of equity by this methodology equals:

$$r = r_f + r_e + r_i + r_s + r_c \qquad \text{Equation 18}$$

where r_f – risk-free rate;

r_e – equity risk premium;

r_s – company size premium;

r_i – industry risk premium;

r_c – company specific risk premium;

By this method final value gets by adding all shown risks.

Equity risk premium indicates uneasiness in dividend payments (time and amount) and in earnings received from company's bonds raising. Equity risk premium determining is a method of calculation the historical medium value of market return and risk-free rate difference [50].

As the study believes, smaller companies correlate with higher investment risks. Moreover, it would be definitely better to add company size premium risk to initial value, specifically, if the investing company is not a big corporate [50].

It is clear, that each field of business has risks, as clear that some of them has higher risks. Also, in some industries investors interest is in bigger returns. For this kind of business areas, it is more applicable to add industry risk premium to initial value [50].

Furthermore, not only project's working area has risk. There are specific risks, so called, company specific risk premium, reflect on company's uncommon aspects. They are might be fluctuating (for example depending on some causes) revenue, of course, it is connected with high risks. So, this risk adding is provide more appropriate cost of equity value [50].

Finally, all described risks were divided into two main subgroups: systematic and unsystematic. Systematic risks, also called uncontrollable, are the risks which correlating with market changes. At the same time, unsystematic risks – controllable, are identified more with company's specificities [50].

3.3.5 Escalation rates

It is clear, that different values will be changed in different ways. The same situation with this case. For example, operation and maintenance costs include specialist working hours (salary, for example), materials, repair. So, there was assumed the most common method, that prices for this case will be increased by inflation. Moreover, several projects were assumed the same indexation level [31].

Completely different situation is with electricity price. Actually, there's no chance to predict the real escalation for electricity price, however, as it was mentioned above, for green energy in the Republic of Kazakhstan there was settled a constant price for electricity by source and might be indexed. According to the law, indexation will be calculated with consumer price index, which is going to be at the level 4-5% annually, as world authorities claim [52].

3.4. Financial analysis

According to [51], most common financial analyses are:

1) Sensitivity;
2) Scenario.

Regarding to several studies, sensitivity analysis is a method shows change tendency under different variables. Meaning, sensitivity analysis answers to the questions like "what will happen, if some inputs will change?". In many cases, sensitivity analysis applies to main financial ratios, like, Net Present Value or Internal Rate of Return. The results of sensitivity analysis are useful when managers looking for influencing of project's outputs on several input variables. However, sensitivity strictly limited on market. In other words, changing the range of variables may not be useful, if the market opportunities are wider. [38], [51].

At the same time, also, one of the frequently used approaches is scenario analysis. This technique allows to see how project's outcomes change, if several assumptions will suddenly change. Therefore it shows how the project will going on if it happens [38].

However, as any method, scenario analysis has several drawbacks. As it was described, scenario analysis limited to outcomes or in other words, there's no strict description of realistic or pessimistic scenarios. Also, one of them is difficulties, meaning to estimate proper values for variables is not an easy deal [51].

Thus, based on the knowledge gained, for this project three different scenarios were assumed. They are:

1) Realistic;
2) Pessimistic;
3) Optimistic scenario;

According to study presented by researchers, realistic scenario includes expected all inputs at the expected level, so called real values [51]. In this case, as a realistic scenario the option with expect revenues, costs and some possible permissions was adopted.

Further, pessimistic scenario, as it investigated in some works, is vice-versa. This option is estimated as a worse variant. In pessimistic scenario most inputs values are at the lower level, than expected [51]. Again, this case is considered as a variant without any benefits, given by the government.

For scientists, an optimistic scenario is determined as the best option [51]. In other words, it shows the highest possible NPV. For the work it could be an option with expected revenues and costs, and all possible exemptions, benefits and permissions.

Before speaking about the results it is crucial to show what kind of benefits and permissions investors could receive in the wind energy sector, and how they would have an effect on the project (both positive or negative).

First of all, it is fixed tariff, which was described in previous chapter. Shortly, it means, that the Government obligated JSC "KEGOC" (Kazakh Electricity Grid Operating Company) to buy all clean energy, which offers to investors constant revenue.

Moreover, there's a significant governmental support for renewable energy investors. According to International Finance Corporation's recent report, there are several privileges [53]:

1) Free custom duties;
2) Government grants;
3) Tax preferences;
4) Investment subsidies.

Free custom duties are allowed for Kazakh residents carrying out transportation of main and replacement parts for whole contract, but no more than 5 years [53].

Investors could get the following grants: land, equipment, transportation means, buildings. Nevertheless, maximum value of government grants should not exceed 30% of the whole investments [53].

Further, investors with priority meaning projects may face such kinds of tax preferences [53]:

a) Reducing corporate income tax up to 100%;
b) Free property taxes;
c) Free land taxes.

Moreover, investments subsidies are given to recover construction and installation works up to 30%, without exceeding all costs [53].

Thus, investors are guaranteed with no changes with privileges described above. Guarantees are given by Legislation and the Tax Code of the Republic of Kazakhstan [53].

Finally, realistic scenario was assumed as a basic variant, what will be compared with different financing types.

3.4.1 Realistic scenario

Investment cost

Investment, or capital, cost, as was mentioned above, is a cost covers expenditures of installation process. It includes grid connection expenditures, installation, electric works and etc.

According to International Renewable Energy Agency's researchers, average capital cost is about 1500 U.S. dollar per 1 MW installed capacity. However, this value ranges significantly, which is shown in the following figure [54].

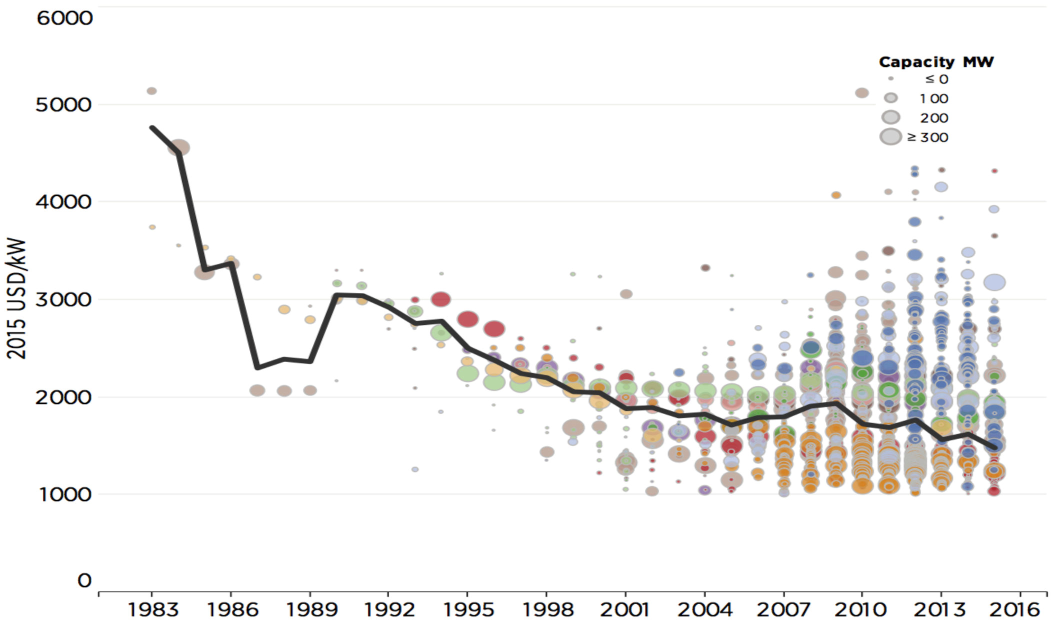

Figure 29 – Capital cost for onshore wind farms 1983-2016 [54].

As can be found out from the figure above, for a wind power plant with capacity less than 100 MW capital costs ranges between 1500 and 2500 U.S. dollars per MW. So, for this case capital cost at the level of 2150 U.S. dollar per MW was assumed.

Moreover, this value sees a decreasing tendency over the years, as experts from IRENA believe [54]. It is clear, that this factor could has an extremely high impact on the project. The tendency is represented below.

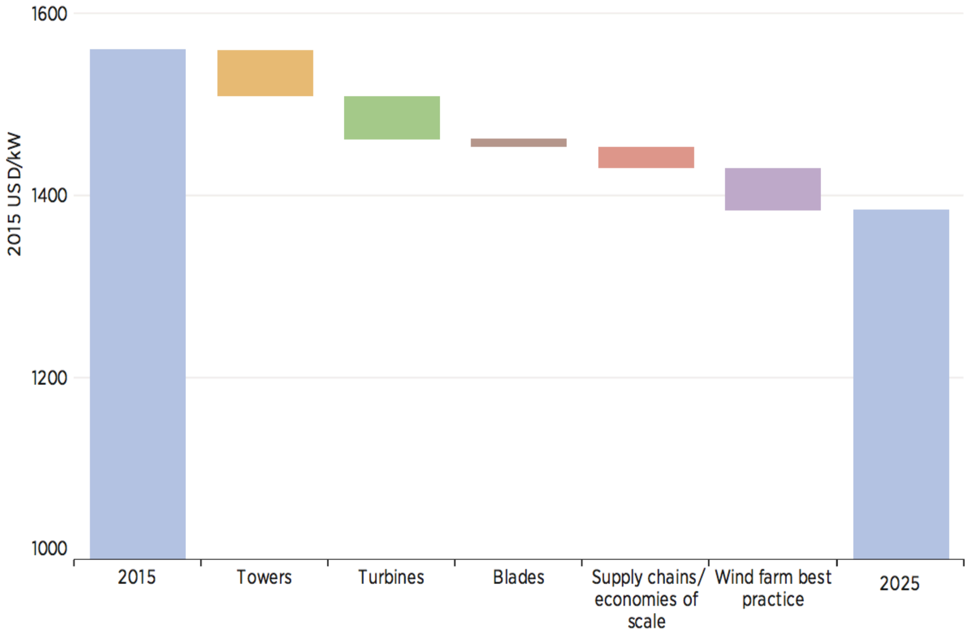

Figure 30 – Capital cost price changing tendency from 2015 till 2025 [54].

Investment cost shares of investigated project, based on information given in the previous chapters, illustrated in the next figure.

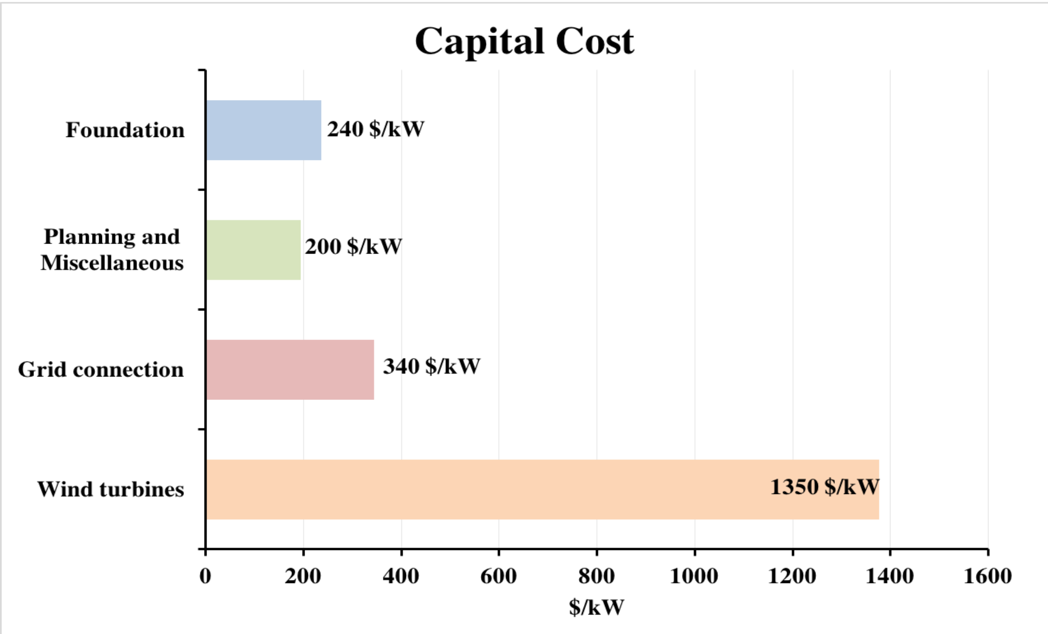

Figure 31 – Capital costs

The figure above shows prices per kW. However, as it was mentioned above, all prices differ in each country, in different times and depend on several situations. To cover this uncertainties sensitivity analysis will show how the project results suffers from capital costs increasing.

Operating and maintenance cost

Shares and what exactly include these costs were described in the previous chapters. Now, it is crucial to estimate proper value of them.

According to several publications, operation and maintenance costs have been declining over the year, as investments costs, and, moreover, they are still falling down. It was proven by recent studies and shown in next figures [55].

