A Feasibility Study and Evaluation of Financing Models for Wind Energy Projects: A Case Study on Izmir Institute of Technology Campus Area

By

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ABSTRACT

Feasibility studies have been done for different scenarios on IZTECH campus area where previous wind data evaluation showed considerable wind potential. RET Screen software has been used for feasibility calculations. Internal rate of return and unit cost of energy have been examined for the proposed scenarios. First scenario represents an autoproducer model which would meet IZTECH's electricity need. Two 600 kW turbines were used in this scenario and the unit cost of energy have calculated as 24 cents/kWh. Second scenario represents an autoproducer group. Two units with 900 kW rated power turbines were used in the scenario and 4.82 cents/kWh is found as unit energy cost. Finally, third and last scenario is planned as production plant with thirteen 900 kW turbines. The energy unit cost would be 2.68 cents/kWh when scenario is applied. This study showed that IZTECH campus area which was inspected before for wind data characteristic and technical potential point of view, found economically viable too. Within the finance models, project finance and syndicated loan credit were examined as the most convenient mechanisms.

ÖZ

Önemli ölçüde rüzgar potansiyeli oldugu belirlenmis olan Izmir Yüksek Teknoloji Enstitüsü (IYTE) kampus arazisinde farkli senaryolar için fizibilite çalismasi yapilmistir. Fizibilite hesaplamalarinda RET Screen programi kullanilmistir. Olusturulan senaryolar için karlilik ve birim maliyet degerleri incelenmistir. Birinci senaryo, IYTE'nin kendi elektrik ihtiyacini karsilayacagi otoprodüktör modeli temsil etmektedir. Bu senaryoda iki adet 600 kW gücünde rüzgar türbini kullanilmis ve birim enerji maliyeti 6.24 cent/kWh olarak hesaplanmistir. Ikinci senaryo otoprodüktör grubu modeline karsi gelmektedir. Iki adet 900 kW gücünde rüzgar türbininin kullanildigi senaryoya göre birim enerji maliyeti 4.82 cent/kWh olarak bulunmustur. Üçüncü ve son senaryo ise üretim santrali olarak tasarlanmis olup, on üç adet 900 kW gücünde rüzgar türbini kurulumunu öngörmektedir. Bu senaryo uygulandiginda birim enerji maliyeti 2.68 cent/kWh olmaktadir. Bu çalisma, daha önce rüzgar veri karakteristikleri ve potansiyeli teknik olarak incelenen IYTE kampus alaninin, rüzgar santrali kurulmasi durumunda, ekonomik olarak da uygun oldugunu göstermistir. Finansman modelleri içerisinde de en uygun çözümün proje finansmani veya sendikasyon kredisi kullanmak oldugu belirlenmistir.

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NOMENCLATURE

A_n: End of period payments series of payments

AWEA: American Wind Energy Association

B_n: Benefit

B: Benefit

BCR: Benefit/Cost Ratio

BOO: Build Own Operate

BOT: Built Operate Transfer

C_n: Cost ($)

C: Cost ($)

ECA: Export Credit Agencies

EIE: Turkish Directorate of Electrical Power Survey and Development Administration

EMRA: Energy Market Regulatory Authority

EU: European Union

EWEA: European Wind Energy Association

F_n: Future Value ($)

I: Interest Rate (%)

IEA: International Energy Agency

IRR: Internal Rate of Return (%)

MENR: Ministry of Energy and Natural Resources

MLA: Multilateral Lending Agencies

n: period (year)

NPV: Net Present Value

NWCC: National Wind Coordinating Committee

O&M: Operation and Maintenance

P_v: Present Value

PBP: Pay Back Period (year)

PPA: Power Purchase Agreement

PV: Present Value ($)

r: Discount Rate

RET: Renewable Energy Technology

ROI: Return on Investment

SIS: State Institute of Statistics

TEAS: Turkish Electricity Generation and Transmission Co.

TEDAS: Turkish Electricity Distribution Co.

TEK: Turkish Electricity Authority

TOR: Transfer of Operating Rights

TPAO: National Oil and Gas Company

WT: Wind Turbine

WECS: Wind Energy Conversion System

Chapter 1

INTRODUCTION

Wind is the natural movement of air across the land or sea. Wind is caused by uneven heating and cooling of the earth's surface and by the earth's rotation. Land and water areas absorb and release different amount of heat received from the sun. As warm air rises, cooler air rushes into take its place, causing local winds. The rotation of the earth changes the direction of the flow of air. This produces prevailing winds. Surface features such as mountains and valleys can change the direction and speed of prevailing winds [1]. Wind turbines convert mechanical power from the wind into electrical power via a rotor connected to a generator.

Wind is a free, inexhaustible resource. Wind energy has excellent long term price stability due to easily projected operation and maintenance expenses [2]. If external/social costs are included, it is estimated that wind power in many countries is already competitive with fossil and nuclear power [3]. Wind energy has become one of today's lower cost renewable energy technologies. Wind energy is currently viewed as one of the most promising of the renewable energy sources. However, despite wind energy's long history and non-polluting qualities, concerns and questions about the technology and its use still exist.

Cumulative global wind energy generating capacity topped 39,000 megawatts (MW) and reached 39,294 MW at the end of 2003. New equipment totaling 8,133 MW in capacity was installed worldwide during the year, an increase of 26%, according to estimates by the American Wind Energy Association (AWEA) and the European Wind Energy Association (EWEA). The growth is expected to continue in the double-digits into the next decade.

The policy for the promotion of renewable energies has been influenced more and more by international obligations. At the global level, there are obligations set forth by the Kyoto Protocol. The EU has to reduce its green- house gas emissions by 6 % of 1990 levels by 2008 –2012. Beyond the different framework conditions in the singular EU Member States which influence the success of renewable energies also the deployed instruments for their promotion play a crucial role. The main instruments for promoting renewables are feed-in tariffs, quota obligations, tenders and tax exemptions [4].

Turkey’s natural energy resources are quite diversified; hard coal, lignite, asphaltite, oil, natural gas, hydro, geothermal, wood, animal and plant wastes, solar and secondary energy resources such as coke and briquettes are produced and consumed. Oil has the biggest share (44%) in total primary energy consumption, while natural gas has a share of 12% [5].

In 1970, growing generation, distribution and consumption of electricity as well as the necessity of expanding the respective services made it essential the forming of an institutional structure and thus TEK (Turkish Electricity Authority) was established. So, the integrity in the power sector was ensured, with the exception of municipalities and the Bank of Provinces [6].

In 1984 with the new regulations, the monopoly of TEK was lifted up and the private entities formed against permissions were also given the opportunity to intervene generation, transmission and distribution of electricity. This is called the BOT (Built-Operate-Transfer); Law No: 3096.

Turkish Electricity Authority had been incorporated in the scope of the privatization and it was split into two separate State Owned Enterprises, namely “Turkish Electricity Generation Transmission Co” TEAS and Turkish Electricity Distribution Co” TEDAS, by the Act of the Council of Ministers [6].

The latest development is the Electricity Market Law (No: 4628), which was issued in the Official Gazette dated 3rd March, 2001. It is concerning the restructuring of the energy sector and it has been targeted the establishment of financially strong, stable and transparent electricity market under competitive and special law provisions for a sufficient, high-quality, continuous, low-cost and environment friendly supply of electricity to the disposal of consumers as well as the maintaining an independent regulatory and supervisory framework.

This law covers the generation, transmission, distribution, wholesale, retail and respective services of electricity including its import-export and also the rights and responsibilities of all real and legal persons connected with those services and establishment of a Energy Market Regulatory Authority and its running procedures and principals as well as the procedures to be followed for the privatization of the electricity generation and distribution assets. TEAS had been restructured to form 3 state- owned public enterprise by the Decree of Council of Ministers No:2001/2026 and dated 05.02.2001 which was issued in the Official Gazette dated 2nd March, 2001 [6].

Every wind farm is unique but the steps in building a wind farm are common. The most important factor to consider in the construction of a wind energy facility is the site's wind resource. Availability and access to existing lines should be considered in selecting a site whenever possible. Roads, transmission equipment, maintenance infrastructure, turbines need to be considered. There are many factors contributing to the cost and productivity of a wind plant. Financing methods can make a major difference in project economics as well [7].

A developer’s key aim is to maximize value creation by ensuring that a project is successfully guided through the development process. This process consists of a number of key steps: site selection, planning approval, grid connection, arrangement of Power Purchase Agreement (PPA) and financial close [8].

The cost of a wind energy system is determined by three components: initial installation costs, operating expenses and the cost of financing. The initial installation cost includes the purchase price of the complete system (including tower, wiring, utility interconnection, power conditioning unit, etc.) plus delivery and installation charges, professional fees and sales tax.

Operating expenses is incurred over the lifetime of the wind system. Operating costs include maintenance and service, insurance and any applicable taxes. The last component, cost of financing, depends on the interest rate on the money invested (how the capital cost is repaid).

Wind energy costs are decreasing every year, whereas most conventional generation costs continue to increase. Wind energy project capital costs as reported by the International Energy Agency(IEA) show substantial variation between countries, due to factors such as market structures, site characteristics and planning regulations; total wind project capital costs vary between approximately US$900 per kW and US$1,600 per kW in different countries [9].

The discount rate has a significant influence on production costs and hence on the financial viability of wind projects. For a 600kW turbine, changing the discount rate from 5% to 10% a year (in real terms) increases the production cost by a little more than 30%, from 5 US cents per kWh to 6.7 US cents per kWh [9]. This effect is considered in the case study.

Wind energy is a capital-intensive technology with short construction times (typically a few months), low operating costs and zero fuel costs. The economics of wind energy are therefore more sensitive to discount rate and plant capital cost than, for example, are those of fossil or nuclear fuelled generation [10].

The present study focuses on the economics of grid-connected wind turbines only. The main parameters governing wind power economics are: (i) investment costs, including auxiliary costs for foundation, grid-connection, and so forth; (ii) operation and maintenance costs; (iii) electricity production/average wind speed; (iv) turbine lifetime; and (v) discount rate. Of these the most important are the turbines' production of electricity and the investment costs. As electricity production is highly dependent on wind conditions, choosing the right turbine site is critical to the economic results.

Chapter 2

WIND ENERGY STATUS

2.1 Global Status of Wind Power

2.1.1 An Overview of Wind Energy in the World

World's primary energy consumption increased by 2.6% in 2002, well ahead of the 10-year growth trend of 1.4% per annum. Reported growth in energy demand of almost 20% in China was behind much of this relative strength. Energy consumption in the world, excluding China, grew by less than 1% during the year 2002 [11].

With Kyoto Protocol, a series of greenhouse gas reduction targets has cascaded down to a regional and national level. These in turn have been translated into targets for increasing the proportion of renewable energy, in the supply mix. Kyoto Protocol called for global cut of 6 % from 1990 levels by the period 2008-2012, a series of greenhouse gas reduction targets has cascaded down to regional and national levels. Wind power and other renewable energy technologies generate electricity without producing the pollutants associated with fossil fuels and nuclear power generation, and emit no carbon dioxide, the most significant greenhouse gas.

Despite the scale of the potential, the current contribution of renewables to world energy supplies is modest. Renewables are estimated to supply around 17% of world primary energy, but most of this is from large hydroelectric schemes and the use of traditional biomass and agricultural waste in developing countries – these supply 3% (18% of electricity) and 14% of primary energy, respectively [12].

However, both can lead to considerable local environmental problems and the potential for sustainable expansion because both are limited. Meanwhile, according to IEA the 'new' renewables such as solar, modern biomass and wind power contribute a much smaller proportion of energy needs at present – around 3% of electricity and 2% of primary energy [13]. Wind is the world's fastest-growing energy source, with installed generating capacity increasing by an average 32% annually for the last five years (1998-2002).

The power of the wind has been utilized for at least 3000 years for pumping water or grinding grain. The first electricity generation by wind energy was achieved around the end of the 19th century. Dane Poul La Cour was the first to build a wind turbine generating electricity in 1891.

The first modern wind turbine was built in Denmark at 1940s. Despite the success of German and Danish wind turbines, the interest in large-scale wind power generation declined after World War II [14,15]. In late 1970s the interest in wind power generation returned as a part of response to the oil crises in 1973 and 1979.

As a result, financial support for research and development programmes of wind energy became available. Governments used several different approaches to promote wind energy. Countries like Germany, USA or Sweden used this money to develop large-scale wind turbine prototypes in the MW range, others concentrated on creating the right market conditions for deployment of the technology.

During the last decade of the 20th century, grid-connected wind capacity world wide has doubled approximately every three years. Due to the fast market development, wind turbine technology has experienced an important evaluation over time.

In many respects, wind power is the great success story of renewables development [12]. Currently wind energy production represents the fastest growing of all renewable energy sources on the market, with most of the growth coming from the Europe (Germany, Spain and Denmark).

Since the Wind Force 12 report, which was published by EWEA and Greenpeace, wind power has maintained its status as the world's fastest growing energy source. Installed capacity has continued to grow at an annual rate in excess of 30%. During 2002 alone, more than 7,000 MW of new capacity was added to the electricity grid. This investment was worth more than €7 billion.

Kyoto in turn has been translated into targets for introducing an increasing proportion of renewables into the supply mix. For example, the 15 member states of the European Union now have an overall target for 22% of their electricity to come from renewables by 2010.

A great deal of information included in this study has been obtained from EWEA reports.

Table2-1 Global Wind Energy Generating Capacity by Country [16]

Global Wind Energy Generating Capacity by Country			
Wind Energy Markets (Installed capacity(MW)	2001 Year End Total	2002 Additions	2002 Year End Total
Country			
USA	4,275	410	4,685
Canada	198	40	238
North America	**4,473**	**450**	**4,923**
Germany	8,754	3,247	12,001
Spain	3,337	1,493	4,830
Denmark	2,417	497	2,880
Italy	697	103	785
Netherlands	493	217	688
UK	474	87	552
Sweden	290	35	328
Greece	272	4	276
Portugal	125	63	194
France	78	52	145
Austria	94	45	139
Ireland	125	13	137
Belgium	31	12	44
Finland	39	2	41
Luxembourg	15	1	16
EU Total	**17,241**	**5,871**	**23,056**
Norway	17	80	97
Ukraine	41	3	44
Poland	22	5	27

(Cont. on the next page)

Table 2-1 (cont.)

Latvia	2	22	24
Turkey	19	0	19
Czech Republic	6.8	0.2	7
Russia	7	0	7
Switzerland	5	0	5
Hungary	1	1	2
Estonia	1	1	2
Romania	1	0	1
Other Europe	**123**	**112**	**235**
India	1,507	195	1,702
Japan	275	140	415
China	400	68	468
Australia	72	32	104
Egypt, Morocco, Costa Rica, Brazil, Argentina, others	225 (est.)		225(est.)
Other Total	2,479	435	2,914
World Total	**24,315**	**6,868**	**31,128**

Global wind power capacity has quadrupled over the past five years, growing from 7,600 MW at the end of 1997 to more than 31,000 MW at the end of 2002 - an increase of over 23,000 MW. This is enough power to satisfy the needs of 16 million average European households, or 40 million people. According to Wind Force12, Europe accounts for 74% of this capacity, and for 85% of the growth during 2002. But other regions are beginning to emerge as substantial markets for the wind industry. Almost 50 countries around the world now contribute to the global total, and the number of people employed by the industry worldwide is estimated to be around 90-100,000, with 70- 80,000 of these in Europe.

Over the past five years, global wind power capacity has continued to grow at an average cumulative rate of 33% (Table2-2). The increase in annual installations has been even higher – a year-on-year average of 35.7% [11].

Table2-2 Growth in World Wind Power Market 1997-2002 [11]

Year	Installed Capacity (MW)	Increase	Cumulative Capacity (MW)	Increase
1997	1,568		7,636	
1998	2,597	66%	10153	33%
1999	3,922	51%	13,932	37%
2000	4,495	15%	18,449	32%
2001	6,824	52%	24,924	35%
2002	7,227	6%	32,037	29%
Average growth over 5 years		**35.7%**		**33.2%**

Table 2-3 Growth Rates in Top Ten Wind Energy Markets [11]

Country	MW 1999	MW 2000	MW 2001	MW 2002	Growth rate 2001-2002	3 years average growth
Germany	4,442	6,107	8,734	11,968	37.0%	39.2%
Spain	1,812	2,836	3,550	5,043	42.1%	40.7%
USA	2,445	2,610	4,245	4,674	10.1%	24.1%
Denmark	1,738	2,341	2,456	2,880	17.3%	18.3%
India	1,035	1,220	1456	1,702	16.9%	18.0%
Italy	277	424	700	806	15.1%	42.7%
Netherlands	433	473	523	727	39.0%	18.9%
UK	362	425	525	570	8.7%	16.4%
Japan	68	142	357	486	36.1%	92.7%
China	262	352	406	473	16.5%	21.8%
World Total	12,874	16,929	22,952	29,329	27.8%	31.6%

2.1.2 The World's Wind Resources and Demand for Electricity

A number of assessments confirm that the world's wind resources are extremely large and well distributed across almost all regions and countries. The total available resource that is technically recoverable is estimated to be 53,000 Terawatt hours (TWh)/year. This is over twice as large as the projection for the world's entire electricity demand in 2020 [11].

Future electricity demand is assessed regularly by the International Energy Agency. The IEA's 2002 World Energy Outlook assessment shows that by 2020, total world demand will reach 25,578 TWh. For wind power to meet 12% of global consumption it will therefore need to generate an output in the range of 3,000 TWh/year by 2020 [11].

According to the Commission's (IEA) "EU Energy Outlook to 2020" study, the use of electricity is expected to expand by 1.7 % per year over the period 1995–2020. Total power capacity requirements are expected to increase by some 300 GW during this period and a similar amount of new capacity will be required for the replacement of decommissioned plants. Thus, the EU is projected to build approximately 600 GW of new plants over the 1995–2020 period. At the same time, the European Parliament in 1998 has set the goal of doubling Renewable Generation in Europe from 6 % of the gross energy consumption to 12% by 2010. It is estimated that this development will have the following effects [13].

- Total avoided fuel cost (1997–2010) 21 billion Euros.
- Half a million new jobs created.
- Reduction of fuel imports by 17.4% compared to 1994.
- Reduction in CO emissions up to 402 million tons per year compared to 1997 [17].

It should be noted that this 12% share of total renewable energy sources in the gross inland energy consumption is translated into a 22.1% for consumption of electricity produced from renewable energy sources or 12.5% excluding large hydro schemes, above 10MW [13].

2.1.3 Environmental Benefits

The excepted growth of renewable energy is being driven by environmental, social, political and economic concerns. A reduction in the levels of carbon dioxide being emitted into the world's atmosphere is an important environmental benefit from wind power generation. Carbon dioxide is the gas largely responsible for exacerbating the greenhouse effect, leading to the disastrous consequences of global climate change. On the assumption that the average value for carbon dioxide saved by switching to wind power is 600 tonnes per GWh, the annual saving under this scenario will be 1,813 million tonnes of CO_2 by 2020 and 4,860 million tonnes by 2040. The cumulative savings would be 10,921 million tonnes of CO_2 by 2020 and 85,911 million tonnes by 2040 [11].

2.1.4 Costs

With wind energy, and many other renewables, the fuel is free. Therefore once the project has been paid for, the only costs are operation and maintenance and fixed costs, such as land rental. The capital cost is high, between 75% and 90% of the total [18].

The capital cost breakdown of a typical 5 MW project is shown below.

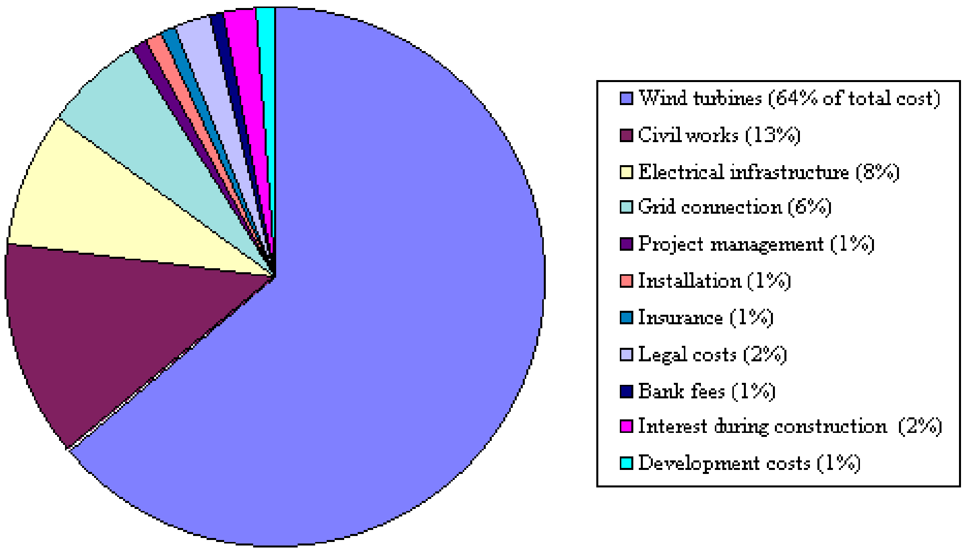


Figure 2-1 The capital cost breakdown of a typical 5 MW [18]

Although the cost varies between different countries, the trend everywhere is the same wind energy is getting cheaper. The cost is coming down for various reasons. The turbines themselves are getting cheaper as technology improves and the components can be made more economically. The productivity of these newer designs is also better, so more electricity is produced from more cost-effective turbines. There is also a trend towards larger machines. This reduces infrastructure costs, as fewer turbines are needed for the same output.

The cost of financing is also falling as lenders gain confidence in the technology. Wind power should become even more competitive as the cost of using conventional energy technologies rises [18].

Onshore wind plant costs have fallen substantially during the last decade. On good sites wind is already competitive with new coal-fired plants and in some locations can challenge gas.

The production cost of a wind power has fallen by 20% over the past five years alone due to lower turbine costs, higher efficiency and availability and lower operation and maintenance costs. And in operation period, wind power is free from fuel price fluctuations and secure of supply concerns.

Using the progress assumptions already discussed, and taking into account improvements both in the average size of turbines and in their capacity factor, the cost per kilowatt hour of installed wind capacity is expected to have fallen to 2.93 €cents/kWh by 2010, assuming a cost per installed kilowatt of €623. By 2020 it is expected to have reduced to 2.34 €cents/kWh, with an installation cost of €497/kW – a substantial reduction of 40% compared with 2002 [11, 15].

Costs are sensitive to wind speed, discount rate and other variables and there is a wide range in existing wind farms. It is particularly important to note that cost falls rapidly with wind speed because power output from wind turbines rises with the cube of the wind speed. For this reason, wind farms at the windiest sites are already close to cost competitive with the average costs of conventional power [12]. Wind power costs are also expected to look increasingly attractive when compared with other power technologies especially when external costs are taken into account.

The booming wind energy business has attracted the serious attention of the banking and investment market, with new players such as oil companies entering the market. Booming wind energy markets are found in Germany, Spain, Denmark, the US and India. Two thirds of wind power installed in 2001 was in Europe. A new market sector is emerging offshore, with more than 20,000 MW of wind farms proposed in the seas around Northern Europe [19].

Wind-based electricity is not yet generally competitive with alternate sources of electricity such as fossil fuels. Thus, it is dependent on nonmarket support for development to take place [20].

In order to promote renewable energy, countries in both Europe and elsewhere have adopted a variety of policy mechanisms. These range from premium payments per unit of output to more complex mechanisms based on an obligation on power suppliers to source a rising percentage of their supply from renewables [11].

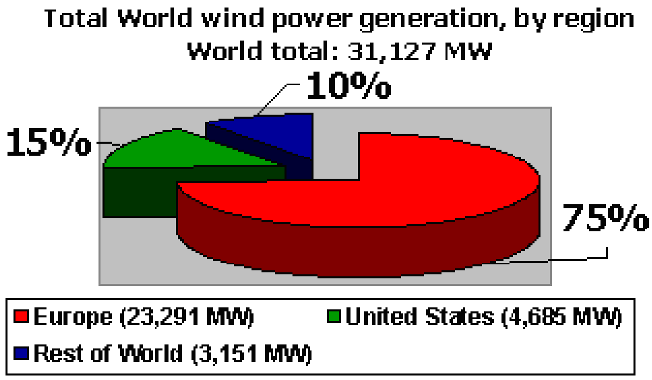


Figure 2-2 Total world wind power generation, by region [16]

The countries with most wind power capacity are Germany - by far the largest, with just over 12,000 MW - followed by Spain, the United States, Denmark, and India [16].

Table 2-4 Capacity Installed at the year end (MW) [11]

Capacity Installed at year end (MW)						
MW	1997	1998	1999	2000	2001	2002
Germany	2,081	2,874	4,442	6,107	8,734	11,968
US	1,611	2,141	2,445	2,610	4,245	4,674
India	940	992	1,035	1,220	1,456	1,702
Denmark	1,116	1,420	1,738	2,431	2,456	2,880
Spain	512	880	1,812	2,836	3,550	5,043

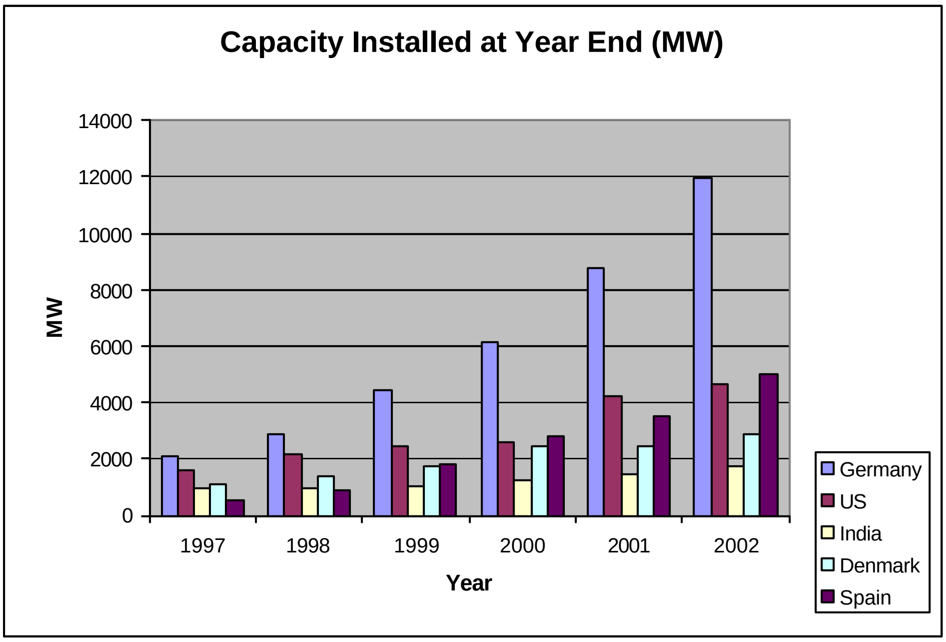


Figure 2-3 Capacity Installed at year end

In the light of these statistical data we can say that wind power's share in electricity demand will increase rapidly as the technology continues to develop, costs continue to fall, and the need to secure and diversify energy supply becomes increasingly evident to decision makers.

Around 8,200 MW of new wind power capacity was installed in 2003, more than in the previous year and enough to maintain the annual growth rate at almost exactly the same level-over 26% [21]. Global wind power generation is now pushing the 40,000MW milestone.

Table 2-5 Top Wind Energy Markets in 2003 [22]

Top Wind Energy Markets in 2003		
Country	**New Capacity in 2003 (MW)**	**Total Capacity end 2003(MW)**
Germany	2,674	14,612
USA	1,687	6,361
Spain	1,377	6,420
India	423	2,125
Austria	285	415
Japan	275	761
Netherlands	233	938
Denmark	218	3,076
UK	195	759
Italy	116	922
Others	861	3,912
Total World	**8,344**	**40,301**

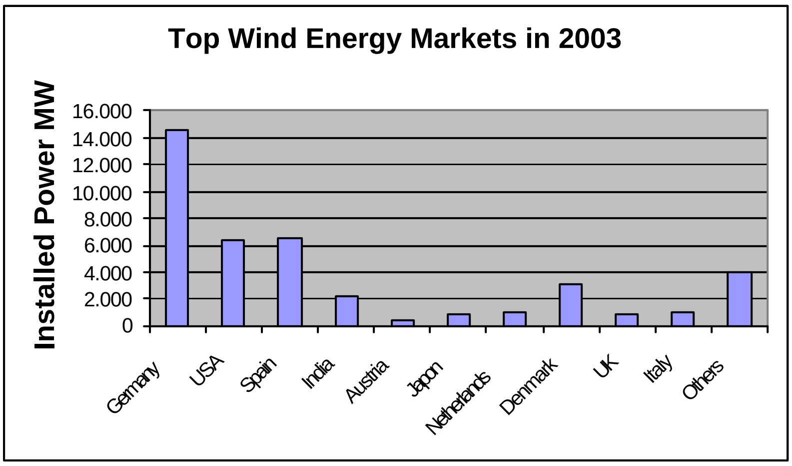


Figure 2-4 Top Wind Energy Markets in 2003 [22]

Analysis by the EWEA shows that there are no technical, economic, or resource limitations for wind power to supply 12% of the world's electricity by 2020. Today wind power supplies approximately 0.4% of world electricity demand. With stronger political commitments worldwide, the wind energy industry could install an estimated 230,000 MW by 2010, and 1.2 million MW by 2020 [16].

2.2 Energy in Turkey

2.2.1 An Overview of Turkish Energy Sector

Turkey is a rapidly growing country, both in economic and population sense, with 8.5% economic growth rate and 1.5% population growth rate. In parallel, it is one of the fastest growing electricity and natural gas markets in the world.

During the past 20 years the electricity market in Turkey was one of the fastest growing in the world. The International Energy Agency estimated growth in consumption between 1973 and 1995 at on average 9 % - 10 % per year. Despite the major economic crisis under which the country has been suffering since the end of 2000, a barely inhibited growth in demand is expected for the coming decade too [23,24].

Turkey is an energy importer. The energy consumption of the country which was 79,600,000 Tons of equivalent petroleum in 2000 is increasing every year. The energy consumption was 128,500,000,000 kWh in 2000 while 3,800,000,000 kWh of this consumption was imported [15].

In 2001, the total installed capacity of the power plants reached 28,318MW, but because of the insufficient water supply in the dam reservoirs and decreasing utilization capacity of hydro electricity power plants, the actual production was 123 billion kWh, whereas the average production capacity of power plants increased to 151.4 billion kWh. Net electricity imports, which were 3 billion kWh in 1998 and 2 billion in 1999, realized around 3.8 billion kWh in 2000 [25]. In 2002, the total installed and average production capacity of power plants increased to 31,845.6MW and 122.724 billion kWh respectively.

According to State Institute of Statistics (SIS), Turkey’s population of more than 65 million is growing at an annual rate of 1.7% and expected to grow to 83.4 million in 2022, with an annual growth rate decelerating to 1% over the next 20 years. Turkey's rapid growth in electricity demand is expected to continue for the foreseeable future.