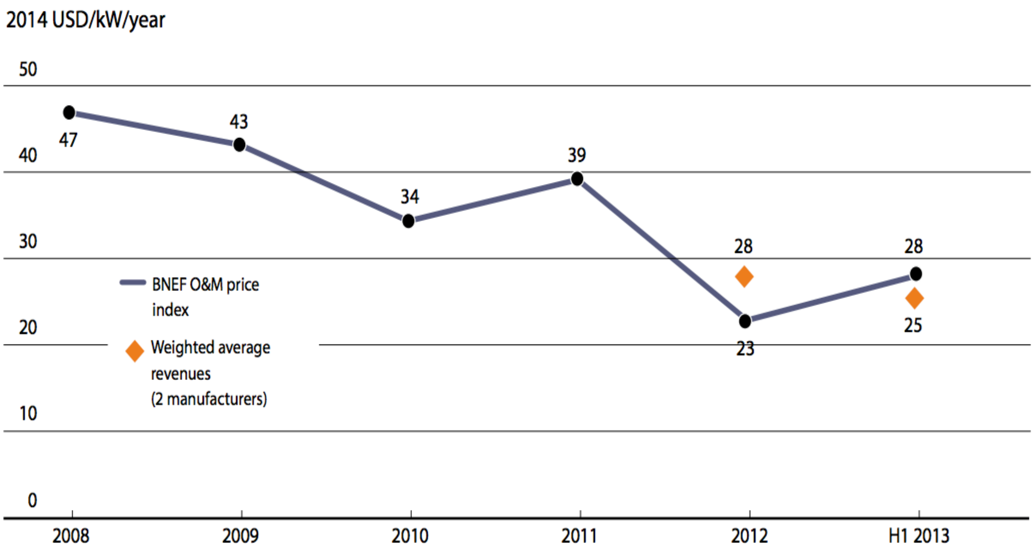

Figure 32 – O&M costs in 2008-2014 [55].

As it obviously seen from the picture, prices have fallen almost twice from 2008 to 2014. Furthermore, it has been falling next years, and according to IRENA experts, in 2016 operation and maintenance costs ranges between 0.005 and 0.025 U.S. dollars per kWh [56].

However, this prices could differ from Kazakhstan's prices, but more or less it would be the same. So, O&M costs were assumed near to the highest value of this range – 20 U.S. dollars per 1 MWh.

Based on the information provided in the previous chapters, cost shares will look as it presented in next figure.

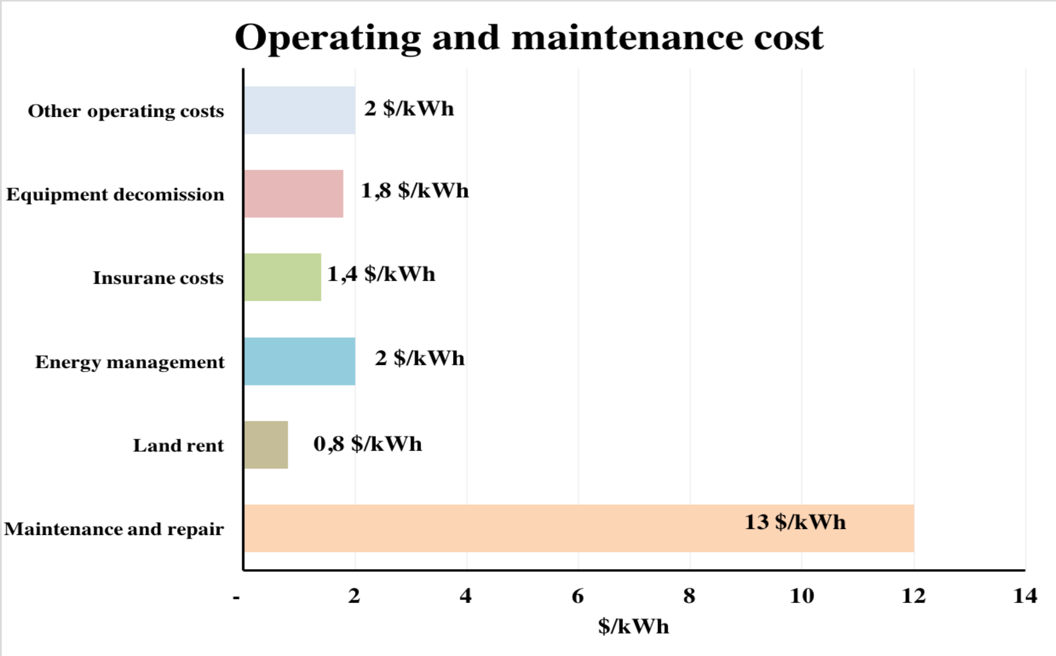

Figure 33 – O&M costs.

The figure above illustrates operation and maintenance costs in each category. As it can be seen, these ratios are matching with prices described above. However, they could differ from prices in different sources.

Revenue

Based on the research before, the expected selling price is a fixed tariff for green energy in Kazakhstan. Meaning, according to the Resolution № 645 of the Government of the Republic of Kazakhstan "About approval of the fixed tariffs" dated from 12 of June 2014 the price, the fixed price for wind energy equals 22.86 Kazakhstan Tenge per 1 kWh with indexation by inflation [7]. Moreover, electricity generation of designed wind farm equals 70.73 GWh per year. Total revenue and cost are filled in the next table.

Table 16 – Revenue and costs

Yeas	Revenue, mln dollars	Costs, mln dollars
1	5.90	1.2
2	6.19	1.27
3	6.50	1.32
4	6.83	1.37
5	7.17	1.42
6	7.53	1.73
7	7.91	1.80
8	8.30	1.87
9	8.72	1.95
10	9.15	2.02

Yeas	Revenue, mln dollars	Costs, mln dollars
11	9.61	2.11
12	10.09	2.19
13	10.60	2.28
14	11.12	2.37
15	11.68	2.46
16	12.27	2.56
17	12.88	2.66
18	13.52	2.77
19	14.20	2.88
20	14.91	3.00

Depreciation

As it was found out before, declining depreciation is used in Kazakhstan.

So, according to information taken from the Tax Code of the Republic of Kazakhstan, depreciation rate for this project's investments will equal 25%. Then, by following equation it can be calculated each depreciated year.

$$D=(\text{INV-Accumulated Depreciation})\cdot\text{Depreciation Rate} \qquad \text{Equation 19}$$

All necessary data is filled out in the following table.

Table 17 – Depreciation

Year	Depreciation, mln dollar	Balance, mln dollar	Year	Depreciation, mln dollar	Balance, mln dollar
1	9.03	27.09	11	0.51	1.53
2	6.77	20.32	12	0.38	1.14
3	5.08	15.24	13	0.29	0.86
4	3.81	11.43	14	0.21	0.64
5	2.86	8.57	15	0.16	0.48
6	2.14	6.43	16	0.12	0.36
7	1.61	4.82	17	0.09	0.27
8	1.21	3.62	18	0.07	0.20
9	0.90	2.71	19	0.05	0.15
10	0.68	2.03	20	0.15	0

Discount rate

Main types, features of discounting was investigated in previous chapters. However, meaning is the same – even if it is the best formula for calculation, it does not have any sense without risks consideration. And this is the main problem in this case.

Firstly, because of specific working sector. As it was described in the beginning of the work, renewables have the lowest shares in total power balance. Renewables is an extremely developing sector, according to the chapters above, but, they are still not fully developed in Kazakhstan, particularly. It means, that only a few amount of companies or specialists know what exactly must be considered as a potential risk, as a technology risks. Moreover, specific sector demands specific workers. According to UNDP experts, that there's lack of good specialists in renewable energy sector in Kazakhstan, which can influence the project [3].

Secondly, economic situation in Kazakhstan. In spite of The World Bank in recent "Doing Business" report placed Kazakhstan 35th place of 190 countries [57], which is a great achievement. However, many experts believe, there's some barriers, that investors can meet. One of them is corruption. Nowadays, Kazakhstan is the 131st country in world's corruption ranking, according to Transparency International [58].

Finally, there were more problems, most of them are already solved with the government help, as it was reported by UNDP specialists [3].

IEA experts investigated Kazakhstan's power market and pointed out, that discount rate is ranged between 7% and 10%, according to recent report [59]. Moreover, discount rate of one of the finished projects in Kazakhstan was settled at the value 11.5% [31]. Based on this, it was considered to use the rate, which was "really" used and worked, and finally, considered discount rate is 11.8%.

Exchange rate

It is clear, that all prices are given in the U.S dollars, but Kazakhstan power market works in national currency – Kazakhstani Tenge (KZT). So, the official exchange rate is 317.1 Kazakhstani Tenge per 1 U.S. Dollar (for early March 2017) and in falling down from January 2016 [60]. But, the forecast provided by Trading Economics experts, up to 350 KZT per 1 USD is expected in 2020 [61].

Results

As it was mentioned above, for the basic option, or realistic scenario, several financing types were adopted. They are:

1) More debt financing (20% own funds, 80% bank debt);
2) More own financing (80% own funds, 20% bank debt);
3) Equal financing (50% own funds, 50% bank debt).

Finally, by summing all assumptions and the information gained during the work the following figures are present cash flows of this project.

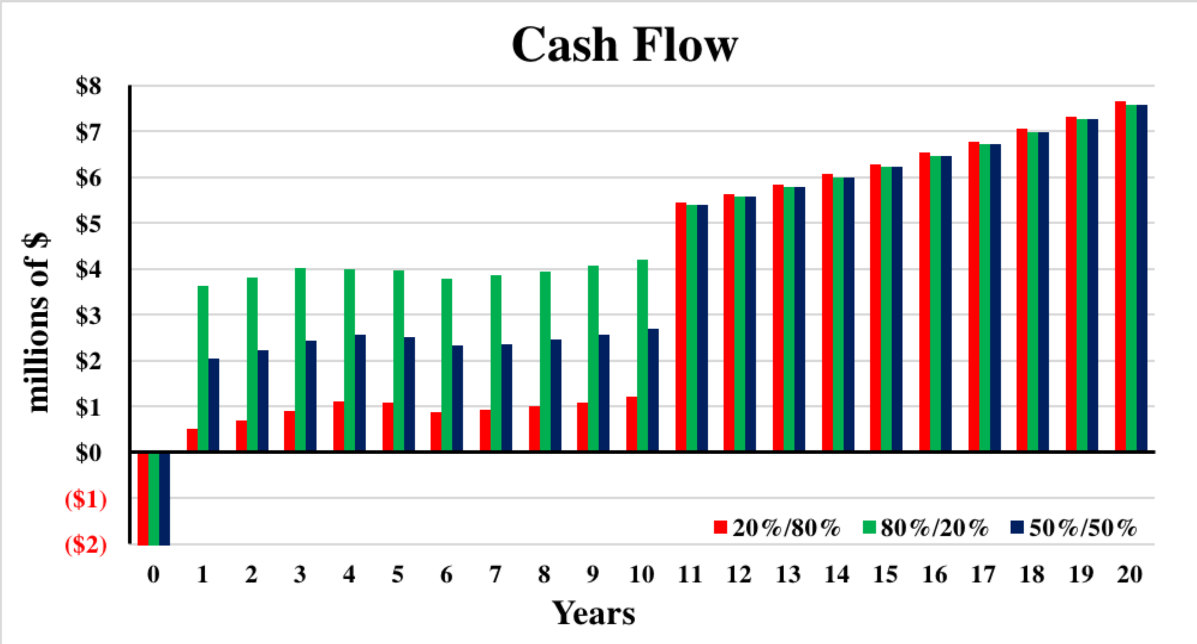

Figure 34 – Cash flow

First of all, it must be noted, debt financed case has lower amount of investments and they are: 7.224 mln $ in 20%/80% case (debt financed case), 18.06 mln $ in 50%/50% (equal amounts case) and 28.9 mln $ in 80%/20% (own money case). As it can be seen, all three cash flow have huge amount of investments in the beginning, and it is logical that the option with more own funds financing has more investments in the beginning. However, during the years' cash flows are positive. It is clear, that project with more debt financing has lower cash flow, because of the bank debt payment, nevertheless, it rises extremely after 10 years, when the bank debt will be fully paid. Moreover, slight fluctuations over the years caused by privileges and other applied benefits.

The graph below shows cumulative cash flow.