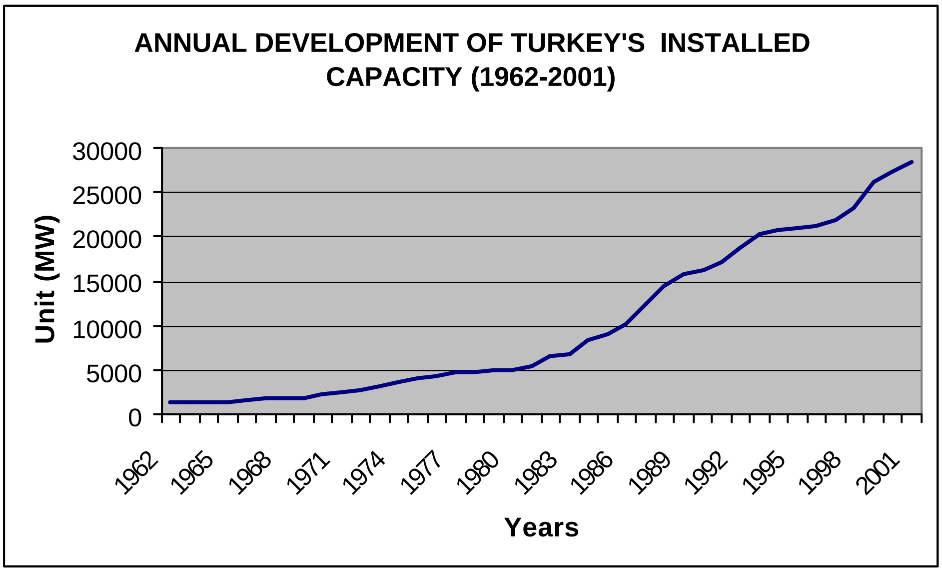


Figure 2-5 Annual Development of Turkey's Installed Capacity

According to SIS, the electric production increased 8.5 percent in 2003 and the production became 140.2 billion kWh. In respect to consumption the consumption rate increased 7.5 percent and became 115.2 billion kWh. 78.8% of the production is met by the thermal plants and 25.2% by hydroelectric plants. The wind energy is even much less then 1%. 44 % of the thermal plants use natural gas and according to the projections and this percentage will increase. Figure 2-6 shows the primary energy production according to the TPAO data base and Figure 2-7 shows the primary energy consumption in Turkey.

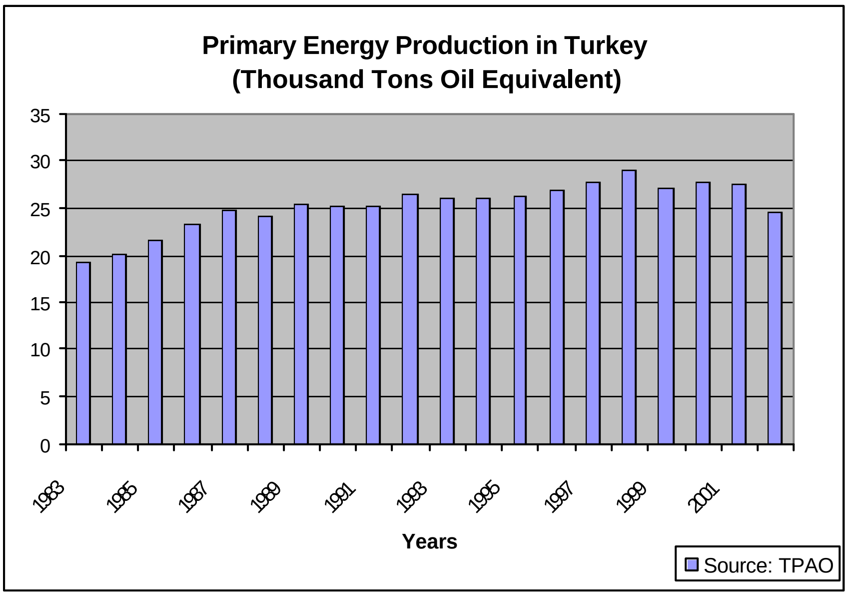


Figure 2-6 Primary Energy Production in Turkey

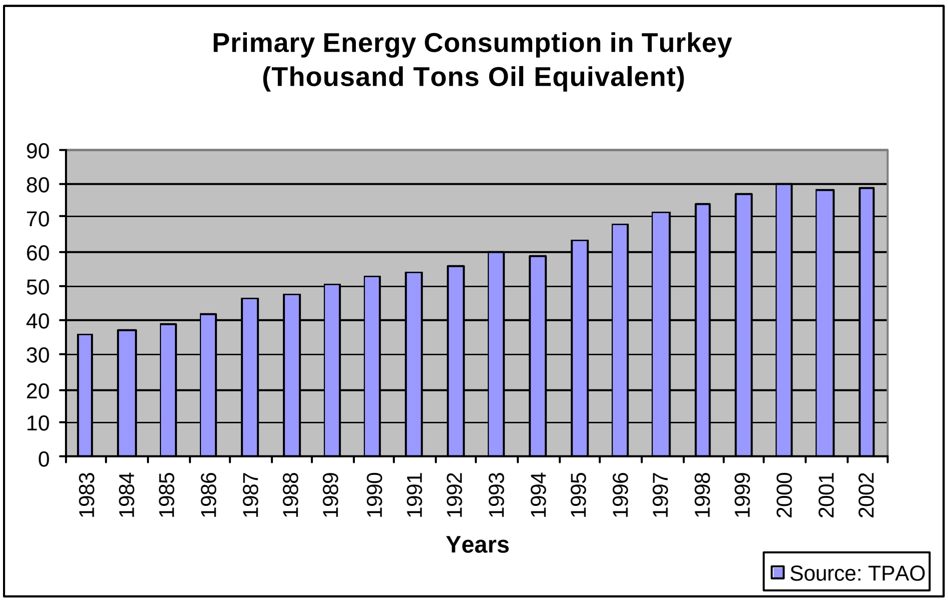


Figure 2-7 Primary Energy Consumption in Turkey

In order to meet this growing demand in electricity, Turkish authorities anticipate that 43,000 MW of capacity will be needed by 2010, with another 44,000 MW to be added between 2010 and 2020. This increase can be covered with an average of 2,500 MW of new generation capacity every year for the next 10 years. To meet the growing energy deficit in the country necessitates the allocation of a total of US$ 3–4 billion each year annually to generation, transmission and distribution of power through 2020 [26]. The huge dimension of these investments makes it more difficult to lay the burden entirely on public resources. In order to overcome the rapidly growing energy shortage and to meet the rising demand, the investment of foreign and local private capital is strongly encouraging by the Turkish Government.

2.2.2 Energy Sector Regulations

Power production and construction activities have been controlled by state own enterprises until 1984.

With regard to privatizatio n activities in the energy sector, Law No:3096 was issued in 1984 to allow the domestic and foreign private sector to invest, operate and trade in the power sector.

With this law, new methods for energy project financing and ownership had implemented. Three models were developed: "Build-Operate-Transfer" (BOT), "Build-Own-Operate" (BOO), and "Transfer of Operating Rights" (TOR).

BOT (Build-Operate-Transfer):

Under BOT model, private investors would finance construct and operate power plant for a certain period of time (usually 15-20 years) sufficient to pay off the debt and pay the equity, then finally transfer ownership back to the state. The investor does not own the plant. The electric power produced by these projects could be sold to the national electricity authority which is TEAS.

BOT model can not be considered as fully privatization because it is based on the principle of private sector building and operating the power plant for an agreed term and transferring the subject facilities to the state at the end of the term. It is rather a method of financing and realization of energy projects via private sector.

Within the framework of the BOT model, 16 hydro-electric power plants, 4 natural gas-burning power plants and 2 wind power plants, with the to tal installed capacity of 2,276 MWs have been put into operation. In addition, the construction of 4 hydro-electric power plants, with the total installed capacity of 293 MWs, is ongoing [27].

TOR (Transfer of Operating Rights):

TOR is a similar concept for privatization. A private developer or consortium receives a power plant in exchange for a transfer fee (usually set via a bid process), then operates and maintains the facility as necessary during the predetermined transfer term. At the end of that term, the power plant is transferred back to the state without any further cost or additional requirements.

BOO (Built-Operate-Own):

As BOO does not impose any time constraints on the project, this approach has been more favorably received by power developers. As a result, the economics of power production is usually more favorable than for the BOT approach, which results in a lower cost of power generation.

BOO is a true independent power producer model (IPP). The investor again plans, builds and operates the power plant but sells the power directly to a consumer and/or to TEAS/TEDAS. BOO does not apply to nuclear and renewables.

BO (Built,Own):

BO Law No.4282 was enacted in 1997 with the experience gained from the implementation of the BOT model. This Law provides for the establishment and ownership of thermal power plants by the private sector, excluding nuclear and renewable plants.

Autoproduction:

Industrial entrepreneurs are allowed to build their own combined power and heat producing plant (cogeneration) just to meet their own power and heat requirement with the Law No.3096 and related regulation dated 04/09/1985. Autoproducers can sell their excess to the grid at a price not to exceed 85% of the average selling price of distribution companies to end-consumers excluding taxes and TEDAS (now TETTAS) is obligated to purchase the surplus electricity generated by Autoproducer.

New Regulations:

The regulatory reform in the electricity and the natural gas sector has been launched by the enactment of the Electricity Market Law ,No.4628, in March 3,2001 and has been continued by the enactment of the Natural Gas Law ,No.4646, in May 2,2001.

In the lights of the recent changes in the legislation:

1. International arbitration is allowed for settlement of disputes.
2. The authority of the High Council has been limited to giving an advisory opinion about concession contract and agreements within two months, rather than a binding decision.

3. Electricity production and distribution projects included the BOT scheme and BOT contracts are not considered as concession contracts, but private law contracts.
4. An independent Energy Market Regulatory Authority (EMRA) has been set up which will undertake a monitoring and auditing of electricity and gas sectors on behalf of public in accordance with the new legal framework and ensuring the formation of Energy Market Regulatory Board which will represent and govern the Energy Market Regulatory Authority.
5. Liberalization of electricity and gas sectors in harmonization with the EU Electricity and Gas Directives and opening of these sectors to competition was ensured.
6. The monopolistic position of BOTAS in the gas sector was removed. The Turkish Electricity Generation and Transmission Company has been divided into three enterprises [25].

The law paves the way for a free market in power generation and distribution in the country.

In summary, the new Laws include the following key elements:

• an autonomous Energy Market Regulatory Authority, governed by a Board,

• a new licensing framework for market participants,

• an energy market, to be comprised of bilateral contracts between market participants,

• a cost-reflecting structure for pricing,

• an eligible consumer concept (eligible consumers to be free to choose their suppliers),

• a transition mechanism to be implemented over a two year program for the electricity sector and a 1.5 year program for the gas sector [27].

Among other things, the legislation calls for: 1) TEAS to be broken up into separate generation, distribution, and trade companies; 2) trade and generation companies to be privatized, while transmission remains in state hands; and 3) a new regulatory board to be set up which will oversee the Turkish power market, set tariffs, issue licenses, and prevent uncompetitive practices [28].

This law sets up a path toward a free market in power generation and distribution.

The state-owned power company, TEAS, was split into three entities in October 2001. Following the 'unbundling', three new companies have been established: the Electricity Generation Corp. (TEÜAS); the Turkish Electricity Transmission Corp. (TEIAS); and the Turkish Electricity Trading and Contracting Corp (TETTAS).

Each activity in the electricity market, such as generation, transmission and distribution of electricity, trade and autonomous production, must be licensed by the regulatory authority. Licenses are awarded for a maximum of 49 years. The statutory minimum duration for production, carriage and distribution license is 10 years. Within the framework of a production license generating companies are allowed to hold shares in distribution companies too [23].

The market structure put in place with the new law is in many aspects fundamentally different from the previous monopolistic and centralized regime. The new structure calls for a dually competitive environment where there are nor state guarantees whatsoever. And the licensing regime which stipulates competition in the market as opposed to competition for the market [27].

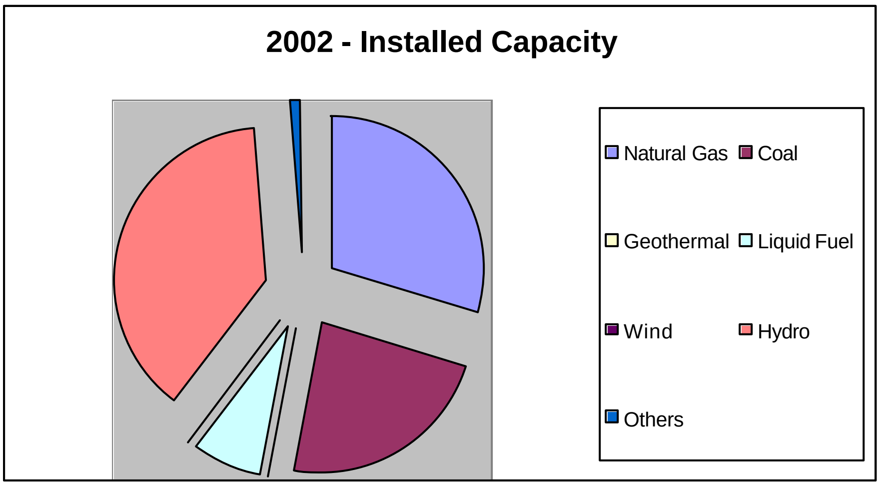


Figure 2-8 Installed capacity in 2002

One thing in primary energy that we should point out is the import dependency and Figure 2-8 shows our dependency to imported fuels clearly.

2.2.3 Wind Energy

Turkey has a considerable potential for electricity generation from wind. A study carried out in 2002 concluded that Turkey has a theoretical wind energy potential of nearly 90,000 MW and an economical wind energy potential of about 10,000 MW. The most promising region is in northwest Turkey, including the area around the Sea of Marmara [29].

Although Turkey has huge amount of wind potential, the installed wind energy capacity is only 18.9MW. The first turbines erected in Çesme- Germiyan with 1.5MW capacity. Three 500kW Enercon turbines were commissioned as autoproducer, under the law 3096, in 1998.

The first BOT wind farm, ARES, was erected Çesme-Alacati and commissioned in November 1998.The facility has 12 Vestas turbines with 600kW nominal power for a total capacity of 7.2 MW. The annual production of the site is about 20,000,000 kWh.

The second BOT wind farm, BORES, is located in Bozcaada. The wind farm is in operation since 2000; it has 17 Enercon turbines for a total capacity of 10.2 MW. The annual energy production is about 40,000,000 kWh [15].

Chapter 3

GUIDELINE FOR WIND ENERGY PROJECTS

This chapter explains the steps that should be taken to develop a successful wind turbine generator project. But it is not possible to show in detail, so the chapter provides a summary for activities to be done. In another words, although each wind project is unique and have different characteristics, it is possible to describe the basic features of a wind project and the steps that developers have to take to get a project realized. This is important to understand all the issues if a new wind project is to be successfully completed. In practice, the steps are iterative and overlap one another to a greater or lesser extent, depending on the specific project circumstances.

Another aspect for successful project development is professional support. Part or potentially all the work involved can be contracted out to an engineering company specialized in wind energy. Involvement of professional support is important for financing. Each planning step should be used to reveal, manage and resolve the risk factors for subsequent steps.

Developing a wind project is a complicated and time-consuming process involving developers, landowners, utilities, the public and various local and state agencies. [30]

The key steps of development and planning for a wind farm are:

- Site Selection
- Ministry of Energy and Natural Resources (MENR) Permit Application
- Feasibility
- Detailed Assessment
- Energy Market Regulatory Authority(EMRA) License Application
- Construction
- Operation
- Decommissioning

3.1 Phase1: Site Selection

The first phase in any wind generation development is to identify a suitable site for the turbines. For many developers the starting point of this process involves looking at a chosen area in order to identify one or more sites which may be suitable for development. The purpose of this phase is to identify suitable sites and define any technical, commercial or environme ntal constraints in order that only the most appropriate sites are taken forward [31]. For successful development, the site selection process should satisfy five crucial technical criteria for successful development

1. Potential Wind Resource
2. Potential Size of Site
3. Electrical Interconnection
4. Land Ownership and Current Usage
5. Construction Issues

Finding a suitable site needs both on site and desk study. “Desk-based” studies to determine whether sites satisfy crucial technical criteria for successful development. The developer need to study topographic and electrical power maps of the local area. Site visit is also necessary, for the developer to collect general information like obvious signs of strong winds (e.g. flagged trees….etc.), the accessibility of the terrain and proximity to the transmission line. A site is selected for further investigation if the preliminary study reveals promising economic potential and an absence of major environmental and technical constraints [32].

3.1.1 Potential Wind Resource

After finding a potentially suitable site, the developer gets permission to erect masts for making site-specific wind measurements. At least one year data is required to determine the average annual wind speed of the site. Wind data is required to determine the average annual wind speed of the site. If wind data show that the site has economic potential for energy generation, the developer will prepare micro sitting, which shows where to put the turbines [29].

Wind speed and proximity to the grid are the most important variables affecting wind farm economics. So if long term wind data from the nearest measurement station is available, these data have to be studied.

According to the Australian Wind Energy Association, with current wind turbine technology and Australian costs, a wind speed of around 6 m/s is considered the viable minimum. But this consideration changes for all countries. For Turkey, this speed is around 7m/s.

3.1.2 Potential Size of Site:

Consideration of the likely size of the site will help to establish whether the development will be commercially viable [33].

Long transmission lines can add to development cost and may eliminate a site, despite promising wind speeds. An examination of the local electricity distribution system and dialogue with the local electricity company will indicate whether an electrical connection to the proposed site is technically and commercially feasible (this only applies to projects which are to be connected to the grid). Information about the electrical grid in the area, map of electric lines and connection possibilities, can be obtained with the electrical company in the area [31].

3.1.3 Electrical Interconnection:

An examination of the grid connection (the local electricity distribution system) will indicate whether an electrical connection to the site is technically and commercially feasible. The capacity of the grid to accept the output of wind farms are limited, this limit is 5% of the short cut power. So the developer should also be aware of the potential impacts of other wind farm developments [33]. A study of the local road network will give an idea of the likely access constraints to the proposed site.

3.1.4 Land Ownership and Current Usage:

Another aspect is consideration of site ownership. Land is often subject to conflicting utilization pressures, in this respect the profile of existing land use should be checked at this early point.

Gaining the approval of the EMRA is a major consultative milestone. The developer’s risk is significantly mitigated once the License is ‘in the bag’. Finance can then be released to perform a more detailed site assessment.

One of the key input to the MENR is the Ministry of Environment’s statement and approval. For instance, the proposed site may be in an area of outstanding natural heritage value.

After the approval of Ministry of Environment, the developers ask MENR to do the expropriation. The expropriation will be done by the MENR on behalf of the developer. Developers should consider the number of landowners likely to be involved in the development and their current and future options for usage of the land.

Environmental Considerations are also subject to the site selection. It is critical to reveal any major environmental issues that could impact the acceptability of the development. For instance, the proposed site may be in an area of outstanding natural heritage value. They are also key input to the EMRA approval is the Ministry of the Environment. The European Wind Energy Association recommends that an environmental impact assessment study is conducted. As well as looking at reports and maps of the area in order to determine specific technical or environmental issues, developers should have regard to existing and emerging national, regional and local planning policies [31].

Visual aspects are also important in environmental considerations. Wind turbines should not be located so close to domestic dwellings that they unreasonably affect the amenity of such properties through noise, shadow flicker, visual domination or reflected light [31].

The following factors should also be taken into account in site selection.

-Ecology

-Archaeological / historical heritage

-Recreational uses

-Civil and military airports

-Restricted areas

3.1.5 Construction Issues:

Construction is another issue for site selection. An overview of site access constraints should be carried out. Most sites are far away from the urban life and often accessible by narrow roads with sharp bends. This may make transportation of long wind turbine blades difficult. Also gradients and dips in access roads may not be suitable for large plant transportation. As a developer we should also be aware that at the location of each wind turbine a handstand and flat lay down area will be required to position heavy lift cranes and pre assemble turbine blades [33].

3.2 Phase2: Feasibility

On the contrary to Phase One, phase two will be focus on site visit and/or survey to determine site's further suitability and availability.

At the end of phase one, the developer had identified a site for further examination. In Phase two, this site should then be subject to:

- a more detailed technical assessment including on-site wind monitoring;

- an economic assessment to establish the commercial viability of the project,

- an assessment of planning constraints;

- a risk analysis

for the installation:

-further consideration and evaluation of grid connection issues [6].

A full technical assay of the site is conducted to reveal the major engineering considerations and environmental factors. From anemometry data, historic wind records and topographical data, long term wind characteristics and power extraction can be predicted. A network analysis is conducted to determine the impacts of embedding the wind farm onto the grid, in terms of surrounding loads, capacity dynamics, constraints and equipment upgrade. A geotechnical study is conducted to determine soil stability, foundation requirements, drainage and potential erosion problems. The legal aspects of the land allocated for the wind farm need ratification, particularly if there is conflicting requirements for land use, or where pre-existing rights need to be regarded. Examples of pre-existing rights include forestry property rights, easements, covenants and leases [32].

3.2.1 Wind Resource

Actual site measurements are vital for the wind projects. For the feasibility study accurate determination of wind speed is needed. In general, the measurement of wind speeds as close as possible to the hub height of a wind turbine is desirable. The cost of tower increases with its height above ground level. Because of the high costs usually 30m masts are used. One or more masts may be required and a typical bankable project requires energy prediction based on at least one year of data, at the hub height (or as near as possible).

After recording on-site data (for at least one year), a long-term assessment is required to remove uncertainty due to the annual wind resource viability. This is usually done by comparing the data measured at the site, with the long-term records from the nearest meteorological station [33].

3.2.2 Land Use and Ground Conditions

The existing uses of the land should be discussed. The legal aspects of the land have to examine carefully. The availability of the land for wind farm must be approved by Ministry of Environment and Forestry. The ownership of the land is also examined carefully.

Turkey is in the middle of two different earthquake zones. So geotechnical engineering investigations should be carried out on the site. This study has to be conducted to determine soil stability, foundation requirements, drainage and potential erosion problems. These investigations will help to assess whether construction of the foundations for the wind turbines, the erection of the machines and the provision of access roads is practical and economic. After micro-siting such investigations could be required at each turbine location.

3.2.3 Energy Yield

Energy yield is an important input into the project layout. Today, special designed computer modeling programs are used for mapping potential energy yield over the site.(eg: Wasp, WindPro) [33]. Unlike conventional energy sources, generation from wind energy is not continuous and constant. So a proper planning for turbine settlement is a must. Before constructing a wind turbine, energy map would help developer to find the area which would give maximum output.

3.2.4 Site Access

The construction of a wind energy project requires access by heavy goods vehicles to the site. Access to the site must be assessed to determine the suitability of existing public and private roads. And find out what improvements or special traffic control arrangements may be required during construction [33].

Movement between turbines must be practical; therefore the route of onsite access roads is also important. On site access roads should avoid steep gradients, not only because of heavy vehicle considerations and also because of potential erosion issues.

3.2.5 Electrical Connection

In grid connected wind energy projects, the cost of connection to the network have a significant affect on the projects' capital cost. Because of the costs for connecting the wind turbine generators to the electrical grid can vary a lot, despite promising wind speeds, long transmission lines can add to development cost and may eliminate a site.

Developers should carry out sufficient electrical investigations to determine potential cost implications of network interconnection and determine the distance to the nearest connection point.

3.2.6 Draft project design

All of the factors considered to date should be taken into account in determining the scale of the proposed wind energy project. However, at this stage, the developer will only be able to consider a range of design and layout options. This should include potential turbine sizes and numbers.

3.2.7 Economic Feasibility

All the steps we explained in Phase 2 are subject to decision making, but economic analysis is also needed both for developers and financiers to decide. The preliminary study would have given an indication of project viability. The purpose of this step is to evaluate the economic feasibility of the proposed site to a level of accuracy required to gain investor development approval.

The data from the comprehensive technical studies, combined with economic and investment data are used for modeling over the anticipated lifetime of the wind farm to assess its economic viability. This incorporates electricity purchase prices negotiated with the utility.

3.3 Phase3: Detailed Assessment

If the information obtained from Phase 1 and 2 shows that proposed wind farm will be viable in all aspects, the developer can implement Phase 3.

It is recommended to continue gathering wind data and to re-appraise the economic viability of the project throughout Phase 3.

3.3.1 Selecting Appropriate Wind Turbine Generator

Equipment Selection:

In addition to the wind resource, the type of the equipment greatly affects the power output. The swept area of a turbine rotor is a function of the square of the blade length so even a small increase in blade length boosts energy capture and cost-effectiveness [33].

The wind speed profile will determine the choice for a wind turbine generator, while the supply of wind influences the relative dimensions of the rotor, generator and shaft height. In poor wind conditions a high shaft height and relative large rotor are necessary.

A number of factors will determine the selection of wind turbine generator for a given site. The wind speed distribution of the site is one of the most important, which has a direct relationship to the amount of electricity. The other most important factor is the power curve of the turbine which affects the revenue (energy) that the site will generate [33].

3.3.2 Electrical Interconnection

Developers will need to continue dialogue with the distribution utility (in our case TEDAS), to identify the significant technical, cost or schedule issues associated with network interconnections. Power utilities have standards for voltage quality and reliability of supply. Developers and turbine manufacturers have to examine these standards, in order to prevent greater investment being made in the power supply system than is necessary to accommodate wind turbine outputs.

3.3.3 Environmental Considerations:

During the feasibility stage developer should have consulted local or state authorities on the scope of the environmental assessment that will be required. Where authorities believe that the proposed wind farm could have significant effects on the environment by virtue of factors such as its nature, size or location, a proponent may be required to submit a formal environmental assessment, sometimes including an environmental management plan. It is very important to seek advice from the planning authority, and/or planning experts on the requirements of environmental impact assessment [33]. Environmental considerations would not be discussed in this study. Only the topics which could be considered in the environmental statement are given [31]. These are; visual and landscape assessment; noise assessment; ecological assessment; archaeological and historical assessment; hydrological assessment; interference with telecommunication systems; aircraft safety; safety assessment; electrical connection; effects on the local economy; global environmental effects; tourism and recreational effects; decommissioning.

3.4 Phase4: Development Application

In this phase, the detailed technical and environmental assessment would be undertaken for the site and electrical grid extension works needed to accommodate the development. If the site is still considered suitable, the developer should apply for the license to EMRA. This process is explained in Chapter2 - the "Energy Sector Regulations".

3.5 Phase5: Construction

Construction of a wind energy plant is respectively shorter than other energy generation plants. It depends on its size and climate of the site. A wind project typically can be built and operational within nine to eighteen months. But the conditions and obligations of the developer doesn't depend on the completion time.

Developers should refer back to the conditions and obligations under which development permission has been granted and development approval conditions should be covered during construction [33].

Wind facility construction requires heavy equipment, including bulldozers, grades, trenching machines, concrete trucks, flat-bed trucks and large cranes. Construction normally begins with grading and laying out the access roads and the service roads that run to the wind turbines. After completing the roads, the concrete foundations for the turbine towers and ancillary structures are excavated and poured. Foundation work is followed by digging the trenches for the underground electrical cables, laying the electrical and communication cables, and building the overhead collection system and substation. Next activities include assembling and erecting the wind turbine towers, mounting the nacelles on top of the tower, and attaching the rotors. Once the wind turbines are installed, the electrical connections between the towers and the power collection system are made, and the system is tested [30].

It may be beneficial for the developer to identify and individual with the overall responsibility for site management, because there will be number of separate contractors involved in the construction work of the project.

In the construction phase the developer will need to enter into a number of construction agreements. Developer may need an expert in the management of engineering contracts to provide financial and legal security to the project [33].

3.6 Phase6: Operation

The continuous satisfactory and continuous safe operation of the plant throughout the project lifetime is developers and/or the owners and operators responsibility. He should comply with all the facts and conditions of the development approval stipulations. The main responsibility of the owner/operator in operation stage is formulating plans for operations and maintenance of the farm (e.g. performance tests, availability tests,…etc.)

A wind facility requires few on-site personnel. Turbines operate automatically. Each wind turbine is equipped with a computer for monitoring and controlling the activity of turbine and also for monitoring wind conditions. The operators use these data for reporting and diagnose the cause of any failure. The operator may restart the turbine directly from the control facility. If he is unable to restart, then specially-trained mechanics are dispatched to repair. By the monitoring system the operator can monitor the power output of each turbine [30].

On going operations and maintenance of the wind farm can be outsourced and contractual arrangements need to be made for outsourcing. This contract must include issues of operational safety issues. Turbine manufacturers give this services but it may be a time consuming and costly action if the manufacturer is at another country. It would be preferable to have two maintenance contracts; one with a local maintenance company for small failures and secondly with the manufacturer for scheduled maintenance and for major breakdowns which shall need expertise [33].

3.7 Phase7: Decommissioning

NWCC defines repowering as follows: "Repowering of a wind facility entails the removal of individual turbines which are then replaced with new equipment." The repowering can be possible only if the economics is supporting.

Another definition of decommissioning made by NWCC is; "The decommissioning of a wind facility entails the dismantling and removal of all wind turbines and towers, as well as the underground and overhead collection and transmission system. Typically, the foundations for the towers and other structures are removed to a specified depth below the ground surface. They all depend on the permits and terms of the land agreements."

Wind farms typically have 20-25 years of design life and agreements are often made on this basis. After the project time the owner/operator may update the wind turbines with more efficient machines or remove them altogether. If the project is built as BOT then after the design life, -20years-, mentioned in the agreements the owner of the wind farm will be MENR and MENR would decide what to do. Neither of the wind projects completed their design life in Turkey so it is not certain what MENR would do or decide.

The subject of decommissioning and site clearance should be adequately covered in the planning conditions and/or planning agreements accompanying permission. However, should the wind energy project cease to produce electricity for a specified period, the owner/operator should remove all the turbines and return the site as closely as practicable to its original state [31].

Unlike most power generation projects, wind turbines can be decommissioned easily and rapidly. Despite this, developers still need to approach the issue of decommissioning responsibly. Notice should be given to the local planning authority in advance of commencing decommissioning work [31].

Normally the scrap value of the turbines themselves will be sufficient to cover the costs of their dismantling. Where this may not be the case, consideration should be given to the setting aside of funds over the life of the project in order to ensure there will be enough money available at the end of the project's life to pay for decommissioning and other reinstatement requirements [31].

Chapter 4

ECONOMIC ASSESSMENT OF WIND FARM PROJECTS

Despite of all positive environmental aspects which are related with the of use wind energy cost effectiveness and reliability are the most characteristic attributes which influence the readiness to invest into wind energy projects. Cost effectiveness of wind energy projects depends on several parameters. These are the total investment cost of the project, the operation and maintenance costs, the depreciation period and interest rates for loans. Furthermore the energy yield which depends on the quality of the sites, the technical availability of the turbines and the reliability of service staff have major influence on the economical development of wind projects [34].

The electricity supply industry is highly capital intensive. It is probably more capital intensive than any other sector, particularly in developing countries. Therefore, planning and proper financial and economic evaluation of projects are important for rationalizing investment and achieving economic efficiency. [35] The economic parameters and important issues in financial evaluation are explained in this chapter.

A feasibility study is the due diligence that every company should do before starting any project. It helps to avoid risk. Risk is an inescapable fact of the business, but a well prepared and researched study can help reduce the risk. The feasibility study should provide all the data and details necessary to take a decision to invest in the project.

The background features; size and location of the facility, technical details, network features, environmental impacts, timing of the project and implementation schedule; have been well defined in the feasibility stage.

This study mainly concerned with the financial and economic evaluation of wind energy projects to ensure their viability. However, it is essential to understand the impact of the other four considerations in electrical power project feasibility. These are; the sector, the market, technology and engineering analysis and management and manpower.

The generation cost of wind energy basically is determined by the following parameters: [36]

- total investment cost, which consists of production, transportation and erection cost of wind turbines; project preparation costs (permits), cost of land, cost of the infrastructure and suchlike;
- operation and maintenance cost
- average wind speed at the particular site and hub height
- availability
- technical life-time
- amortization period
- real interest rate.