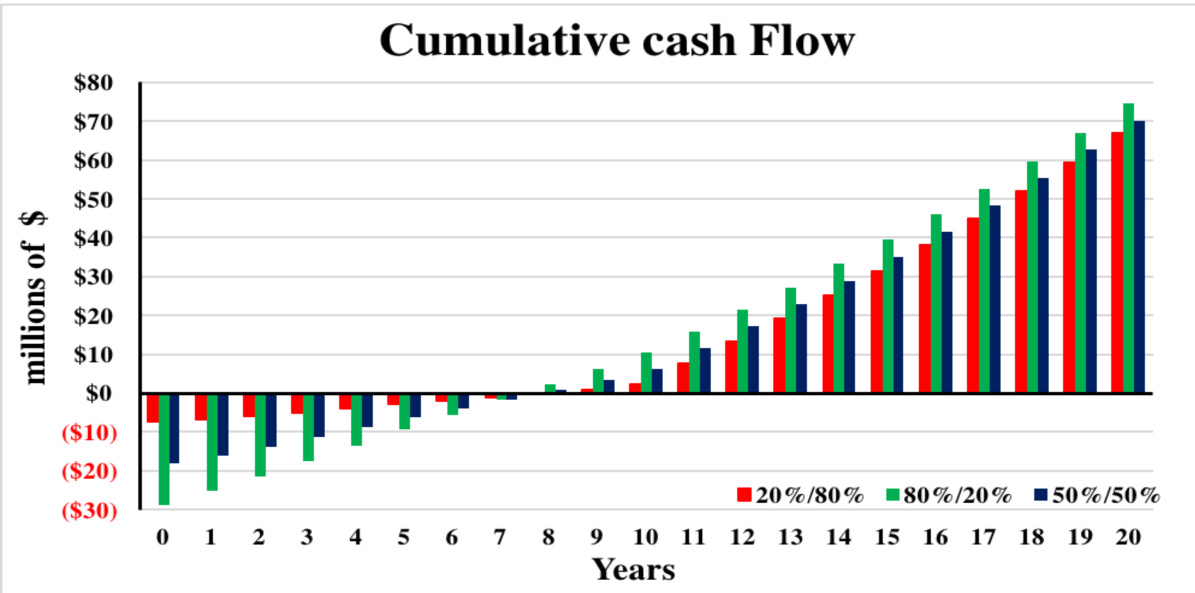

Figure 35 – Cumulative cash flow

Analogically, cumulative cash flow illustrates lower cash flows in the first years with own financing and it is starting to be positive quickly, while debt financed project has higher cash flow, but with slightly rising factor. Moreover, debt financed project has lower cash flow in the end of project, than own financed.

All cash flows for realistic scenario are presented in the Appendix B.

Further, main financial rates which describes effectiveness of the projects filled in the following tables.

Table 18 – Financial rates of realistic scenario

Name	20%/80%	80%/20%	50%/50%
NPV, mln $	9.531	4.89	7.05
IRR, %	20.88%	14,05%	16.06%
DPB, years	10.86	12,42	11.7
LCOE, $/kWh	0.065	0.075	0.07

As could be seen, in realistic expectation all project option has Net Present Value over 0, and debt financed option is most profitable with NPV slightly over 9.5 million USD and Internal Rate of Return = 20.88%. It should be pointed, that discount rate was assumed as 12%, meaning, all IRR values are over discount rate. Discounted payback period is slightly less than 11 years, which is also could be considered as a good point. Moreover, levelised cost of electricity is in a range between 0.05 – 0.12 $/kWh, according to IRENA [54].

3.4.2 Pessimistic scenario

Regarding the previous assumptions, there was decided, pessimistic scenario is a variant with no benefits, meaning, there is no permissions, privileges and any other benefits. Also, pessimistic scenario concerns fully own funding, in other words there's no external financing. However, revenue and costs are at expected value.

By summing all gained data cash flow are represented in next figures.

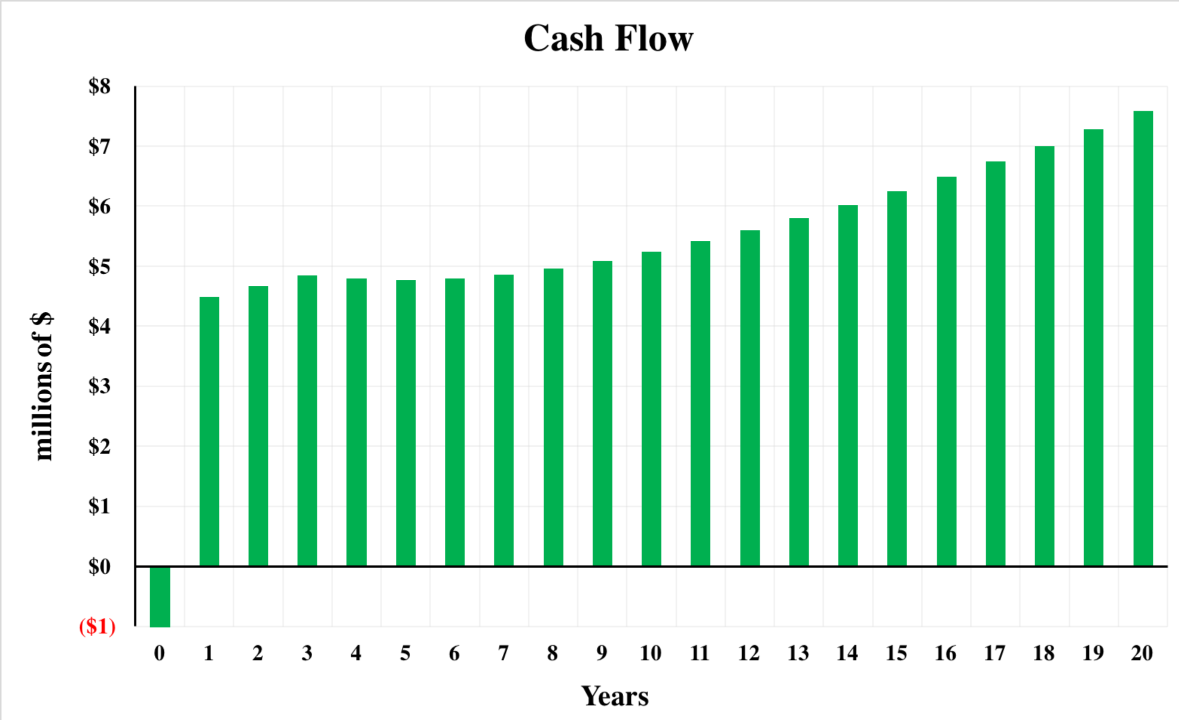

Figure 36 – Pessimistic scenario's cash flows

As it can be seen, there is slightly different picture from realistic scenario. It is a huge amount of investments and each year positive cash flows.

And cumulative cash flow in the following figure.

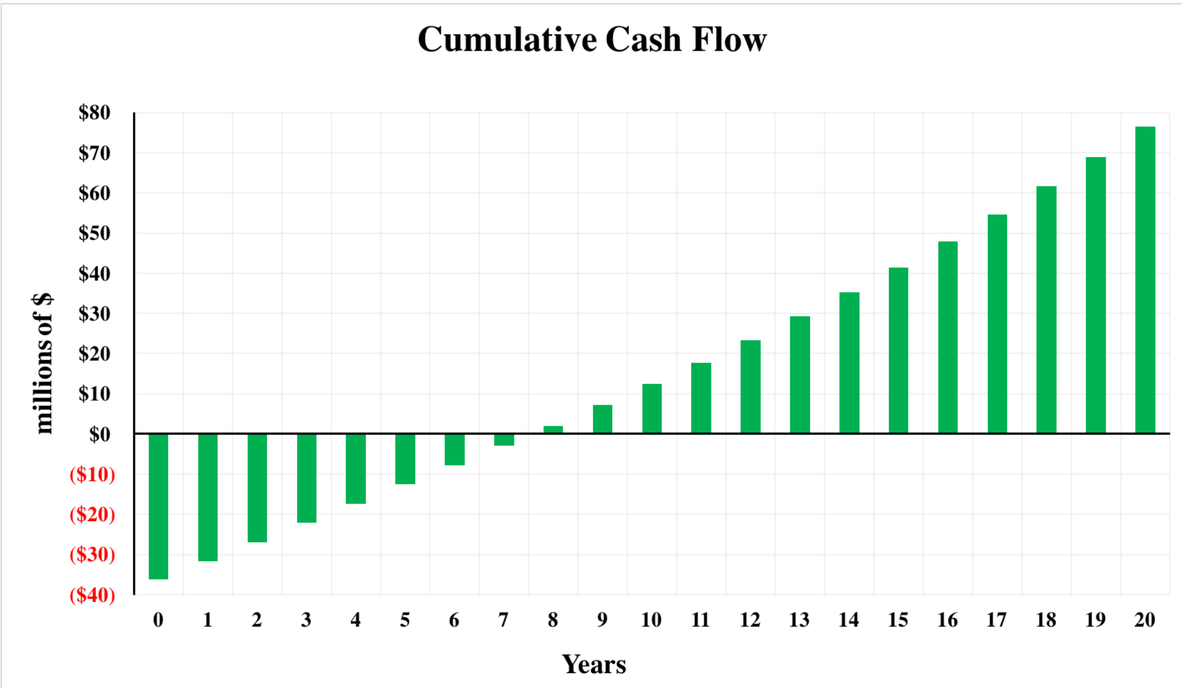

Figure 37 – Pessimistic scenario's cumulative cash flows

The figure above brings the point, that cumulative cash flow is positive in 8th year.

Further, main financial ratios in the next table.

Table 19 – Financial rates of pessimistic scenario

Name	Pessimistic scenario
NPV, mln $	2.8
IRR, %	12.9%
DPB, years	13.46
LCOE, $/kWh	0.079

Thus, according to the figures and tables described above it could be concluded, project will see NPV = slightly less 3 million U.S. dollars and Internal Rate of Return is also a bit higher that estimated discount rate – 12.9% > 12%. Even if pessimistic expectations are much lower than in realistic, they are positive and profitable, moreover, LCOE is still in pointed range.

3.4.3 Optimistic scenario

In this case, all benefits receiving, all types of financing and all privileges are expected. For example, government grant for customs costs, tax holidays, privileges for land renting and etc. In other word, positive things are at high level and negative – at low. Moreover, electricity production and costs are at estimated values.

In the same was done in previous chapters, all assumptions are taken into account. Next figures show cash flows of this way of project.

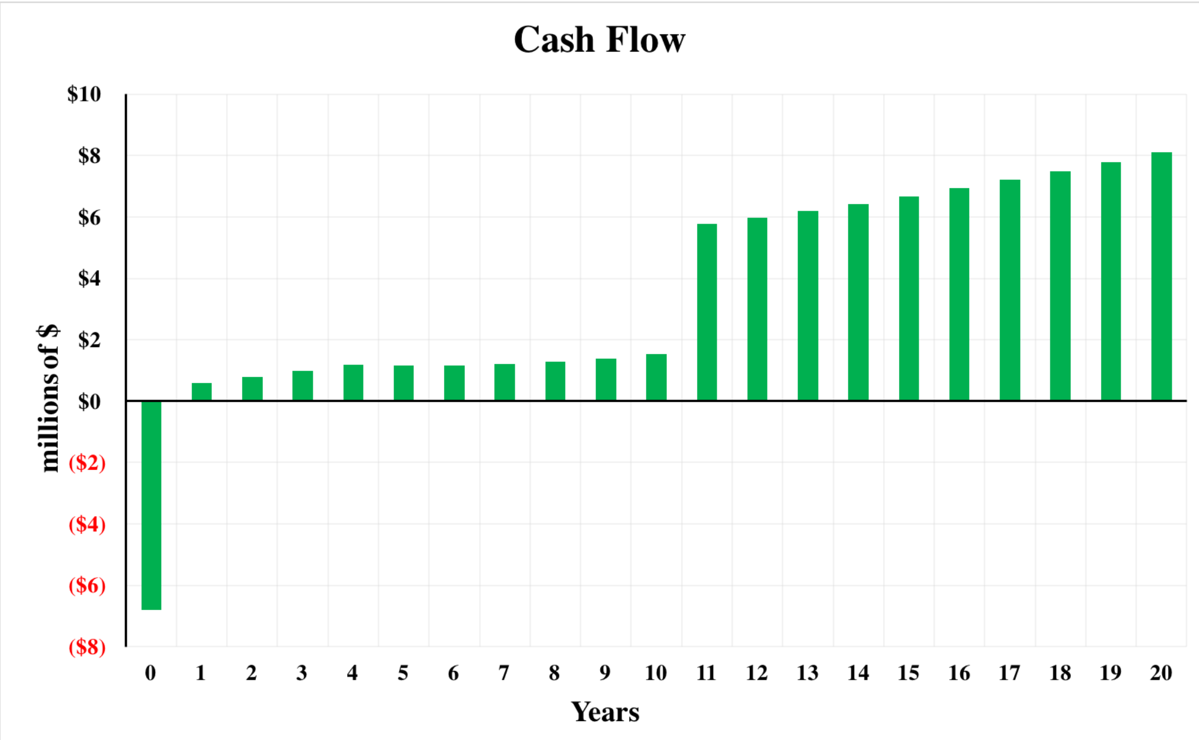

Figure 38 – Optimistic scenario's cash flows

The figure above illustrates another point of view how cash flow will be going on. There's a difference in investments, they are lower than in any case, after ten-year cash flow rises rapidly.

And cumulative cash flow in the following figure.

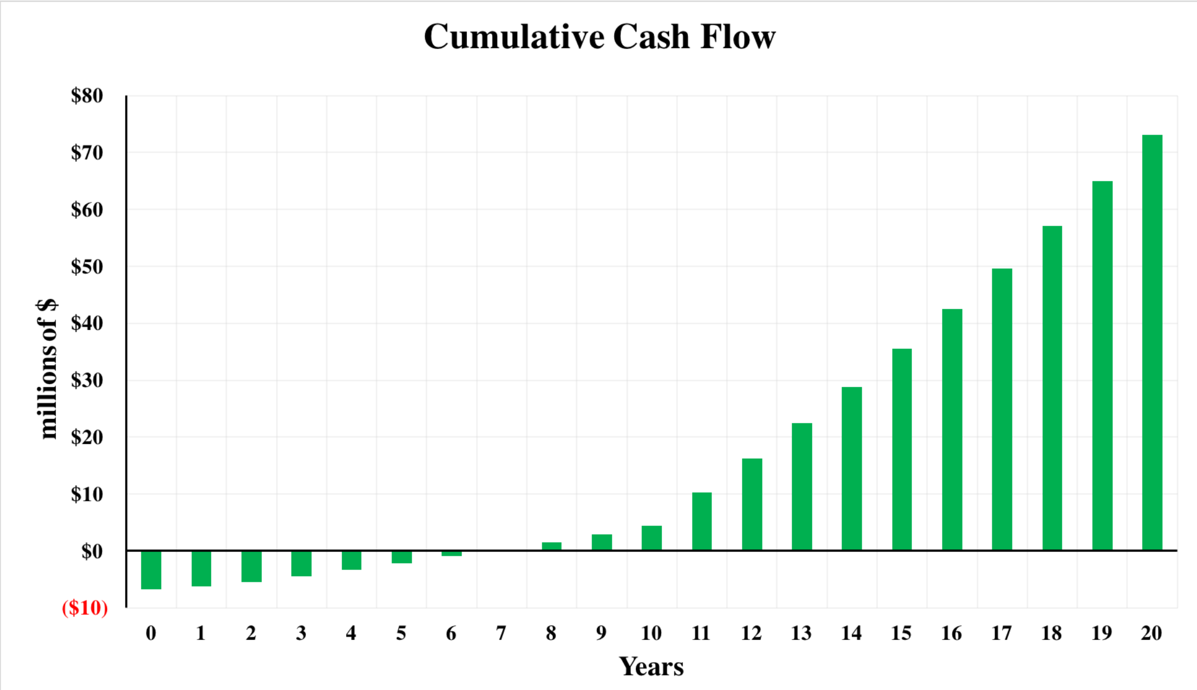

Figure 39 – Optimistic scenario's cumulative cash flows

The figure above shows, that cumulative cash flow is positive in eight years.

Further, main financial ratios are in the next table.

Table 20 – Financial rates of optimistic scenario

Name	Optimistic scenario
NPV, mln $	11.54
IRR, %	23.04%
DPB, years	10.07
LCOE, $/kWh	0.06

Thus, the figures and tables described above illustrates, that project will see NPV slightly above 11.5 million U.S. dollars and Internal Rate of Return is higher than estimated discount rate – 23.04% > 12%. Discounted payback period is 10 years and LCOE is in a bottom line of the range, which is considered as a good achievement.

Chapter 4

Sensitivity analysis

As it was mentioned above, sensitivity analysis one of the most common approaches for avoiding risks, uncertainties if some input data will change. Moreover, people could see which scenario is better in some given situations.

For this case, there was assumed to divide whole sensitivity analysis into two main parts: technical and economic data. Technical data means there are some variables in sensitivity that are going to be concerning to technical parameters, such as electricity production, electricity losses, number of turbines, capital cost, operation and maintenance price and etc. While, economic part includes economic influences on project. They are: discount rate, exchange rate (Kazakhstan Tenge to U.S. Dollar), selling price, shares of own funds and etc.

4.1 Technical parameters

Regarding to the previous assumptions and explanations, technical issues can significantly affect project results, even small uncertainties.

Firstly, one the most crucial thing influencing on the results is capital cost. Meaning, investments could have been assumed at one level, however, they might be changed with some unexpected causes. So, sensitivity on investment price is shown in the next figure.

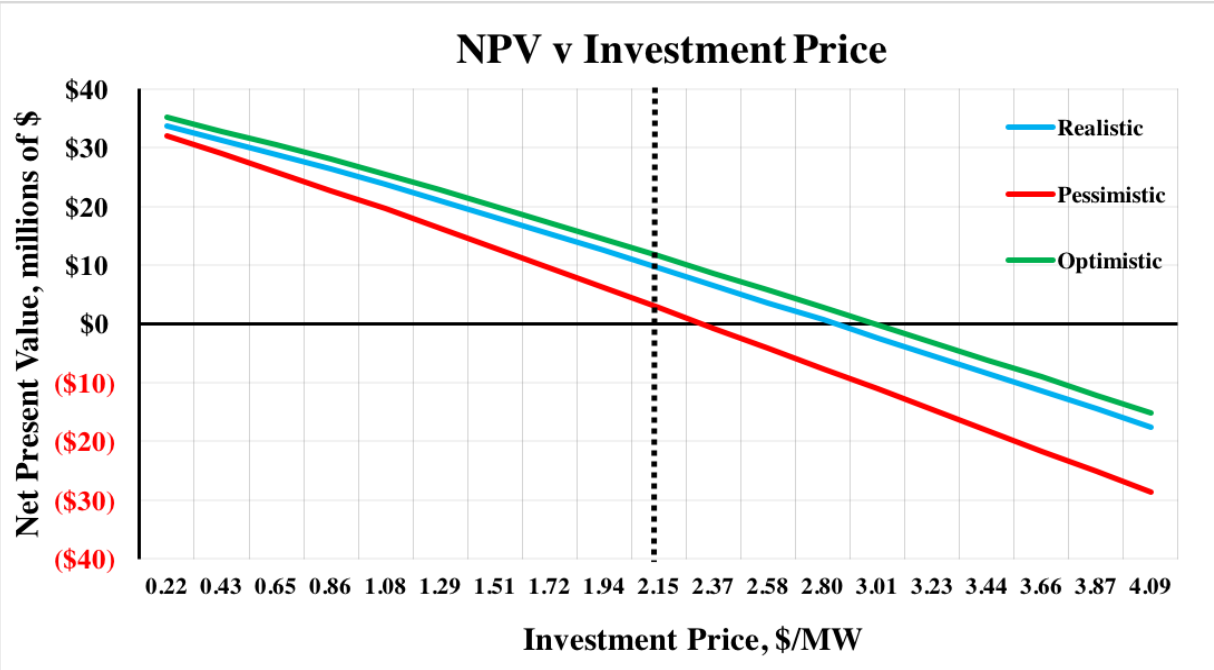

Figure 40 – NPV on investment price dependency

The figure above clearly demonstrates how the investments effects on projects net present value. As it was discussed before, expected investment cost for this project are in the range between 1.5 and 2.5 U.S. Dollars per 1 MW installed capacity, and regarding to this assumption base and optimistic scenarios are out of such risks with NPV at the level around 5 million USD at least. In other words, in realistic expectations the project is profitable if investment price is not above 3$/MW, which means increasing over 40% of initial value. While pessimistic scenario gives some troubles, if the price will be over 2.37 USD per 1 MW. Nevertheless, this graph gives more positive forecast for the project.

At the same time, operation and maintenance costs are not less vital for sensitivity investigation. This parameter is also directly concerns to technical conditions of the project. Even if expecting conditions will be more or less good, sensitivity on O&M costs is given in the next figure.

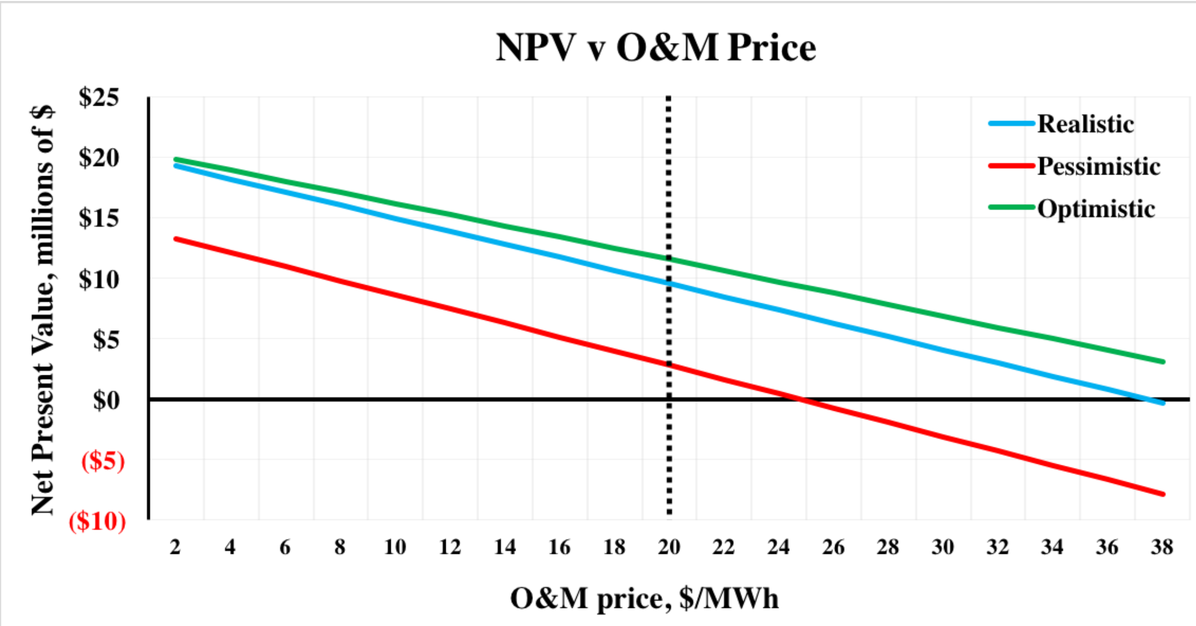

Figure 41 – NPV on O&M price dependency

Project's net present value dependency on operation and maintenance costs is shown in the picture above. According to the previous assumptions, expected O&M price is in the range between 0.005 – 0.025 USD per 1 kWh, and assumed value is 0.02 USD/kWh (or 20 USD per 1 MWh). And again, realistic and optimistic scenarios face very good results with enduring up to at least 38 USD/MWh of maximum price for maintenance respectively. However, in pessimistic case project is also in the given range with maximum price around 25 USD/MWh. To sum up, pessimistic expectations could face big troubles, if price will be over 25 USD/MWh, because increasing O&M price up to 10-20% (24 USD/MW) is quite possible in near future, however, project's realistic expectation could stay alive with 50% increasing of O&M price.

Further, electricity production was calculated regarding to wind speed records in this region. However, wind speed more or less could change and there could happen the situation when the production will drop or rocket at once. That is why sensitivity for productions is very important and presented in the next figure.

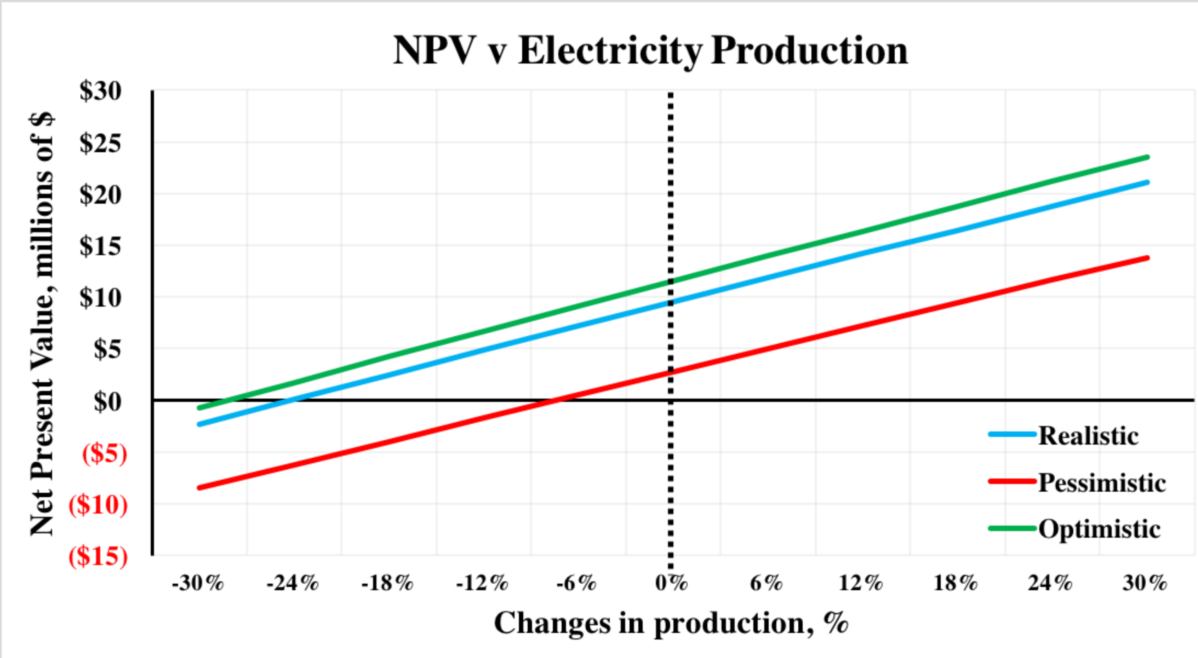

Figure 42 – NPV on electricity production dependency

The figure above shows how electricity production is increasing and decreasing up to 30%. And the picture is like: Realistic and optimistic options could suffer about 25% (24% and 28% respectively) of production declining, while pessimistic option sees a negative net present value if electricity generations falls more than around 9%. Finally, overall declining of electricity production to 6% means around 4.5 GWh annually. Meaning, it is not expecting declining more than by 10-15%, which again could face a negative NPV in pessimistic scenario.