The required capital cost includes the following elements:

1- Feasibility Study (1-10% of the total wind energy project cost) including:

- Site investigation

-Wind resource assessment and analysis

-Environmental assessment

-Preliminary design

-Detailed cost estimation

-Report preparation

-Project management

-Travel and accommodation

2- Development (1-10% of the total wind energy project cost) including:

-PPA negotiation

-Permits and approvals

-Land rights & land survey

-Financing

-Legal and accounting

-Project management

-Travel and accommodation

3- Engineering (1-10% of the total wind energy project cost) including:

-Micro-siting

-Mechanical design

-Electrical design

-Civil design

-Tenders and contracting

-Construction supervision

4- Renewable energy equipment (40-80% of the total wind energy project cost) including:

-Wind turbine(s)

-Spare parts

-Transportation and installation

5- Balance of plant (10-30% of the total wind energy project cost) including:

-Wind turbine(s) foundation

-Wind turbine(s) erection

-Road construction

-Transmission line and substation

-Construction of operation and maintenance facilities

-Transportation

6- Miscellaneous (1-10% of the total wind energy project cost) including:

-Contingencies

-Personnel training etc.

-Interest during construction

-Commissioning

The annual costs associated with the operation of a WECS projects are:

-Spare parts (parts and labor)

- Operation and Maintenance (O&M)

-Contingencies

-Land Lease

-Property taxes

-Insurance Premium

-Transmission line maintenance

-Travel and accommodation

-General and administrative

There are two cost inputs to a wind developer or owner. The capital, or installed, costs of the plant are primarily a function of the size of the installation (due to economies of scale). Operating costs are the second input, and, similarly, depend on size, and may be dependent also on capacity or energy yield.

It is estimated that wind power in many countries is already competitive with fossil fuel and nuclear power if external and/or social costs are included. The wind as a fuel may be free, but the equipment necessary to generate electricity from wind tends to be expensive, so economic studies are quite important.

4.1 Capital Costs

The economy of a wind energy project depends primarily on the wind turbine (WT) price and the energy yields. Also variables like additional capital expenses, subsidies, reimbursement and constructive parameters of wind turbines influence the energy generating costs.

The economics of wind energy differ significantly from country to country. There are no absolutes in energy prices. No single number can be assigned to the price of wind energy.

The unit cost of electricity can be determined from capital investment and operation costs but the value of electricity is somewhat more difficult to determine. But it must be calculated before investment decision made. In this thesis only the unit cost of electricity is evaluated.

Wind turbine prices vary little with size, but there are sound reasons for pursuing the development of large machines. The use of large machines means fewer are required for a given capacity, and a number of items in the “balance of plant” cost category decrease with machine size, or machine numbers, especially: foundation costs, electrical interconnection costs and access tracks [35].

A wind turbine contains many components. Rotor, gearbox, generator, bedplate, various sensors, controls, couplings, a brake and lightning protection are at the top of the tower of a horizontal axis turbine. Transformers, switchgear, protective relays, controls are at the foot of the tower.

To have a working system a distribution line, which connects the turbine to the utility grid, land, an access road, control and O&M building are also required.

Some capital costs, such as distribution lines, land and access roads can vary widely with the site.

Turbine costs include the following; purchase price of the turbine, shipping, import duty, import broker fee, concrete and other foundation costs and labor.

The steady extension of wind energy use within the past years was accompanied by new turbine generations. New generations with more installed power and improved economy. The wind turbine prices decreased due to the serial production. But next to the prices, the additional expenses are an essential factor of the economy of a wind energy project. Such additional expenses could be: foundation costs, grid connection costs (e.g. transformer, delivery station, grid reinforcement etc.) development of ground (drive ect.) and planning costs. [37]

In Germany the additional expenses percentage referring to wind turbine prices are foundation (7%), grid connection (17%), development of ground (2%), planning costs (4%), sum of additional expenses (30%). Further costs which accrue regular due to the operation of a wind turbine are the so called operation costs. This could be for example: insurance, maintenance costs, costs of leased area, spare parts [38].

4.2 Operation and Maintenance (O&M)

Operational costs vary between countries and wind farms. As some elements are fixed annual sums, wind farms on high wind speed sites may have lower costs. The main components are; service, consumables, repair, insurance, administration, possible lease of site, and so on.

Danish and German experiences indicate that the annual operation and maintenance costs for new grid-connected wind turbines in the 0.5-1.5MW size range are approximately 0.5-0.9 US cents / kWh, of which half consists of insurance cost. For machines with over 10 years of operation these costs may go up to a level of 1.3-1.7/ US cents kWh [36].

Availability and thus energy production depends on reliability and accessibility of the wind turbine installations. In particular, wind turbines located offshore and in mountainous terrain are subject to potentially very high costs, through increased operation and maintenance costs and loss of availability. In this respect, it is essential to accelerate the development of early failure detection systems and systems to monitor machine condition. These systems would be linked with planning systems for maintenance, and the data obtained may be used as inputs to improve the reliability of the wind turbine design [39].

The annual O&M cost is often estimated as 3% of a wind turbine's ex works cost. Technical life time or designed life time for European machines is typically 20years. Individual components are to be replaced or renewed in a shorter interval. Consumables such as oil in gearbox, braking clutches, etc. are often replaced with intervals of 1 to 3 years. Parts of the yaw system are replaced in intervals of 5 years. Vital components exposed to fatigue loads such as main bearings, bearings in gearbox and generator are foreseen to be replaced halfway through the total design life time [3].

Chapter 5

ECONOMIC CONCEPTS: CONSIDERATIONS IN PROJECT EVALUATION

In order to compare the projects and make investment decisions, common units must be used to express the outputs of each alternative before any comparison can be made. Monetary units are the most commonly used units.

Some projects will provide outputs in the near future and other projects may delay outputs for an appreciable time or distribute them uniformly over the project lifetime. Outputs today do not have the same value as outputs tomorrow. Project owners and bankers have different perspectives for evaluation while owner concerns only with the return to equity, banker considers both equity and loans. Owners/Developers are mainly concerned with cash flow and considers all money flowing in (income from sales) as positive and all money flowing out (project cost, operation costs…etc) as negative. They are interested in net benefits and net present values in comparison to the value of their investment (equity).

Banker's point of view is different from a developer. The bankers analyze the project for loan considerations. The banker evaluates the return on the total investment (equity plus loan) and considers its profitability.

Despite different point of view, the important aim for all parties is to ensure that the project is the least-cost alternative for attaining the required output. It is necessary to ensure that a project is profitable and that its return is higher than the opportunity cost of capital.

The Electricity Supply Industry (ESI) is one of the best venues for using least-cost solution techniques, since there is always more than one way in which a project can be executed so that its benefits can be secured. Least-cost solutions aim to evaluate all realistic alternatives, financially and economically, before deciding the alternative which can achieve the project benefits at the least cost [40].

The aim of the least-cost solution is finding, technically and economically, the most suitable alternative for the utility. In most electrical power engineering decisions, there is more than one alternative for achieving the required result. The least-cost solution considers all these alternatives and evaluates them. In choosing the least-cost solution the decision makers are concerned with the differences in the present value of the cost of the alternatives. In many cases, the outputs of each alternative are the same, as a result of meeting the project objectives. But in wind energy projects, the output of different turbines with the same installed capacity is different because of the technical considerations of the turbines.

When there are differences in the amount of the energy output, the comparison can be done by per discounted kWh of electricity output, through evaluating, the overall system of the alternatives. The essential economic concepts and criteria which may lead to safe conclusions with respect to the economic and financing viability in terms of investment and operation of a Wind Energy Conversion System (WECS) at a given site with prescribed wind and other relevant conditions are the following: Pay Back Period (PBP), Return of Investment (ROI), Net Present Value (NPV), Internal Rate of Return (IRR), Benefit/ Cost Ration (BCR) [41].

The computation of the PBP index is a useful approach to obtain a quick and appropriate economic viability system evaluation, whereas the computation of the NPV, IRR and BCR indicates constitutes a more accurate approach for a similar evaluation procedure [41]. For an investment project to be properly evaluated, one must take into account all the required initial investment cost elements for the WEC system and also the costs and benefits associated with the operation etc. the system. Several methods can be used to determine the financial benefit of a wind system investment.

Only the three important ones are considered in this study. These are; estimating the payback period, IRR and NPV methods. These methods are more appropriate for grid-connected systems than for remote, off-grid systems.

5.1 Net Present Value Method

"Time Value of Money" and "discounting" concepts have to be understood before discussing Net Present Value.

5.1.1 Time Value of Money

Projects in the electricity supply industry live for a long time. Normal useful life of a conventional power station is about 25-30 years and for a wind power project it is about 20-25 years. For power generation projects most expenditure and income occurs after commissioning. Such future financial flows will fluctuate according to time and circumstances. Correspondingly, these will have a different financial value than flows occurring during project evaluation. Therefore, the time value of money is highly important for capital-intensive long life projects, like electricity supply industry [40].

5.1.2 Discounting

In general, financial flows occur after commissioning, they do not occur during project evaluation. In evaluation stage, the project developers and decision makers have to know if the project is feasible or not. So cash flow tables are important for developers for decision making. But cash flows occurring at different times cannot be readily added, since a dollar today is different from a dollar a year later. So before dealing with financial flows occurring at different times, these have to be adjusted to the value of the base year. Therefore, an important factor to be discussed in project evaluation is the time value of money. The time value of money states that a dollar today is worth more than a dollar at some time in the future.

There is variety of reasons for this: risk, inflation, opportunity cost, etc.

- Inflation; future incomes are eroded by inflation
- The existence of risk; an income or expenditure which occurs today is a sure amount, future income or expenditure may vary from anticipated values;
- The need for a return-by undertaking investment and forgoing expenditure today, an investor expects to be rewarded by a return in the future [40].

An entrepreneur expects to gain a premium on his investment, to allow for the following three factors: inflation, risk taking and the expectation of a real return. That is, he expects to regain his money, plus a return, which tallies with the market and his estimation of these three factors [40].

Money today will be more valuable than tomorrow's money because of risk and expectation of reward by foregoing today's expenditure, even if inflation is ignored or allowed. To an investor point of view, a dollar today is more valuable than tomorrow's dollar because it can be invested immediately and can earn a real income, that is, a return higher than inflation. Today's dollar will equal tomorrow's dollar plus a real value.

Present valuing (discounting) is central to the financial and economic evaluation process. Since most of the project costs, as well as benefits, occur in the future, it is essential that these should be discounted to their present value (worth) to enable proper evaluation [40].

$$PV = F_n.\frac{1}{(1+r)^n} \tag{5.1}$$

where F_n is future value and r is the discount rate.

Discount rate is the reward that investors demand for accepting a delayed payment. It is also referred to as the rate of return or opportunity cost of capital.

The value of $\frac{1}{(1+r)^n}$ is called discount factor. It is universal, with n positive for all future years and negative (-n) for all past years financial outlays, with n=0 for the base year.

It has to be emphasized that valuing is based on compounding returns. That is, the expected return on the first year's money is also added to the original investment and then the sum reinvested at the same interest rate. This is different from simple return (simple interest), where interest is only paid on the original investment. [40]

5.1.3 Net Present Value Calculation

Net present value is computed by assigning monetary values to benefits and costs, discounting future benefits and costs using an appropriate discount rate, and subtracting the sum total of discounted costs from the sum total of discounted benefits. Discounting benefits and costs transforms gains and losses occurring in different time periods to a common unit of measurement. Programs with positive net present value increase social resources and are generally preferred [42].

The present value (PV) method aims at present valuing (discounting) all costs and benefits of the project or cash flows (net benefits) to a specified date, the base year [40].

In this case, all cash flows prior to or after the base year are discounted to the base year through multiplying by the discount factor $\left[1 \div (1+r)^n\right]$ where n is negative for years prior to the base year. All values are considered to occur at the year-end [40].

Cost (C) and benefit (B) are the two financial streams of the project along the life of the project. Benefit item must contain all the benefits for the same estimated life frame of the project.

The present value is the value at Year 0, with equal payments being made at the end of each period. Economic alternatives can always be compared by examining the PV of each scenario/alternative.

$$P_v = A_n \frac{(1+i)^n - 1}{i(1+i)^n} \tag{5.2}$$

where P_v is present value, i the interest rate, A_n end of period payments series of payments and n is the period.

The cost stream, being outward flowing cash is regarded as negative. The difference between the two streams is the net cash flow. The value of the net cash flows in certain years can be negative, particularly during construction and the early years of the project.

Discounting the net benefits stream into its present value, by multiplying each year's net benefits, i.e. project income minus project cost, by that year's discount factor, will present the net present value (NPV) of the project. Notice that outward flowing cash (costs) is negative and inward flowing cash (income) is positive [40].

If the net result is higher than zero, this proves that the project will provide benefits higher than the discount rate and is worthwhile undertaking.

The NPV method is a powerful indicator of the viability of projects. However, it has its weakness in that it does not relate the net benefit gained to the capital investment and to the time taken to achieve it. However, it is a very useful method for choosing the least-cost solution, since it is the alternative which fulfils the exact project requirements, and has the higher NPV that is preferred [40].

$$NPV = \sum_{N} (B_n - C_n)/(1+r)^n \tag{5.3}$$

where; NPV is net present value, B_n benefit , C_n: cost , n period and r the discount rate.

One of the advantages of the NPV method is that is accounts for the time value of money. The NPV method determines the worth of a project over time, in today's dollars. The greater the NPV value of a project, the more profitable it is. This method can be used to rate and compare the profitability of several competing options [43].

Usually, projects are undertaken because they have a positive net present value. That is, their return is higher than the discount rate, which is the opportunity cost of capital. The calculation of net present value is the most important aspect in project evaluation and its positive estimation, at the designated discount rate, is essential before undertaking a project.

According to the literature surveyed the life cycle costs of a project and its feasibility depends on 3 factors; the investment cost, the operational costs and the discount rate utilized.

Many developers think that the discount rate is the most important of these three factors. It greatly affects the whole economics of the project and the decision making, particularly in capital intensive projects like those of electricity supply industry [40].

It greatly affects estimation of the net returns from the project during the evaluation stage. Because of this, it is important in decision process. A high discount rate will favor low capital cost with higher operational cost project alternatives. A low discount rate will tend to weigh the decision in favor of the high capital cost and low operational cost alternatives [40].

In spite of its crucial importance, we will not discuss 'choice of the discount rate'. We will take a specific discount rate and do the calculations according to this specific rate.

5.2 Internal Rate of Return (IRR)

Calculating the internal rate of return is a popular and widely used method in the evaluation of projects. The internal rate of return (IRR) is that discount rate which equates the two streams of costs and benefits of the project. Alternatively, it is the rate of return, r, that project is going to generate provided the streams of costs (C_n) and benefits (B_n) of the project materialize. It is also the rate r that would make the NPV of the project equal to zero. [40]

$$\sum [C_n/(1+r)^n] = \sum [B_n/(1+r)^n] \tag{5.4}$$

where C_n is the costs B_n the benefits, r the discount rate and n the period.

If IRR is equal to or above the opportunity cost for a private project or the social discount rate (as set by the government) in public projects, then the project is deemed a worthwhile undertaking. Utilities, governments and development funds set their own criteria for the opportunity cost of capital and for the social discount rate below which they will not consider providing funds. Such criteria depend on the amount and availability of required funds. Criteria also depend on the presence and expected return of alternative projects in other sectors of the economy, the market rate of interest and the risk of the project [40].

The main merit of the IRR is that it is an attribute of project evaluation. Its calculation does not involve the estimation of a discount rate; therefore, the evaluator avoids the tedious analysis [40].

Maximization of NPV while utilizing as a discount rate, the opportunity cost of capital is the guiding principle for project evaluation. The internal rate of return is not the only criterion for project evaluation for investment decision. NPV with a proper discount rate is a criterion, when the discount rate reflects the true opportunity cost of capital [40].

5.3 Simple Payback Method

5.3.1 Payback Period

A common and simple way to evaluate the economic merit of an investment is to calculate its payback period, or break-even time. The payback period is the number of years of energy-cost savings it takes to recover an investment's initial cost. To determine the payback, the investor first estimates the wind turbine's total initial cost, annual energy-cost savings, and annual operating costs. Dividing total initial cost by the difference between annual energy-cost savings and annual operating costs gives the payback period [44].

The payback period is the amount of time (usually measured in years) to recover the initial investment in an opportunity. Unfortunately, the payback method doesn't account for savings that may continue from a project after the initial investment is paid back from the profits of the project, but this method is helpful for a "first cut" analysis of a project [43].