Regarding to investigation provided in energy policy of the Republic of Kazakhstan, which was described in the previous chapters, electricity price for sold green energy are fixed and equals 22.68 KZT/kWh. But, these tariffs are limited by law and this contract can be guaranteed signed up to 15th year and then prolonged. However, there can be some problems if the law changes and investors might need to sign a new contract. If it happens and price will drop, then the results might be changed extremely. The following figure is fully describing how NPV will behave if it happens.

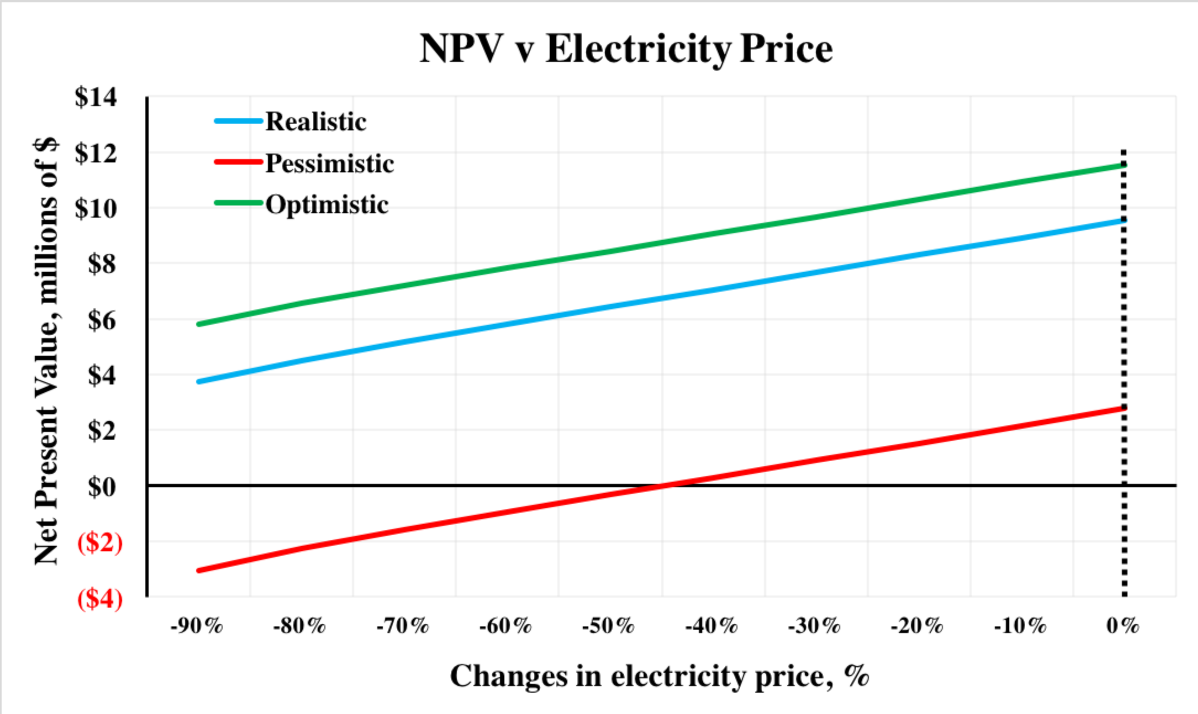

Figure 43 – NPV on electricity price changing dependency (after 15th year)

The figure above has the main idea, after 15th year the price is falling up to 90% which means a drop almost twice in NPV value for realistic and optimistic scenarios. However, in pessimistic case project could not stay alive if the tariff will be lower more than 45%.

Further, as it was described above, electricity losses could rise significantly, thus, what will happen if they will increase over the years.

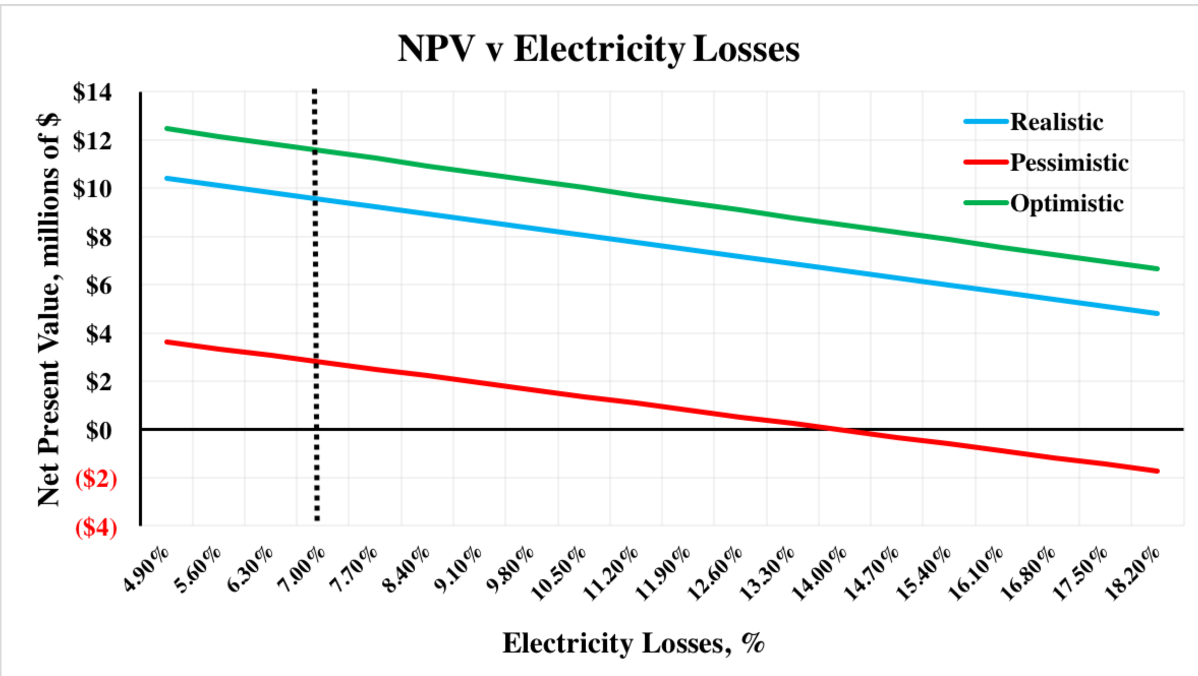

Figure 44 – NPV on electricity losses changing dependency

This figure shows, that project suffer at least 14% of total losses, which equals around 9 GWh annually. In other words, even if losses will be extremely high, project is still considered as a profitable.

4.2 Economic parameters

According to discussions before, economic influence on the project was considered as an economic parameter, meaning all economic assumptions and constants should be investigated in this sensitivity analysis.

First of all, discount rate is one the most crucial assumption. This parameter was considered regarding the economic situation in the Republic of Kazakhstan, according to several studies described above, some recent expert assumptions. However, no one knows what will happen in the future. So, based on this information sensitivity analysis on discount rate with range from 8.5% to 17.5% was prepared and provided in the next figure.

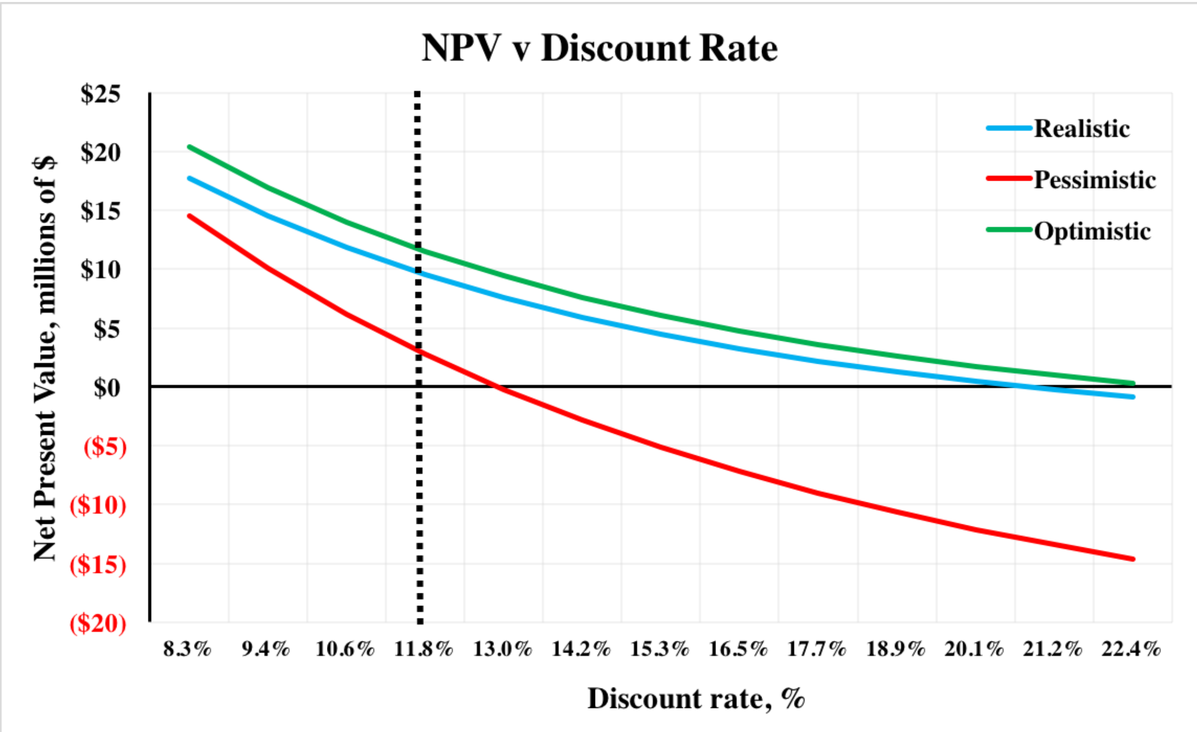

Figure 45 – NPV on discount rate dependency

This figure shows most expected range of discounts rate. As it was found out before, for Kazakhstan the engineering sector has most likely range of discount rate is between 8% and 10%, estimated value is 11.8% and considering some troubles it increases up to 20% in realistic case. The picture is following: even if discount rate rises significantly, realistic and optimistic scenarios will suffer and will be considered as a profitable project. However, pessimistic scenario gives another opportunity: up to almost 13% the project is acceptable, but no more.

Based on discussions and assumptions provided above, all prices are given in the U.S. Dollars, because all equipment is sold in the foreign currency. However, the project is going to be run in Kazakhstan, meaning exchange rate consideration is a must have option. Sensitivity on this parameter is provided in the next figure.

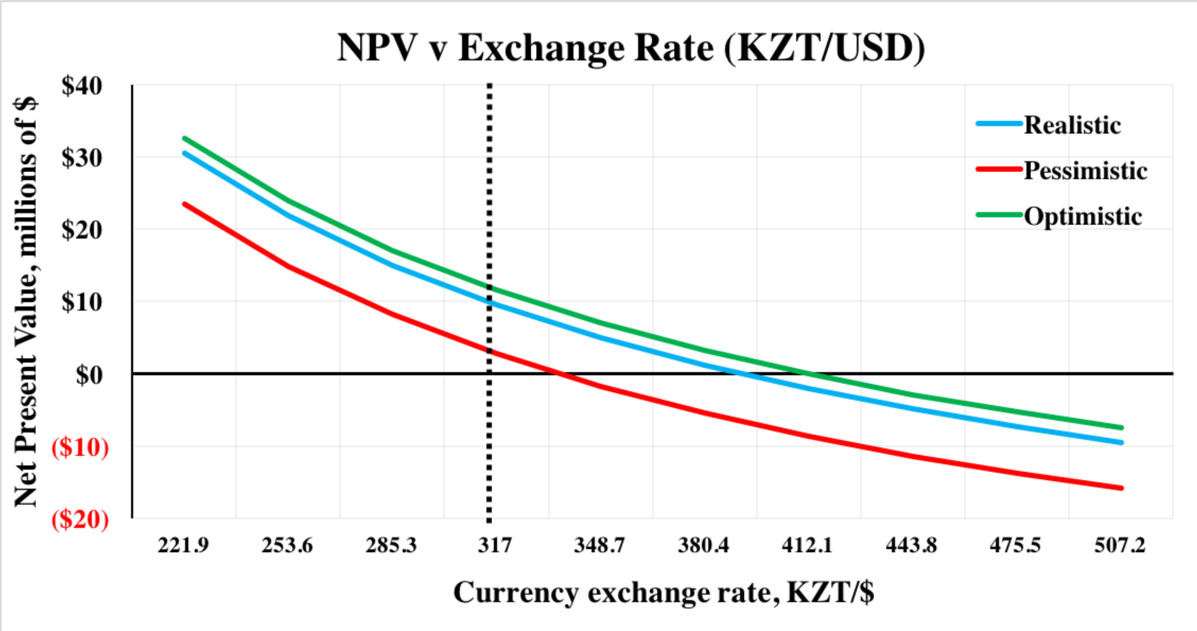

Figure 46 – NPV on exchange rate dependency

Regarding to previous discovers, exchange rate between Kazakhstani Tenge and the U.S. Dollar is 317.1 KZT/USD (for early March 2017). However, the forecast is not satisfying – around 350 KZT/USD [61]. According to the graph, in realistic and optimistic expectations project faces positive NPV and suffers up to 390 and 400 KZT/USD respectively. While pessimistic scenario gives dangerous feelings in 350 KZT/USD exchange rate project are not profitable, which could face some troubles if it happens. Nevertheless, there were a lot of negotiations about price calculations in renewables, and the future expectations is to bind up tariff to exchange rate (Euro or US Dollar), because, according to mentions above all prices are given in the foreign currency.

Finally, tornado chart, it shows how the main parameter's fluctuations influence on NPV.

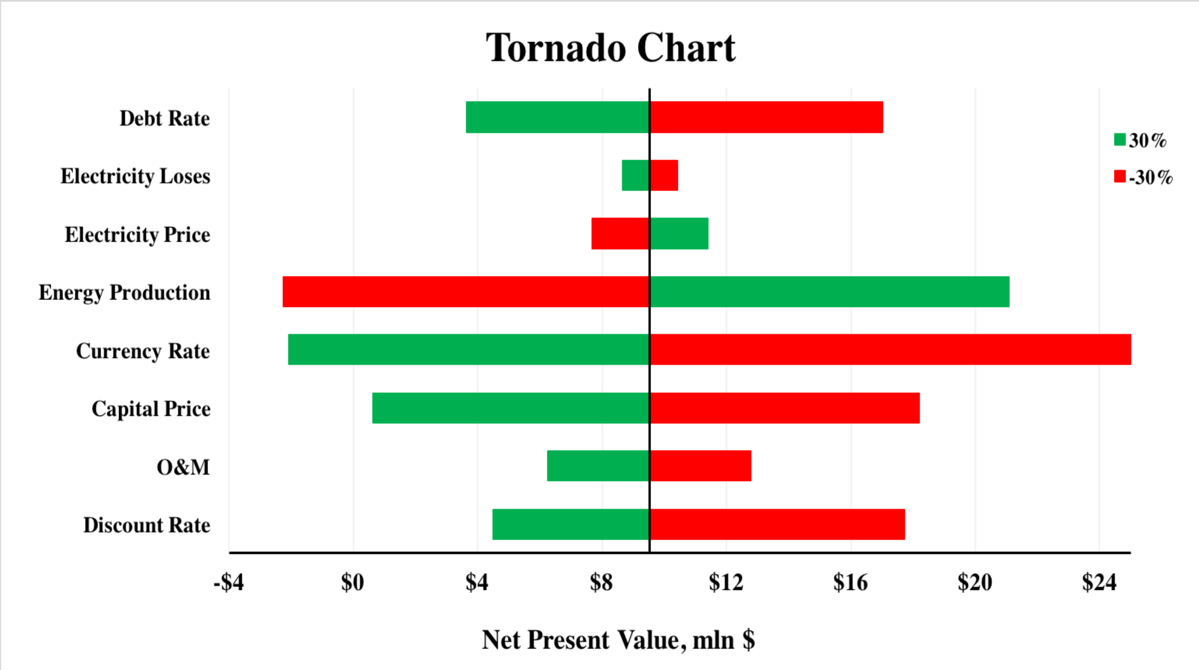

Figure 47 – Tornado chart

On the illustration above there is a chart showing what will happen if some parameters increase or decrease up to 30%. Thus it was summed up, that energy production and currency rate are influencing with the highest effect, meaning decreasing of electricity production up to 30%, or increasing USD exchange rate up to 30% will have an extremely effect on the project with NPV around -2 mln $. This point could have a strong position in decision making.

Conclusion

The initial aim of this Master's thesis was to design parallel working wind power plant in South Kazakhstan which also will satisfy economic feasibility of the project. The whole work was divided into four main chapters with several subparts in each of them.

The first chapter was devoted to benefits of wind energy resources applying. Basically, this chapter consists of wind energy resource data, potential advantages and problems solutions which could face not only investors, but the Government as well. There were mentioned crucial problems in energy sector such as current electricity and power balance in the investigated region, where a deep scarcity in energy balance is going to increase over the years. Investigated wind potential of the Republic of Kazakhstan claims that around 1TWh could potentially be generated by wind farms. Moreover, there were shed some light on vital information regarding to Kazakh's policy on renewables with law rules explanation. Current huge ecology problems and renewables impact on future ecology situation were discussed, and social aspects as well.

Further, the second part of the work was focused on technical aspects of wind farm designing. As it was discussed above wind power potential was researched, however, the main data with wind speed in the investigated region was done manually, such as wind speed extrapolation, data collection, Weibull distribution obtaining. Moreover, discussions on wind turbine selection process and their production were provided, effectiveness was obtained and compared with each other respectively. Finally, the results are following: average speed 7.25 at the height 90 meters, total energy generation around 70.7 GWh.

The aim of the third chapter was economic analysis. Precisely, the main financial indicators, their historical forecast and potential influence on the results were explained. There's also a subpart with discussion on discount rate estimation, tax code part with features in depreciation and income tax, approaches for calculation. Further, discussion on the methodology applied in wind engineering for economic evaluation was provided. It includes capital and operational and maintenance costs estimation. Furthermore, all results were broken into three different scenarios: Realistic, pessimistic and optimistic; which were based on privileges and benefits which investor could face, and finally main scenario was investigated with different types of financing. To sum up, all three scenarios have positive net present values, appropriate internal rate of return and levelised cost of electricity. In realistic expectations the project has NPV around 9.5 million dollars, IRR at 20.88%, LCOE is 0.065 USD/kWh and discounted payback period is just less 11 years.

Finally, the last fourth chapter was pointed at sensitivity analysis. Since a large number of input data was accepted and the economic state of the country was taken into account, the need for sensitivity analysis has strong reasons. This chapter also was divided into two main subchapters: technical parameters and economical parameter. The study of sensitivity of technical parameters includes possibility of decreasing electricity production, increasing electricity loses, electricity price dropping. Moreover, there are also capital and O&M prices increasing. The economical parameters part includes discount rate increasing, currency exchange rate changing and financing types.

To sum up, the project of wind power plant design has various advantages in Kazakhstan and the point of all three scenarios' positive net present values proves this statement. Moreover, investor's side will be facing different kind of helps and privileges with 100% guarantees from the Government side. Though, on the other hand, for future study it is recommended to provide more deep research on wind speed data, to obtain wind speed correlation in wider period of time. Moreover, as each project it is, there are some obstacles, such as currency rate or not so desired economic situation in country, which could make troubles for investing side. This point could significantly decrease foreign investor's interest in this kind of project, even if they look profitable in current situation.

Bibliography and references

[1] Ministry of Environment Protection, *Kazakhstan's Second National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change*. Astana, 2009.

[2] Global Carbon Atlas, "CO2 Emissions." [Online]. Available: http://www.globalcarbonatlas.org/en/CO2-emissions. [Accessed: 06-May-2017].

[3] K. Lettice, "Lessons Learnt from the UnDP-Gef Project 'Kazakhstan — Wind Power market development initiative,'" p. 59, 2011.

[4] UNDP/GEF and Government of Kazakhstan, "Prospective of Wind Power Development in Kazakhstan," Almaty, 2008.

[5] Kazakhstan Respublikasynyn Energetika Ministirligi, "Electr energiyasymen kuatynyn 2030 zhyldarga deiingi bolzhamdy tengerimin bekitu," p. 16, 2014.

[6] "The Kazakhstan Electricity Association Committee on Renewable Energy Sources." .

[7] "Postanovleniye Pravitelstva Respubliki Kazakhstan №645 'Ob utverzhdenii fiksirovannyh tarifah.'" [Online]. Available: http://adilet.zan.kz/rus/docs/P1500000148#z3.

[8] "Raschetno-finansovyi centr po podderzhke vozobnovlyaemyh istochnikov energii." [Online]. Available: http://www.rfc.kegoc.kz/fiksirovannye-tarify/.

[9] "Postanovleniye Pravitelstva Respubliki Kazakhstan №876 Ob utverzhdenii Pravil tsentralizovannoy pokupki i prodazhi raschetno-finansovym tsentrom ehlektricheskoy ehnergii, proizvedennoy obektami po ispolzovaniyu vozobnovlyaemykh istochnikov ehnergii."

[10] "Postanovleniye Pravitelstva Respubliki Kazakhstan №724 'Ob utverzhdenii Kontseptsii razvitiya toplivno-ehnergeticheskogo kompleksa Respubliki Kazakhstan do 2030 goda.'"

[11] "Ukaz Prezidenta Respubliki Kazakhstan № 577 O Kontseptsii po perekhodu Respubliki Kazakhstan k 'zelenoi ehkonomike.'"

[12] United Nations Climate Change Secretariat, "Summary of GHG Emissions for Sweden," 2012.

[13] IRENA (Inernational Renewable Energy Agency), "Renewable Energy and Jobs," pp. 1–20, 2016.

[14] M. Cabello and J. A. G. Orza, "Wind speed analysis in the province of Alicante, Spain. Potential for small-scale wind turbines," *Renew. Sustain. Energy Rev.*, vol. 14, no. 9, pp. 3185–3191, 2010.

[15] M. H. Zhang, "Wind Resource Assessment and Micro-siting," *Sci. Eng.*, p. 2015, 2015.

[16] F. Bañuelos-Ruedas, C. Á. Camacho, and S. Rios-Marcuello, "Methodologies Used in the Extrapolation of Wind Speed Data at Different

Heights and Its Impact in the Wind Energy Resource Assessment in a Region," *Intech*, p. 20, 2011.

[17] REN21, *Renewables 2015-Global Status Report*, vol. 4, no. 3. 2015.

[18] "General Electric Company." [Online]. Available: https://www.gerenewableenergy.com/wind-energy/turbines.html.

[19] "Suzlon Power Generator Company." .

[20] Enercon company, "ENERCON product overview."

[21] General Electric, "GE-1.7 100 Brochure," pp. 1–8, 2015.

[22] "Vestas Company." [Online]. Available: https://www.vestas.com/.

[23] Vestas Company, "2 MW Platform," p. 16, 2013.

[24] Suzlon Company, "2.1 MW Platform," p. 12, 2013.

[25] A. K. Azad, M. G. Rasul, M. M. Alam, S. M. Ameer Uddin, and S. K. Mondal, "Analysis of wind energy conversion system using Weibull distribution," *Procedia Eng.*, vol. 90, pp. 725–732, 2014.

[26] Y. Q. Xiao, Q. S. Li, Z. N. Li, Y. W. Chow, and G. Q. Li, "Probability distributions of extreme wind speed and its occurrence interval," *Eng. Struct.*, vol. 28, no. 8, pp. 1173–1181, 2006.

[27] P. Ramírez and J. A. Carta, "The use of wind probability distributions derived from the maximum entropy principle in the analysis of wind energy. A case study," *Energy Convers. Manag.*, vol. 47, no. 15–16, pp. 2564–2577, 2006.

[28] E. K. Akpinar and S. Akpinar, "A statistical analysis of wind speed data used in installation of wind energy conversion systems," *Energy Convers. Manag.*, vol. 46, no. 4, pp. 515–532, 2005.

[29] F. Castellares and A. J. Lemonte, "A new generalized Weibull distribution generated by gamma random variables," *J. Egypt. Math. Soc.*, vol. 23, no. 2, pp. 382–390, 2015.

[30] B. Bavanish and K. Thyagarajan, "Optimization of power coefficient on a horizontal axis wind turbine using bem theory," *Renew. Sustain. Energy Rev.*, vol. 26, pp. 169–182, 2013.

[31] LLP "GKM Company," "Projekt stroitel'stva VES," 2015.