If annual cash flows are equal, the payback period is found by dividing the initial investment by the annual savings.

$$\text{Payback Period (in years)} = \frac{\text{Initial Investment Cost}}{\text{Annual Operating Savings}} \quad (5.5)$$

$$\text{Annual Operating Savings} = \text{Annual Energy Cost Savings} - \text{Annual Operating Costs} \quad (5.6)$$

Annual electric savings are the retail value of electricity from the wind system that you would have otherwise bought from the utility company. It is determined that by multiplying the retail cost of electricity given on your electric bill by the number of kilowatt-hours the wind turbine is supposed to produce in a typical year [44].

Chapter 6

FINANCING WIND ENERGY PROJECTS

Specifically with regard to financing wind energy, as the industry grows, the investment requirement increases accordingly. The European Wind Energy Association estimates the funding requirement will be around USD 125-140 billion over the next twenty years [45].

Despite encouraging growth forecasts and a fair amount of enthusiasm, private investment in the renewable energy sector is currently very modest and largely limited to energy sector specialists. The industry is still heavily dependent on government and public sector funding, and favorable political policies and framework conditions are still essential for the commercialization of renewable energy [46].

Although many renewable energy companies are small players, the renewable industry is growing rapidly, with established energy companies and financial institutions entering the market. While the entry of large companies is improving the profile and attractiveness of the renewable industry to more conservative investors, the investment amounts are still smaller than fossil fuel exploration.

These are titled as enhancing domestic capital markets, accessing international capital markets, enhancing public-private partnership, restructuring tariffs and reducing subsidies, and lastly restructuring the power industry. The importance and priority of every each of the items varies in accordance with the conditions to specific country [45].

Sources of finance and financing methods, which are used by these agencies, are listed below [47 ,48];

6.1 Sources of Finance

- Private Equity Funds-Equity
- Banks- Loan, Bond
- Export Credit Agencies (ECA's) – Loan
- Multilateral Lending Agencies (MLA's) – Loan, Equity
- Leasing Companies – Loan
- Vendor Financing – Loan

- Securitization – Loan
- Institutional Investors – Bond, Equity
- High Net Worth Individual Investors – Bond, Equity
- Host Governments – Loan, Equity

6.2 Financing Methods

The financing methods for energy projects are:

- Project Finance
- Balance Sheet Finance
- Sale and Lease Back
- Mortgaging
- Cooperatives and Guilds
- Renewable Energy Investment Funds
- Individual Ownership
- Government Aid and 'soft' Loans
- Third Party Finance
- Syndicated Loan Credit

Allocation of funds is significantly more available in Europe (developed countries). Most European countries have some incentive mechanisms for renewable energy generation.

Since classic market forces—i.e., price, demand, and supply—do not account for environmental or other non-economical advantages of renewables, most European countries have provided some sort of incentives to support renewable energies at various stages of their development. In general, these incentives can be categorized as follows [49].

1) Public funds for research, development and demonstration programs.

2) Direct support of investment costs (either in % of total costs or as a certain amount per installed kW).

3) Support through premium prices for electricity from Renewables (an amount per kWh delivered).

4) Other financial incentives—special loans, favorable interest rates, etc.

5) Tax incentives such as favorable depreciation terms, etc.

6) Other incentives, such as regional funds for structural support, which are not meant exclusively for renewables [49].

In practice, a refined renewable energy introduction policy will not employ only one of these incentives, but use a combination of different sorts of incentives. There is no single or one-way strategy for success. Different approaches have led to different market developments for different countries. According to the researches the premium fixed price strategy is far more successful than the quota system.

Wind energy industry is capital intensive, and requires long term finance. For the developed countries' case, financing wind plant investment is relatively conventional from traditional sources particularly from commercial finance sources. On the other hand, this path does not apply to the developing countries. As the political and economic stability has not established for most of the developing countries, external fund providers are generally more reluctant to invest in these countries [45]. But renewable energy projects are still a relatively minor or new element of the business activity of financial institutions. This chapter will focus on overcoming financial constraints which have been widely acknowledged as the most significant challenge faced by renewable energy projects.

Traditionally, when a developer asks for money from a bank, the borrower carries all the risk of failure. The bank requires the borrower to provide some form of security like property, land or equipment for recovering its debt if the borrower fails to maintain the agreed loan repayments. The bank can use this security.

But the value is principally derived from the electricity it will generate rather than the resale price of the second-hand turbines so such security is difficult to deliver for a wind power development. Because of this, wind energy developers need (require) a different approach from a bank/financier. By this new approach, banks or financial institutions have to take on more risks associated with the success of the project. This is Project Finance. A contract like ESA is generally a pre-requisite of project finance.

6.2.1 Project Finance

Project finance is any financing of a venture where the financiers look to the cash flow and earnings of that particular project as the principal source of repayment for the borrowed funds, and to the assets of the venture as the key collateral [48].

It is generally possible when;

- The project is an independent economic unit and will generate sufficient cash flow to service the project debt and pay an acceptable rate of return to the equity investors.
- The project will be technically feasible and will generate output as its design capacity.

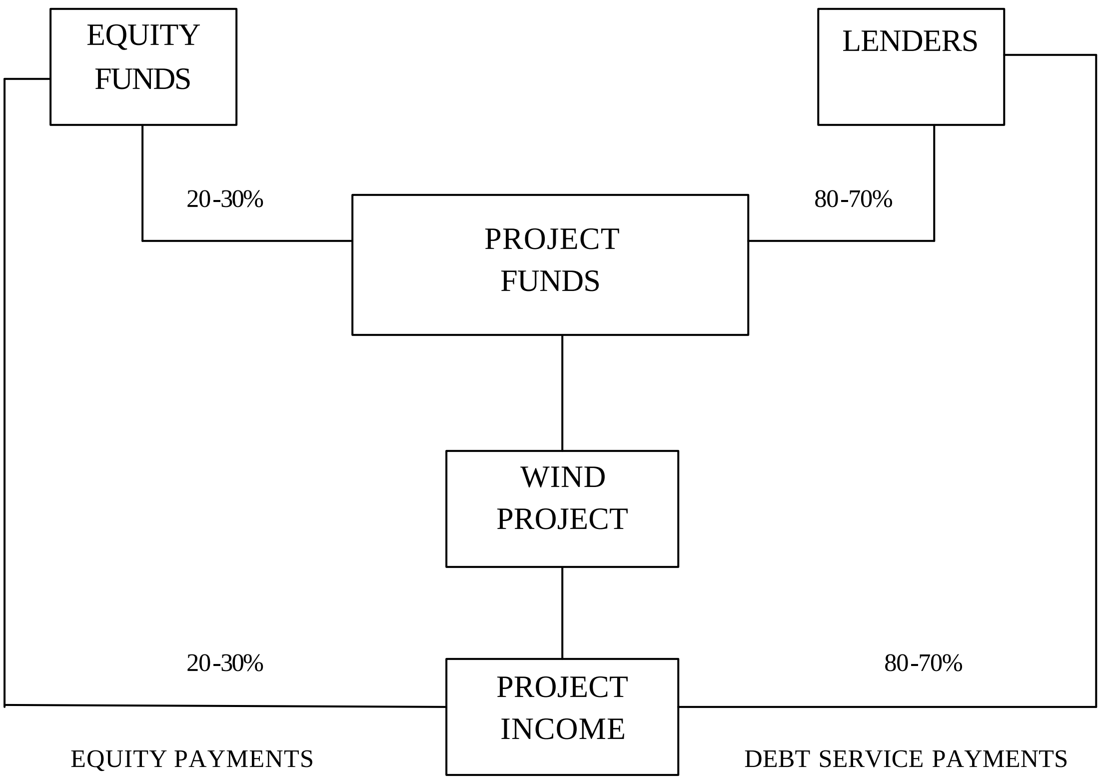


Figure 6-1 Structure of Project Financing

With project financing, banks/financial institutions have to take more of the project risk than in traditional lending, so they need to have a special risk management approach for wind energy projects.

There may be construction risk, currency risk, political risk, market risk, timing risk, along with many other types of risk. A successful project finance structure will efficiently allocate these various types of risks to those investors/participants most able and willing to assess and bear the risk [50].

The banks and/or financial institutions have different risk management approaches. But the general framework can be summarized as;

• Thoroughly evaluating the risk through a process of due diligence; Due diligence is a fundamental requirement of project financing for wind power projects.

Due diligence can be defined as; the practice of researching the feasibility of a project including evaluating contracts, visiting the project site, meeting with project participants, building a financial model, and confirming key legal and regulatory aspects [48].

It examines the legal and technical robustness of a project and therefore provides some guide to the level of risk being taken on by the investor/bank and banks are seeking to find ways to control those risks [51]. A sample of due diligence requirement list for a wind energy project is shown in Figure 6.2.

• controlling the risk through fixed cost and, ideally, turnkey construction contracts and long-term power purchase contracts; construction contracts offer a broad range of possibilities for allocating risk among project participants. Power purchase agreement (PPA) would include an energy payment to cover the projects operating expenses.

• creating an element of security through debentures over assets and undertakings, first charges over site leaseholds and issued share capital, and a debt service reserve, and;

• maintaining the commitment of the project owners to the project's success through a minimum equity stake of at least 20% of the total project cost.

There are some side benefits resulting from financing the wind projects as project financing, which may have a bearing on the motives of the company seeking such a structure [52] :

a) credit sources may be available to the project which would not be available to the sponsor;

b) guarantees may be available to the project which would not be available to the sponsor;
c) a project financing may enjoy better credit terms and interest costs in situations in which a sponsor's credit is weak;
d) higher leverage of debt to equity may be achieved;
e) investment protection for foreign investors may be improved by joining as joint ventures with international parties, thus lessening the sovereign risk;
f) a more favorable labor contract or climate may be possible by separating the operation from other activities of the sponsor; and / or
g) construction financing costs may not be reflected in the sponsor's financial statement until such time as the project begins producing revenue.

In some instances, any one of the reasons stated above may be the primary motivation for structuring the wind projects as a project financing.

INFORMATION REQUIRED	*OPTIMUM (WHERE RELEVANT)*
Site wind data	
• Hourly or ten-minute wind speed and direction data	*A minimum of at least one year*
• Description of equipment used to record data	
• Available calibration certificates for equipment	*Calibrated in the UK at one of the main wind tunnel establishments*
• Conversion factors (eg m/s per Hz) applied in recording wind speeds	
• Maintenance records for the monitoring work	
• Location, height and orientation relative to mast of all sensors	*In close proximity to proposed turbine positions at a height at least 2/3rds of the hub height of the proposed turbines, with sensors on booms to minimise effect of mast on recordings*
Reference wind data *(from nearby meteorological station)*	
• Hourly or ten-minute wind speed and direction data	*Concurrent with the site data*
• Historic data of at least 10 years with evidence of no significant changes in exposure during the measurement period	*As provided by the Met. station in the form of either a time history or a high resolution frequency table*
• Description of equipment used to record data	
• Available calibration certificates for equipment	
• Maintenance records for the monitoring work	
• Location, height and orientation relative to mast of all sensors	
Wind turbine information *(for output predictions)*	
• Turbine make and model	
• Turbine rotor diameter	
• Turbine hub height	
• Turbine power curve warranted for the site	
• Turbine rotor thrust curve	
• Independent measured power curve report for the turbine model	
• Turbine rotational speed	
Wind farm information *(for output predictions)*	
• Maps showing turbine layout and areas of rough land cover	
• Detailed topographic maps	*Preferably in digital form*
• Siting constraints (boundaries, minimum spacing)	

Figure 6-2 A sample of due diligence requirements for a particular bank [51]

6.2.2 Syndicated Loan Credit

A syndicated loan is a number of separate loans made by individual banks to the same borrower, which are subject to the same terms and conditions [53]:

- each lending bank is obliged to lend funds to the borrower
- each lender possesses individual rights to interest and principal from the borrower
- borrower's obligation to repay is owed to each syndicate bank in specified amounts(and not to any one bank)

The pricing is consist of a fixed rate (LIBOR or US Prime Rate) plus. Interest rate is floating because it depends on LIBOR or US prime rates which are highly cost relative to other markets. This is the major disadvantage of the syndicated loan market.

The general advantages of the syndicated loan market are [52]:

1. Large amounts of debt can be raised. The syndicated loan market is the largest source of international capital.
2. Loans may be made in any of several currencies.
3. The number of participants can be substantial.
4. Banks participating in syndicated loans are sophisticated and able to understand and participate in complex credit risks presented by project financing.
5. Prepayment is customarily permitted.

Although, funding period depends on the project, it can be said that usually it is 15 years for energy projects.

There are 4 types of syndication credit [54]:

1. Traditional syndicated loans-floating rate
2. Syndicated bank loan-fixed rate
3. Revolving credit
4. Standby facility

Usually there are 3 main participants: borrower, lead manager and participants. Syndicated loans are arranged by a manager or lead manager. There are specific procedures which have to be followed. Terms and conditions are negotiated by the manager. There has to be a consensus within all parties. Borrowers are able to find large size of financing with syndicated loans. Their flexibility and accessibility to relatively quick and cheaper funds are the major advantages of syndicated loans.

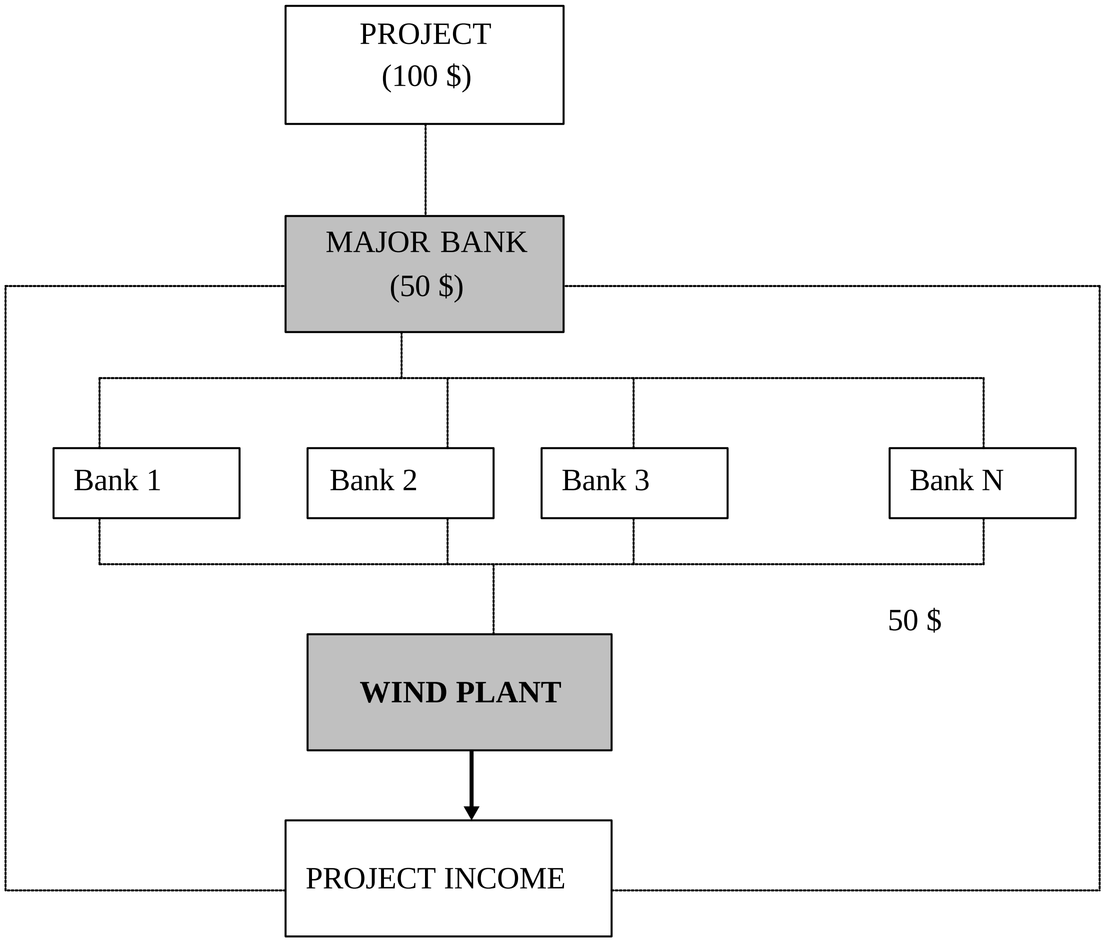


Figure6-3 Structure of a Syndicated Loan Structure

The main problem for developers in wind energy sector is financing a project. The problems to obtain finance arise because many renewable energy projects are capital intensive and require longer repayment periods than conventional technologies. As the county struggles with inflation and unstable economic conditions, the financial sector can not provide long term, low cost funds. Under this scope, the realization of projects can be possible with the contribution of multinational agencies and foreign investors. Although, there are many financial methods this study examined project finance and syndicated loan credit which are the most suitable methods for energy project financing.