[32] L. Sumarokova, "Elektrosnabzheniye promyshlennyh predpriyatii," *Tomsk. Politekh. Univ.*, p. 288, 2012.

[33] J. F. Manwell, J. G. Mcgowan, and A. L. Rogers, *Wind Energy Explained Theory, Design and Application Second Edition*. 2009.

[34] L. J. Vermeer, J. N. Sørensen, and A. Crespo, "Wind turbine wake aerodynamics," *Prog. Aerosp. Sci.*, vol. 39, no. 6–7, pp. 467–510, 2003.

[35] M. R. Patel, "Wind and Solar Power Systems. Design, Analysis and Operation," *C++ Prim.*, p. 473, 2006.

[36] M. N. Soltani, P. Hou, W. Hu, and Z. Chen, "Optimized Placement of Wind Turbines in Large Scale Offshore Wind Farm using Particle Swarm Optimization Algorithm," 2015.

[37] A. Arshad, "Net Present Value is better than Internal Rate of Return," *Interdiscip. J. Contemp. Res. Bus.*, vol. 4, no. 8, pp. 211–219, 2012.

[38] R. A. Brealy, S. C. Myers, and F. Allen, *Principles of Corporate Finance*. 2014.

[39] W. S. Oliveira and A. J. Fernandes, "Economic evaluation applied to wind energy projects," *Cyber Journals Multidiscip. Journals Sci. Technol. J. Sel. Areas Renew. Energy*, vol. 2, no. 9, pp. 1–12, 2011.

[40] I. Welch, *Corporate Finance*, 3rd ed. Los Angeles, 2014.

[41] M. A. Gurau, "The use of Profitability Index in Economic Evaluation of Industrial Investment Projects," *Proc. Manuf. Syst.*, vol. 7, no. 1, pp. 55–58, 2012.

[42] IRENA (Inernational Renewable Energy Agency), "Wind Power," *Renew. ENERGY Technol. COST Anal. Ser.*, vol. 1, no. 5, pp. 1–64, 2012.

[43] C. Mone, T. Stehly, B. Maples, and E. Settle, "2013 Cost of Wind Energy Review," *Natl. Renew. Energy Lab.*, no. February, p. 94, 2014.

[44] W. Short, D. Packey, and T. Holt, "A manual for the economic evaluation of energy efficiency and renewable energy technologies," *Univ. Press Pacific*, vol. 2, no. March, p. 120, 2005.

[45] Deloitte, "Establishing the investment case. Wind power," no. April, p. 27, 2014.

[46] National Bank of Kazakhstan, "Monetary policy." [Online]. Available: http://nationalbank.kz/?docid=3326&switch=english. [Accessed: 17-Dec-2016].

[47] The Code of the Republic of Kazakhstan, "The Tax Code on taxes and other obligatory payments the budget," p. 414, 2015.

[48] Trading Economics, "Kazakhstan Corporate Tax Rate." [Online]. Available: http://www.tradingeconomics.com/kazakhstan/corporate-tax-rate. [Accessed: 17-Dec-2016].

[49] M. N. C. DA COSTA, "Financial Evaluation of Hydroelectric Power Plant," 2014.

[50] P. Dubravka Tosic, "A Basic Introduction to the Methodology Used to Determine a Discount Rate," pp. 1–12.

[51] H. K. Barker and G. E. Powell, *Understanding Financial Management*. 2007.

[52] Trading Economcics, "Kazakhstan Consumer Price Index (CPI) Forecast 2016-2020." [Online]. Available: http://www.tradingeconomics.com/kazakhstan/consumer-price-index-cpi/forecast. [Accessed: 08-Apr-2017].

[53] Mezhdunarodnaya Finansovaya Korporaciya, "Posobiye dlya investorov. Razrabotka proektov po ispol'zovaniyu vozobnovlyayemyh istochnikov energii dlya proizvodstva elektricheskoi energii v Respublike Kazakhstan," 2015.

[54] IRENA (Inernational Renewable Energy Agency), *The Power to*

Change: Solar and Wind Cost Reduction Potential to 2025, no. June. 2016.
[55] IRENA (Inernational Renewable Energy Agency), "Renewable Power Generation Costs in 2014," no. January, p. 92, 2015.
[56] IRENA (Inernational Renewable Energy Agency), "Wind power - technology brief," *Energy*, no. 16, pp. 1–28, 2016.
[57] World Bank Group, "Ranking of economies - Doing Business." [Online]. Available: http://www.doingbusiness.org/rankings. [Accessed: 07-Mar-2017].
[58] Transparency International, "Corruption Perceptions Index 2016." [Online]. Available: http://www.transparency.org/news/feature/corruption_perceptions_index_2016. [Accessed: 07-Mar-2017].
[59] International Energy Agency, "Clean Energy Technology Assessment Methodology Pilot Study Kazakhstan," 2016.
[60] "Official internet-resource of the National Bank of Kazakhstan." [Online]. Available: http://nationalbank.kz/?docid=3321&switch=english. [Accessed: 07-Mar-2017].
[61] Trading Economics, "Kazakh Tenge Forecast 2016-2020." [Online]. Available: http://www.tradingeconomics.com/kazakhstan/currency/forecast. [Accessed: 07-Mar-2017].

Appendices

Appendix A – Electricity generation

Table 21 – Electricity generation for Suzlon S97 wind turbine.

Wind speed, m/s	Wind speed distribution, %	Distribution in hours per year, hour	Annual energy production, MWh
0	0%	0.00	0
1	3.49%	305.79	0
2	6.17%	540.06	0
3	8.17%	715.93	36
4	9.48%	830.33	166
5	10.10%	884.37	354
6	10.09%	884.11	663
7	9.58%	839.48	965
8	8.70%	762.54	1182
9	7.60%	665.75	1331
10	6.40%	560.51	1177
11	5.21%	456.17	958
12	4.10%	359.53	755
13	3.14%	274.80	577
14	2.33%	203.92	428
15	1.68%	147.05	309
16	1.18%	103.13	217
17	0.80%	70.38	148
18	0.53%	46.77	98
19	0.35%	30.28	64
20	0.22%	19.10	40
21	0.13%	11.75	25
22	0.08%	7.05	15

Table 22 – Electricity generation for V100-2MW wind turbine

Wind speed, m/s	Wind speed distribution, %	Distribution of hours per year, hour	Annual energy production, MWh
0	0%	0.00	0
1	3.49%	305.79	0
2	6.17%	540.06	0
3	8.17%	715.93	18
4	9.48%	830.33	125
5	10.10%	884.37	292
6	10.09%	884.11	486
7	9.58%	839.48	756
8	8.70%	762.54	1029
9	7.60%	665.75	1185
10	6.40%	560.51	1115

Wind speed, m/s	Wind speed distribution, %	Distribution of hours per year, hour	Annual energy production, MWh
11	5.21%	456.17	912
12	4.10%	359.53	719
13	3.14%	274.80	550
14	2.33%	203.92	408
15	1.68%	147.05	294
16	1.18%	103.13	206
17	0.80%	70.38	141
18	0.53%	46.77	94
19	0.35%	30.28	61
20	0.22%	19.10	38
21	0.13%	11.75	23
22	0.08%	7.05	14
23	0.05%	4.12	8
24	0.03%	2.35	5

Table 23 – Electricity generation for GE-1.7 wind turbine

Wind speed, m/s	Wind speed distribution, %	Distribution of hours per year, hour	Annual energy production, MWh
0	0%	0.00	0
1	3.49%	305.79	0
2	6.17%	540.06	0
3	8.17%	715.93	14
4	9.48%	830.33	62
5	10.10%	884.37	177
6	10.09%	884.11	398
7	9.58%	839.48	630
8	8.70%	762.54	877
9	7.60%	665.75	999
10	6.40%	560.51	891
11	5.21%	456.17	753
12	4.10%	359.53	611
13	3.14%	274.80	467
14	2.33%	203.92	347
15	1.68%	147.05	250
16	1.18%	103.13	175
17	0.80%	70.38	120
18	0.53%	46.77	80
19	0.35%	30.28	51
20	0.22%	19.10	32
21	0.13%	11.75	20
22	0.08%	7.05	12
23	0.05%	4.12	0
24	0.03%	2.35	0

Appendix B – Cash flows in all scenarios

Table 24 – Cash flow in realistic scenario

Year	0	1	2	3	4	5	6	7	8	9	10
INVESTMENTS											
Wind turbines	4,623,360										
Grid connection	1,155,840										
Planning and Miscellaneous	650,160										
Foundation	794,640										
Total	**7,224,000**										
REVENUE		**5,652,775**	**5,878,886**	**6,114,042**	**6,358,603**	**6,612,948**	**6,877,465**	**7,152,564**	**7,438,667**	**7,736,213**	**8,045,662**
COSTS											
Maintenance and repair		848,818	882,771	918,082	954,805	992,998	1,032,717	1,074,026	1,116,987	1,161,667	1,208,133
Land rent		-	-	-	-	-	71,602	74,466	77,444	80,542	83,764
Energy management		141,470	147,129	153,014	159,134	165,500	172,120	179,004	186,165	193,611	201,356
Insurance costs		56,588	58,851	61,205	63,654	66,200	68,848	71,602	74,466	77,444	80,542
Equipment decommission		127,323	132,416	137,712	143,221	148,950	154,908	161,104	167,548	174,250	181,220
Other operating costs		-	-	-	-	-	179,004	186,165	193,611	201,356	209,410
Total		**1,174,199**	**1,221,167**	**1,270,013**	**1,320,814**	**1,373,647**	**1,679,199**	**1,746,366**	**1,816,221**	**1,888,870**	**1,964,425**
DEPRECIATION		**9,030,000**	**6,772,500**	**5,079,375**	**3,809,531**	**2,857,148**	**2,142,861**	**1,607,146**	**1,205,359**	**904,020**	**678,015**
EBIT		**(4,272,802)**	**(1,825,014)**	**66,010**	**1,541,669**	**2,708,100**	**3,246,849**	**3,998,152**	**4,624,151**	**5,158,671**	**5,627,184**
BANK LOAN											
Interest		2,167,200	2,004,660	1,842,120	1,679,580	1,517,040	1,354,500	1,191,960	1,029,420	866,880	704,340
Principle repayment		2,042,541	2,205,081	2,367,621	2,530,161	2,692,701	2,855,241	3,017,781	3,180,321	3,342,861	3,505,401
EBT		**(4,304,420)**	**(1,857,897)**	**31,813**	**1,506,104**	**2,671,112**	**3,355,923**	**4,111,590**	**4,742,126**	**5,281,365**	**5,754,786**
TAX		**-**	**-**	**-**	**-**	**230,814**	**400,285**	**583,926**	**742,541**	**882,897**	**1,010,089**
EAT		**(6,471,620)**	**(3,862,557)**	**(1,810,307)**	**(173,476)**	**923,258**	**1,601,139**	**2,335,704**	**2,970,165**	**3,531,588**	**4,040,357**
CF	**(7,224,000)**	**515,840**	**704,863**	**901,447**	**1,105,895**	**1,087,706**	**888,760**	**925,070**	**995,204**	**1,092,747**	**1,212,971**
CUMULATIVE CF	**(7,224,000)**	**(6,708,160)**	**(6,003,297)**	**(5,101,850)**	**(3,995,956)**	**(2,908,250)**	**(2,019,491)**	**(1,094,421)**	**(99,217)**	**993,530**	**2,206,501**

Continue of Table 24 – Cash flow in realistic scenario

Year	11	12	13	14	15	16	17	18	19	20
INVESTMENTS										
Wind turbines										
Grid connection										
Planning and Miscellaneous										
Foundation										
Total										
REVENUE	**8,733,114**	**9,082,439**	**9,445,736**	**9,823,566**	**10,216,508**	**10,625,169**	**11,050,176**	**11,492,183**	**11,951,870**	**12,429,945**
COSTS										
Maintenance and repair	1,256,459	1,306,717	1,358,986	1,413,345	1,469,879	1,528,674	1,589,821	1,653,414	1,719,550	1,788,332
Land rent	87,114	90,599	94,223	97,992	101,912	105,988	110,228	114,637	119,222	123,991
Energy management	209,410	217,786	226,498	235,558	244,980	254,779	264,970	275,569	286,592	298,055
Insurance costs	83,764	87,114	90,599	94,223	97,992	101,912	105,988	110,228	114,637	119,222
Equipment decommission	188,469	196,008	203,848	212,002	220,482	229,301	238,473	248,012	257,933	268,250
Other operating costs	217,786	226,498	235,558	244,980	254,779	264,970	275,569	286,592	298,055	309,978
Total	**2,043,002**	**2,124,722**	**2,209,711**	**2,298,099**	**2,390,023**	**2,485,624**	**2,585,049**	**2,688,451**	**2,795,989**	**2,907,829**
DEPRECIATION	**508,511**	**381,383**	**286,037**	**214,528**	**160,896**	**120,672**	**90,504**	**67,878**	**50,909**	**152,726**
EBIT	**6,181,601**	**6,576,334**	**6,949,988**	**7,310,939**	**7,665,589**	**8,018,873**	**8,374,623**	**8,735,854**	**9,104,972**	**9,369,390**
BANK LOAN										
Interest	-	-	-	-	-	-	-	-	-	-
Principle repayment	-	-	-	-	-	-	-	-	-	-
EBT	**6,181,601**	**6,576,334**	**6,949,988**	**7,310,939**	**7,665,589**	**8,018,873**	**8,374,623**	**8,735,854**	**9,104,972**	**9,369,390**
TAX	**1,236,320**	**1,315,267**	**1,389,998**	**1,462,188**	**1,533,118**	**1,603,775**	**1,674,925**	**1,747,171**	**1,820,994**	**1,873,878**
EAT	**4,945,281**	**5,261,067**	**5,559,991**	**5,848,751**	**6,132,471**	**6,415,098**	**6,699,698**	**6,988,683**	**7,283,978**	**7,495,512**
CF	**5,453,792**	**5,642,450**	**5,846,028**	**6,063,279**	**6,293,367**	**6,535,770**	**6,790,202**	**7,056,561**	**7,334,886**	**7,648,238**
CUMULATIVE CF	**7,660,293**	**13,302,743**	**19,148,771**	**25,212,050**	**31,505,418**	**38,041,188**	**44,831,390**	**51,887,951**	**59,222,837**	**66,871,075**

Table 25 – Cash flow in pessimistic scenario

Year	0	1	2	3	4	5	6	7	8	9	10
INVESTMENTS											
Wind turbines	**23,116,800**										
Grid connection	**5,779,200**										
Planning and Miscellaneous	**3,250,800**										
Foundation	**3,973,200**										
Total	**36,120,000**										
REVENUE		**5,899,779**	**6,135,770**	**6,381,201**	**6,636,449**	**6,901,907**	**7,177,983**	**7,465,103**	**7,763,707**	**8,074,255**	**8,397,225**
COSTS											
Maintenance and repair		848,818	882,771	918,082	954,805	992,998	1,032,717	1,074,026	1,116,987	1,161,667	1,208,133
Land rent		56,588	58,851	61,205	63,654	66,200	68,848	71,602	74,466	77,444	80,542
Energy management		141,470	147,129	153,014	159,134	165,500	172,120	179,004	186,165	193,611	201,356
Insurance costs		99,029	102,990	107,110	111,394	115,850	120,484	125,303	130,315	135,528	140,949
Equipment decommission		127,323	132,416	137,712	143,221	148,950	154,908	161,104	167,548	174,250	181,220
Other operating costs		141,470	147,129	153,014	159,134	165,500	172,120	179,004	186,165	193,611	201,356
Total		**1,414,697**	**1,471,285**	**1,530,137**	**1,591,342**	**1,654,996**	**1,721,196**	**1,790,044**	**1,861,645**	**1,936,111**	**2,013,556**
DEPRECIATION		**9,030,000**	**6,772,500**	**5,079,375**	**3,809,531**	**2,857,148**	**2,142,861**	**1,607,146**	**1,205,359**	**904,020**	**678,015**
EBT		**(4,544,918)**	**(2,108,015)**	**(228,311)**	**1,235,576**	**2,389,763**	**3,313,926**	**4,067,913**	**4,696,702**	**5,234,124**	**5,705,655**
TAX		**-**	**-**	**-**	**247,115**	**477,953**	**662,785**	**813,583**	**939,340**	**1,046,825**	**1,141,131**
EAT		**(4,544,918)**	**(2,108,015)**	**(228,311)**	**988,461**	**1,911,810**	**2,651,141**	**3,254,331**	**3,757,362**	**4,187,299**	**4,564,524**
CF	**(36,120,000)**	**4,485,082**	**4,664,485**	**4,851,064**	**4,797,992**	**4,768,959**	**4,794,002**	**4,861,477**	**4,962,721**	**5,091,319**	**5,242,539**
CUMULATIVE CF	**(36,120,000)**	**(31,634,918)**	**(26,970,433)**	**(22,119,369)**	**(17,321,377)**	**(12,552,419)**	**(7,758,416)**	**(2,896,940)**	**2,065,781**	**7,157,100**	**12,399,639**

Continue of Table 25 – Cash flow in pessimistic scenario

Year	11	12	13	14	15	16	17	18	19	20
INVESTMENTS										
Wind turbines										
Grid connection										
Planning and Miscellaneous										
Foundation										
Total										
REVENUE	**8,733,114**	**9,082,439**	**9,445,736**	**9,823,566**	**10,216,508**	**10,625,169**	**11,050,176**	**11,492,183**	**11,951,870**	**12,429,945**
COSTS										
Maintenance and repair	1,256,459	1,306,717	1,358,986	1,413,345	1,469,879	1,528,674	1,589,821	1,653,414	1,719,550	1,788,332
Land rent	83,764	87,114	90,599	94,223	97,992	101,912	105,988	110,228	114,637	119,222
Energy management	209,410	217,786	226,498	235,558	244,980	254,779	264,970	275,569	286,592	298,055
Insurance costs	146,587	152,450	158,548	164,890	171,486	178,345	185,479	192,898	200,614	208,639
Equipment decommission	188,469	196,008	203,848	212,002	220,482	229,301	238,473	248,012	257,933	268,250
Other operating costs	209,410	217,786	226,498	235,558	244,980	254,779	264,970	275,569	286,592	298,055
Total	**2,094,098**	**2,177,862**	**2,264,976**	**2,355,575**	**2,449,798**	**2,547,790**	**2,649,702**	**2,755,690**	**2,865,917**	**2,980,554**
DEPRECIATION	**508,511**	**381,383**	**286,037**	**214,528**	**160,896**	**120,672**	**90,504**	**67,878**	**50,909**	**152,726**
EBT	**6,130,505**	**6,523,194**	**6,894,723**	**7,253,463**	**7,605,814**	**7,956,707**	**8,309,970**	**8,668,615**	**9,035,044**	**9,296,665**
TAX	**1,226,101**	**1,304,639**	**1,378,945**	**1,450,693**	**1,521,163**	**1,591,341**	**1,661,994**	**1,733,723**	**1,807,009**	**1,859,333**
EAT	**4,904,404**	**5,218,555**	**5,515,778**	**5,802,770**	**6,084,651**	**6,365,365**	**6,647,976**	**6,934,892**	**7,228,035**	**7,437,332**
CF	**5,412,915**	**5,599,938**	**5,801,816**	**6,017,298**	**6,245,547**	**6,486,037**	**6,738,480**	**7,002,770**	**7,278,944**	**7,590,058**
CUMULATIVE CF	**17,812,554**	**23,412,493**	**29,214,309**	**35,231,607**	**41,477,154**	**47,963,191**	**54,701,671**	**61,704,441**	**68,983,385**	**76,573,443**

Table 26 – Cash flow in optimistic scenario

Year	0	1	2	3	4	5	6	7	8	9	10
INVESTMENTS											
Wind turbines	**4,623,360**										
Grid connection	**1,155,840**										
Planning and Miscellaneous	**455,112**										
Foundation	**556,248**										
Total	**6,790,560**										
REVENUE		**5,899,779**	**6,135,770**	**6,381,201**	**6,636,449**	**6,901,907**	**7,177,983**	**7,465,103**	**7,763,707**	**8,074,255**	**8,397,225**
COSTS											
Maintenance and repair		848,818	882,771	918,082	954,805	992,998	1,032,717	1,074,026	1,116,987	1,161,667	1,208,133
Land rent		-	-	-	-	-	-	-	-	-	-
Energy management		70,735	73,564	76,507	79,567	82,750	86,060	89,502	93,082	96,806	100,678
Insurance costs		56,588	58,851	61,205	63,654	66,200	68,848	71,602	74,466	77,444	80,542
Equipment decommission		127,323	132,416	137,712	143,221	148,950	154,908	161,104	167,548	174,250	181,220
Other operating costs		-	-	-	-	-	-	-	-	-	-
Total		**1,103,464**	**1,147,603**	**1,193,507**	**1,241,247**	**1,290,897**	**1,342,533**	**1,396,234**	**1,452,083**	**1,510,167**	**1,570,573**
DEPRECIATION		**9,030,000**	**6,772,500**	**5,079,375**	**3,809,531**	**2,857,148**	**2,142,861**	**1,607,146**	**1,205,359**	**904,020**	**678,015**
EBIT		**(4,233,685)**	**(1,784,332)**	**108,319**	**1,585,671**	**2,753,862**	**3,692,589**	**4,461,723**	**5,106,264**	**5,660,069**	**6,148,637**
BANK LOAN											
Interest		2,167,200	2,004,660	1,842,120	1,679,580	1,517,040	1,354,500	1,191,960	1,029,420	866,880	704,340
Principle repayment		2,042,541	2,205,081	2,367,621	2,530,161	2,692,701	2,855,241	3,017,781	3,180,321	3,342,861	3,505,401
EBT		**(6,400,885)**	**(3,788,992)**	**(1,733,801)**	**(93,909)**	**1,236,822**	**2,338,089**	**3,269,763**	**4,076,844**	**4,793,189**	**5,444,297**
TAX		**-**	**-**	**-**	**-**	**247,364**	**467,618**	**653,953**	**815,369**	**958,638**	**1,088,859**
EAT		**(6,400,885)**	**(3,788,992)**	**(1,733,801)**	**(93,909)**	**989,457**	**1,870,471**	**2,615,810**	**3,261,475**	**3,834,551**	**4,355,438**
CF	**(6,790,560)**	**586,575**	**778,427**	**977,954**	**1,185,462**	**1,153,905**	**1,158,092**	**1,205,176**	**1,286,514**	**1,395,710**	**1,528,052**
CUMULATIVE CF	**(6,790,560)**	**(6,203,985)**	**(5,425,558)**	**(4,447,604)**	**(3,262,143)**	**(2,108,238)**	**(950,145)**	**255,030**	**1,541,544**	**2,937,254**	**4,465,306**

Continue of Table 26 – Cash flow in optimistic scenario

Year	11	12	13	14	15	16	17	18	19	20
INVESTMENTS										
Wind turbines										
Grid connection										
Planning and Miscellaneous										
Foundation										
Total										
REVENUE	**8,733,114**	**9,082,439**	**9,445,736**	**9,823,566**	**10,216,508**	**10,625,169**	**11,050,176**	**11,492,183**	**11,951,870**	**12,429,945**
COSTS										
Maintenance and repair	1,256,459	1,306,717	1,358,986	1,413,345	1,469,879	1,528,674	1,589,821	1,653,414	1,719,550	1,788,332
Land rent	-	-	-	-	-	-	-	-	-	-
Energy management	104,705	108,893	113,249	117,779	122,490	127,390	132,485	137,784	143,296	149,028
Insurance costs	83,764	87,114	90,599	94,223	97,992	101,912	105,988	110,228	114,637	119,222
Equipment decommission	188,469	196,008	203,848	212,002	220,482	229,301	238,473	248,012	257,933	268,250
Other operating costs	-	-	-	-	-	-	-	-	-	-
Total	**1,633,396**	**1,698,732**	**1,766,681**	**1,837,349**	**1,910,843**	**1,987,276**	**2,066,767**	**2,149,438**	**2,235,416**	**2,324,832**
DEPRECIATION	**508,511**	**381,383**	**286,037**	**214,528**	**160,896**	**120,672**	**90,504**	**67,878**	**50,909**	**152,726**
EBIT	**6,591,207**	**7,002,323**	**7,393,018**	**7,771,689**	**8,144,770**	**8,517,220**	**8,892,904**	**9,274,867**	**9,665,546**	**9,952,386**
BANK LOAN										
Interest	-	-	-	-	-	-	-	-	-	-
Principle repayment	-	-	-	-	-	-	-	-	-	-
EBT	**6,591,207**	**7,002,323**	**7,393,018**	**7,771,689**	**8,144,770**	**8,517,220**	**8,892,904**	**9,274,867**	**9,665,546**	**9,952,386**
TAX	**1,318,241**	**1,400,465**	**1,478,604**	**1,554,338**	**1,628,954**	**1,703,444**	**1,778,581**	**1,854,973**	**1,933,109**	**1,990,477**
EAT	**5,272,966**	**5,601,859**	**5,914,414**	**6,217,351**	**6,515,816**	**6,813,776**	**7,114,323**	**7,419,893**	**7,732,437**	**7,961,909**
CF	**5,781,477**	**5,983,242**	**6,200,451**	**6,431,879**	**6,676,712**	**6,934,448**	**7,204,827**	**7,487,771**	**7,783,345**	**8,114,635**
CUMULATIVE CF	**10,246,783**	**16,230,025**	**22,430,477**	**28,862,356**	**35,539,068**	**42,473,516**	**49,678,344**	**57,166,115**	**64,949,460**	**73,064,095**