Chapter 7

CASE STUDY ON IZTECH CAMPUS AREA

Successful wind farm development depends on good location like any other form of property development. Location dictates three key factors – wind (energy output), grid availability, and construction conditions – all of which impact on a developer's value creation.

A few years ago, IZTECH undertook some steps to initiate a wind farm project on the campus area. The main objective was to generate the need of the campus buildings. Then the study is enlarged and the scenarios are diversified. Still the study presented for the wind farm is quite preliminary and for the final wind farm lay out, it would be essential to make a detailed inspection of the area.

First, the previous studies about the project are summarized in this chapter. Initial studies evaluated the wind potential and the practicability of a wind farm considering availability of land and wind resource.

This study starts with finding the maximum capacity which can be installed in the campus area with consideration of grid constraint, accessibility and energy consumption. Then the energy consumption of the campus is evaluated as secondary step. Third step, economic analysis is done for three alternative scenarios. And lastly, sensitivity analysis and variance analysis is done for all three scenarios.

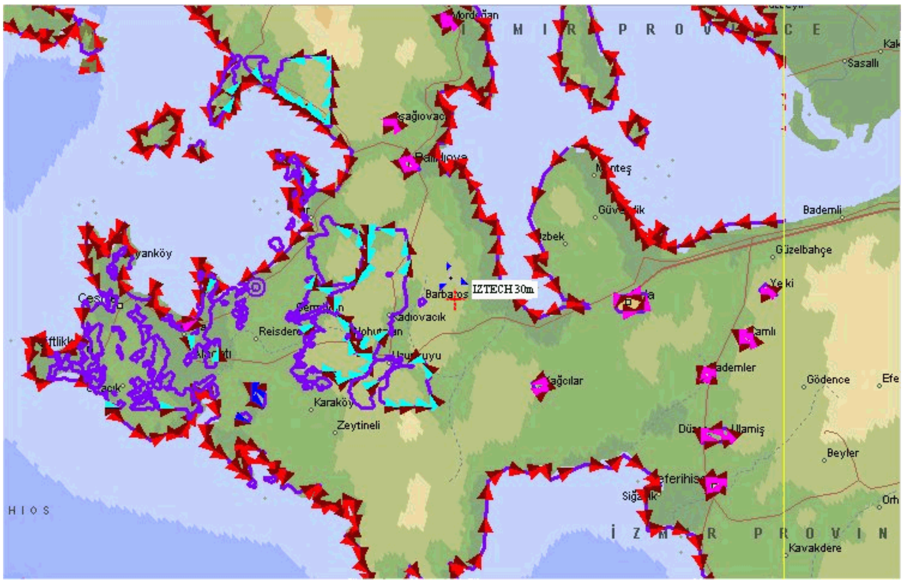
7.1 Site selection:

The proposed site is IZTECH Campus area, which is located in Urla-Izmir. Campus area is 3500ha with several hills covered with typically Mediterranean bush. The only settlement in the area is the campus buildings. No agricultural or animal raising activities are being practiced in the area.

The site has been chosen from the visual inspection of the site by taking into account the wind data, the magnitude, prevailing wind directions, the proximity to the village, the orography etc [55].

Fig. 7-1 shows the area of interest and the location of the wind mast of IZTECH.

Figure 7-1 Location of the IZTECH mast on Izmir map



7.2 Available Data

7.2.1 Historical Data

An accurate estimation of the wind resource is the very basis of a site’s energy production and revenue generation potential. Wind resource is strongly affects the turbine choice and site design. Error in wind estimation has the potential to significantly impact on the project’s viability. Because of this reason, collecting wind data is a crucial phase for wind energy development.

Wind Energy Division of the Turkish Directorate of Electrical Power Survey and Development Administration (EIE) installed several wind measurement stations in several regions since 1990. Monthly mean wind data are available from these stations and these data show very promising areas for the use of wind energy. The nearest EIE mast to IZTECH site is Kocadag, mast which is close to Barbaros village [56,57].

7.2.2 IZTECH Site Data

IZTECH mast is 30m tall tabular tower, which was erected in July 2000. [6] The mast located at 400m height, between Sineklidag, Çiftlik Dagi, Canavarlidag and Nurdag mountains with coordinates 465684E, 4243843N (in UTM Coordinate System)

It has two anemometers which are 10m and 30m height and a wind vane in 30m. Temperature, humidity and atmospheric pressure data are also obtained from the data logger.

First data were measured at the end of July 2000. Data collected from July to end of year 2000 are collected in 1-hour interval. From the beginning of the year 2001 wind computer is reconfigured to collect data in 10-minute interval [55].

Data, which had been collected between July 21st of 2000 and November 30th of 2001, have been used in evaluation.

In the year 2000 data were collected in 1hour intervals with a rate of 24 observations per day. Data were collected with a rate of 144 observations per day in year 2001 using ten minutes interval [55].

7.2.3 Wind Field Modeling

WindPRO and WASP software's had been used to evaluate the wind statistics.

The conclusions, which can be obtained from the results of the reference [6], are explained below.

- Total mean speed at 10m is 7.03m/s and 8.14m/s at 30m.

The wind regime of the area gives an average wind speed of 7.03m/s at the height of 10meters. The current average wind appears to be favorable for wind generation.

- Prevailing wind direction is North and North Northeast on IZTECH campus area.
- 8 sectors out of 12 sectors have mean speeds higher than 7m/s at 30m height. These are very good results which means IZTECH campus area has large wind energy potential.
- IZTECH campus area is located in Çesme peninsula. North direction of the site is directly open to the sea. Sea is blocked by narrow land area at the south direction. Considering strong northerly and southerly winds, it can be said that most of the wind is blowing from the sea.

- Collected data from IZTECH has been evaluated by WindPRO and WasP programs to create wind speed map of the campus area (Fig 7-2). The energy map is also created by WindPro (Fig 7-3).

Wind speed map of campus area is indicating some "excellent" zones as well as lot of "very good" areas. IZTECH mast site is also in class 6 which is "excellent" because its calculated mean speed was 8.14m/s. Four site locations are found which have large areas in class 6 and very suitable for energy production [55].

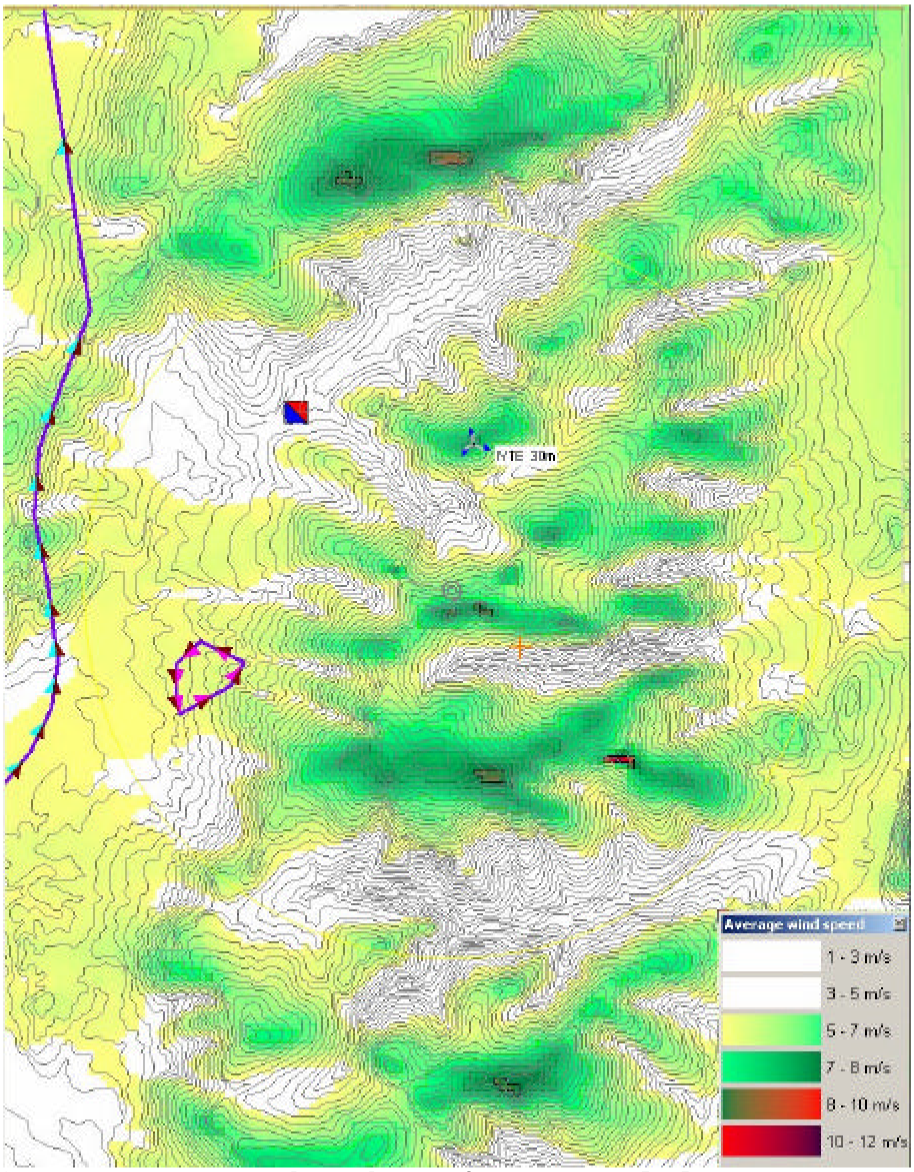


Figure 7-2 Average wind speed map of campus area [55].

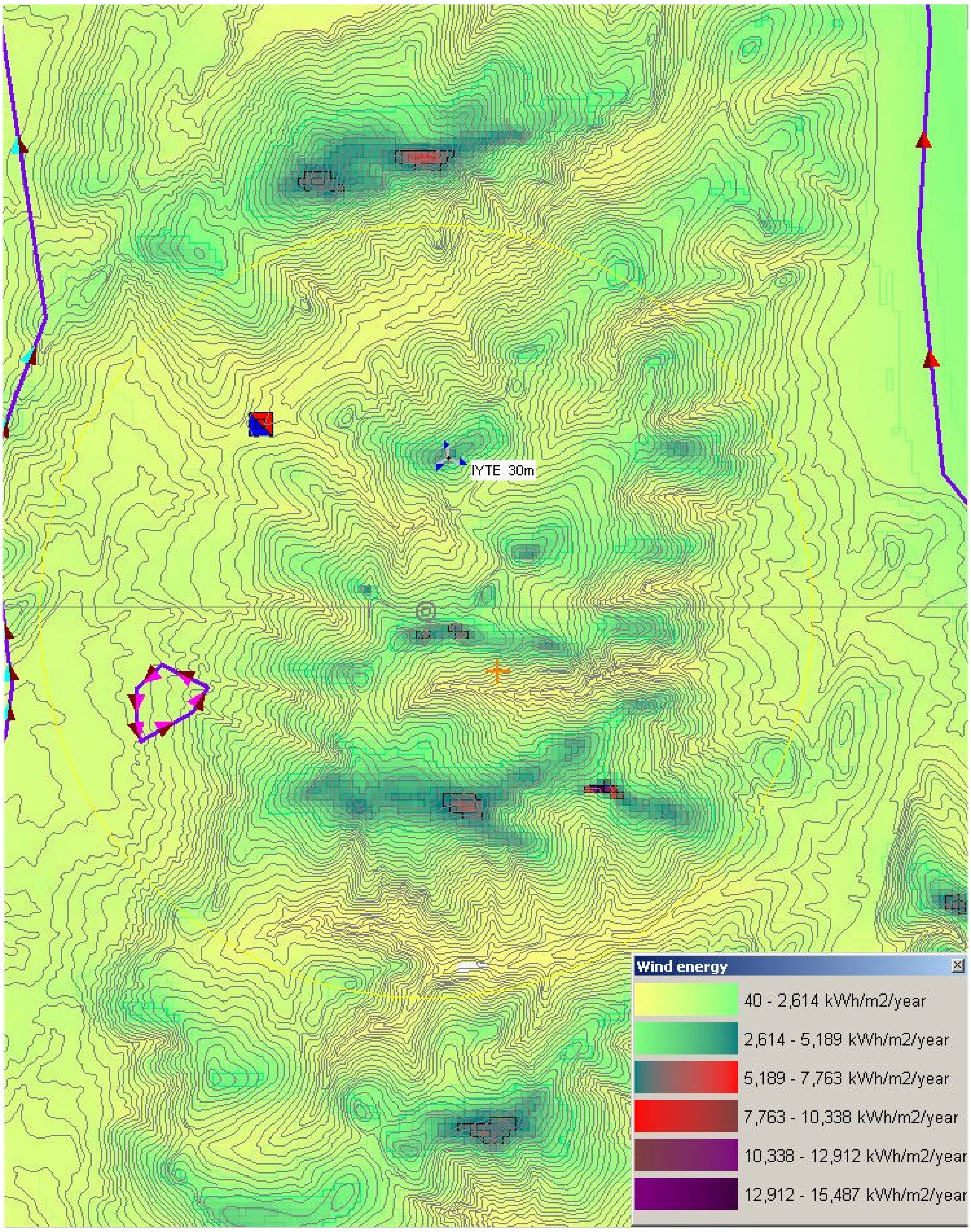


Figure 7-3 Wind energy map of campus area (kWh/m^2/year) [55].

7.2.4 Wind Farm Arrangement – Selecting Best Fit Turbine for IZTECH Campus Area

Turbine technologies can perform differently under similar site conditions, owing to variations in turbine specification and design. Adequate warranty cover for both availability and performance is also an obvious consideration when choosing a turbine supplier [58].

After these observations the best turbine(s) would be chosen for the site according to the technical and economic criteria. In the previous study turbine efficiency was the criterion for turbine selection.

Taking into account the analysis of the data, annual energy productions of five turbines with different energy capacity, were calculated by WindPRO software by using measured data of the IZTECH mast. These turbines are; Enercon600kW, Vestas 660kW, Vestas 850kW, Nordex1000kW and Nordex 1500kW.

Table 7-1 shows calculated annual energy production of the turbines and their efficiencies.

Table 7-1 Comparison of Annual Energy Production (AEP) of five turbines and their efficiencies [55].

Turbine Type	Theoretical AEP(MWh)	Calculated AEP(MWh)	Efficiency
Enercon 600kW	5,256	2,196	41.8%
Vestas 660kW	5,781.6	2,405	41.6%
Vestas 850kW	7,446	3,076	41.3
Nordex 1000kW	8,760	3,478	39.7%
Nordex 1500kW	13,140	5,927	45.1%

All turbines have high technical efficiencies; Enercon 600 kW and Nordex 1500kW have the highest efficiencies. A micrositting is done for the possible maximum installation capacities for these two turbines with the land constraint.

Wind speed and wind energy maps have been used to select suitable sites to locate wind turbines.

Four sites were selected which have mean speeds more than 8m/s to install Enercon 600kW with 46m hub height and 44 m rotor diameter. Turbines have been located 150 m distance apart each other to prevent energy production loses of park effect. Forty seven turbines have been located as aligned position in four sites according to the prevailing direction [55].

Two sites were selected to install Nordex 1500 kW with 60m hub height and 64m rotor diameter which have mean speeds more than 8 m/s and enough area to mount these huge turbines. Twenty six turbines have been located 250 m distance apart and aligned according to prevailing wind direction to prevent from park effect production loses [55].

WindPRO software calculated annual energy production of every individual turbine and total production of all potential sites. Calculated energy production of located forty seven Enercon 600kW turbines with total capacity of 28.2 MW, is 100.3 GWh. Calculated energy production of twenty six Nordex 1500kW turbines with total capacity 39 MW, is 122.4GWh [55].

The next study done for the area is "Land Use Analysis". [59] This survey evaluated the previous micrositing in land use perspective.

7.2.4.1 Availability of land:

When the wind turbine layouts applied to the campus plan, it is seen that six turbines of 600 kW sitting at the south of the Izmir-Çesme Road, and six more turbines of 600 kW sitting at Kocadag, on the north of the mast are located out of the campus boundary. The seven turbines of 1500kW, sitting on the north of the mast in the second alternative, is also out of the campus boundary [60].

Due to the factor of availability of land, it is accepted that the wind farm project would be developed on the land under/with the ownership of university, without exceeding the campus boundaries. In accordance with the assumption, the size of the development turns out to be smaller, including the numbers of turbines lessening to thirty five in the first alternative, and to nineteen in the second [60].

7.2.4.2 Grid Availability:

The availability of cost-effective grid connection is critical, as it provides the lifeline between generation and supply. Securing a grid connection has the potential to be problematic, time-consuming and extremely costly [58].

The nearest connecting point is Urla Substation. It is 154/34.5kV line with 25MVA transformer power. The short-circuit power at the network nodes has been calculated. It is 238MVA for Urla 34.5kV [56]. According to this, the maximum capacity which can be connected to 34.5kV line is 12MW.

$$238\,MVA \times 0.05 = 12\,MW \tag{7.1}$$

Next step should be financial assessment. This study presented here is an attempt to cost analysis of a wind farm and a look to financial opportunities for wind energy projects.

7.3 Economic Analysis

The study presented for the wind farm is quite preliminary and it would be essential for the final wind farm lay-out a detailed inspection of the area.

The economic analysis of the project was conducted by using RETScreen software, version 2000, which developed by National Resource Canada's CANMET Energy Diversification Resource Laboratory. A brief summary of RETScreen software is given in Appendix [61]. And the economic analyses which were performed for turbines mentioned above.

Three scenarios are illustrated. First scenario is an autoproducer which establishes the energy of the campus. Second scenario is another autoproducer which provides energy for Campus and a second facility. And the third scenario is for an Independent Power Producer (IPP) with maximum capacity which could be installed and connect in the campus area according to the constraints.

The cost of WECS's turbine prices are taken from the reference [62]. Although this study intended to be the continuation of the previous studies [6, 59], different turbine types had to be used for the financial evaluation because of the unavailability of turbine prices.

The economics of grid connected wind power depend very much upon the perspective taken. How quickly investors want their loans repaid, what rate of returns they require, what is the repayment period ext., can affect the feasibility of a wind project.

Public authorities and private investors have different perspectives. Public authorities and energy planners tend to assess different energy sources on the basis of the levelised cost. These calculations do not depend upon variables such as inflation or taxation system. Public utility is the most important criterion for decision-makers. The private investors make decisions on project cash flow and payback time. They take into account the variables introduced by government policy and shifts in financial and foreign exchange markets. Public authorities and energy planners require the capital to be paid off over the technical lifetime of the wind turbine, i.e. 25 years, whereas the private investor would have to recover the cost of the turbines during the length of the bank loan. The interest rates used by public authorities and energy planners would typically be lower than those used by private investors. This study uses “Private investor” perspective as a decision-maker.

7.3.1 SCENARIO 1: IZTECH Autoproducer

The aim of the autoproducer is to meet the energy demand of Iztech campus. The first step is to decide the capacity of the plant by finding annual energy consumption of the campus.

7.3.1.1 Energy Consumption of Campus

Annual electricity consumption of the Campus by years is shown in Table 7-2. According to the data, annual increase ratio of the electricity consumption is 31% in 2001 and 49% in 2002. The ratio is increasing by years with the development of the Campus.

Table7-2 Annual Electricity Consumption of Campus (2000-2001-2002)

Annual Electricity Consumption(kWh)		
2000	2001	2002
492,361	646,061	964,082

The campus settlement is still growing. Fig 7-4 shows the growth of campus buildings and Table7-3 shows the planned final building structure of the Campus. [63]

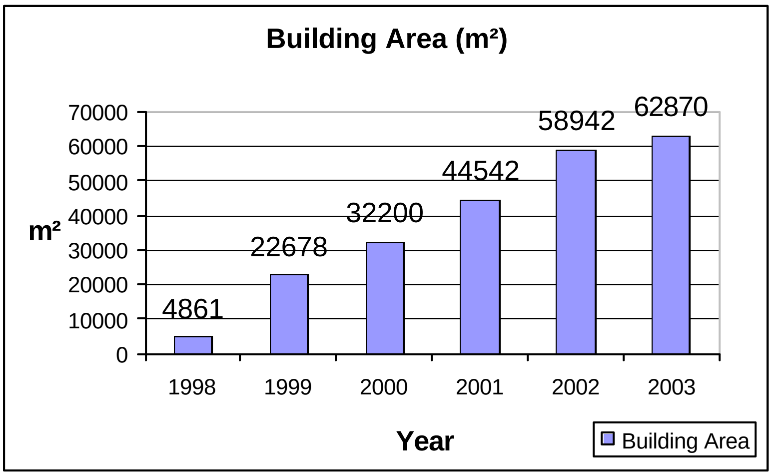


Figure 7-4 Usage area of existing buildings

Table 7-3 Projected final building area

Building	Area (m²)
Rectorship and Affiliated Administrative Units	7,000
Engineering Faculty	45,000
Arch. Fac.	30,095
Science Fac.	42,800
Environmental Reference R&D	2,250
Staff Houses	3,600
IZTECH R&D and Education Center	3,000
Incubator Center	4,200
Library	6,100
Sport Center	10,930
Medical Center	9,033
Cafeteria	4,700
Dormitories	14,300
TOTAL	**176,008**

To be able to determine the energy consumption of the total campus area, unit energy consumption is calculated based on the existing building data. Then, total energy consumption of the Campus is determined as 2,878,866kWh (Eq.7.2). Then 5% is added for accuracy (Eq.7.3). After these calculations the estimated energy consumption is about 3,200,000kWh/year. The annual electricity consumption of the campus is shown in Table7-4.

Table 7-4 Annual Electricity Consumption of the Campus

	Annual Electricity Consumption (kWh/year)	Existing Buildings Total Area (m²)	Annual Electricity Consumption (kWh/year.m²)
2000	492,361	32,200	15.29
2001	646,061	44,542	14.50
2002	964,082	58,942	16.36
2003		62,870	
Projected Final Situation	2,878,866	176,008	

$$176.008 * 16.335 = 2.878.866\, kWh / year \tag{7.2}$$

$$2.878.866 * 1,05 = 3.022.809\, kWh / year \tag{7.3}$$

This consumption is not the present value. This is the estimated future energy demand of the campus. According to the plans made by the IZTECH administration, the development of the campus will be finished at the end of 2005. The estimations and plans used in this study are made according to this annual consumption.

The civil construction cost has to be calculated by designing the sites of the foundation. The design of foundation is based on the static weight of the nacelle, weight of rotor, weight of the tower, and the dynamic wind load for a survival speed. The civil construction also included the cost of a control room for housing computer, control devices, regularly required inventory items, and space for human occupancy. The construction cost of foundation for three wind machines of sizes 600,900, 1000, 1500 and 1800kW are found to be approximately 15000,15000, 25000,25000 and 35000 US$, respectively. The room size is taken as 7.5mx4.5m and its cost is estimated as 20000US$.

Table 7-5 shows the technical characteristics of the WECS which are used in evaluation. Cost related data of turbines used in the analysis is shown in Table 7-6.

Table 7-5 Technical data of wind turbines used in the analysis

Wind Turbine Type	Rated Output (kW)	Cut-in Speed (m/s)	Cut-out Speed (m/s)	Rated Speed (m/s)	Hub Height (m)	Rotor Diameter (m)	Expected Life (years)
Enercon E40	600	2.5	28-34	12	50	44	25
Neg Micon NM52	900	3.5	25	16	61.5	52.2	25
Enercon E-58/10.58	1000	2.5	28-34	12	70	58.6	25
Neg Micon NM64C	1500	4	25	14	68	64	25
Enercon E-66	1800	2.5	28-34	12	65	70	25

Table 7-6 Cost related data of wind turbines used in the analysis.

Wind Turbine Type	Rated Output (kW)	Total Initial Cost (US$)	Tower Foundation & Erection Cost (US$)	Control Room Cost (US$)	O&M Cost (US$)
Enercon E40	600	2,186,195	82,000	20,000	186,615
Neg Micon NM52/900	900	1,703,198	46,000	20,000	174,115
Enercon E-58/10.58	1000	2,245,396	51,000	20,000	181,819
Neg Micon NM64C/1500	1500	2,363,578	56,000	20,000	176,384
Enercon E-66/18-70	1800	2,944,210	61,000	20,000	207,957

The analysis was conducted for an energy escalation rate of 0%, inflation rate of 0%, project lifetime of 25 years, debt ratio 70%, debt term of 10 years, debt interest rate of 8.5 % and discount rates of 15 %. Table 7-8 is a summary table for the alternatives which were calculated by RETScreen.

The results of the economic analysis are presented in the following tables. The analysis was performed for the five cases each.

Table 7-7 Cost break down (thousand US$)

WECS:	0.6 MW		0.9MW		1MW		1.5MW		1.8MW	
Item	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
Equipment	1,349,680	61.7	921,260	54.1	1,437,604	64	1,546,240	65.4	2,099,540	71.3
Feasibility	40,600	1.9	40,600	2.4	40,600	1.8	40,600	1.7	40,600	1.4
Development	157,000	7.2	157,000	9.2	157,000	7	157,000	6.6	157,000	5.3
Engineering	36,100	1.7	36,100	2.1	36,100	1.6	36,100	1.5	36,100	1.2
Balance of Plant	512,000	23.4	476,000	27.9	481,000	21.4	486,000	20.6	491,000	16.7
Miscellaneous	90,815	4.2	72,238	4.2	93,092	4.1	97,638	4.1	119,970	4.1
O&M cost	186,615		172,023		181,819		176,384		207,957	

Table 7-7 shows the cost break down for the selected turbine types. The installed capacities of the turbines are approximately the same. Because of this, the amount of money invested on feasibility, development and engineering components are taken equal for different turbine types.

The cost of energy associated with wind turbines designed for wind farms has been resolved into the components of capital cost, operations and maintenance costs, and the levelized costs of overhaul and major subsystem replacement. The estimated percentage values are portrayed in Figure 7-5.

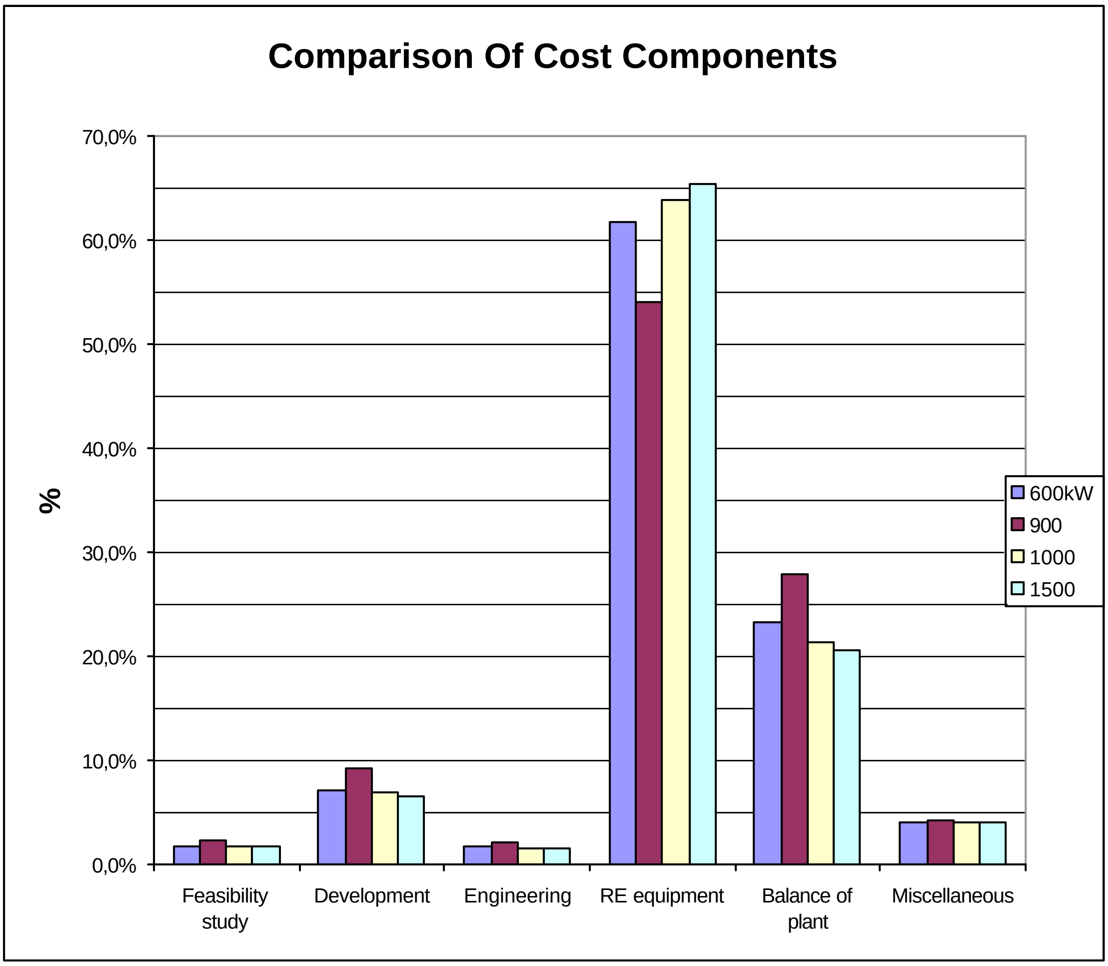


Figure 7-5 Comparison of Cost Components

The relative magnitudes of these estimated values provide insight into where the overall economics of these systems may be impacted. Figure7-5 shows that the leading component of capital cost is, renewable energy equipment (wind turbine), followed next by the costs of balance of plant. Together, these two leading components represent about 80-85 percent of the total initial cost for this scenario. These values underscore the importance of developments in turbine technology and reliability which will deeply affect the initial costs.

7.3.1.2 Calculating the Cost Per kWh

Cost of energy is an important factor for decision makers. Investors want to maximize profit. Minimizing the cost is a method for achieving this goal. All the alternatives have to be in the same unit for comparison. Cost per kWh can give a general idea for comparing.

Annual Cost= (Initial Cost/Expected Life) + Annual Operating Costs (7.4)

This formula defines the annual cost over the wind system's lifetime. The annual cost is equal to the total initial cost divided by the expected life (for our case 25 years), plus the annual operating costs for maintenance.

Cost Per kWh= Annual Cost/Annual Energy Output (7.5)

Costs per kWh values for alternatives are given in summary table. These costs can be compared with the utility company rates. If the wind system applications indicate lower costs than the utility sales price than the project is acceptable.

Table 7-8 Summary of all alternatives

IZTECH Autoproducer	**1**	**2**	**3**	**4**
Turbine Rated Power(kW)	600	900	1000	1500
Manufacturer / Turbine Type	Enercon E40	NEG-Micon NM52	Enercon E58	NEG-Micon NM64
Number of Turbines	2	1	1	1
Wind Plant Capacity(MW)	1.2	0.9	1.0	1.5
Estimated Energy Delivered (MWh)	4,437	3,200	4,005	3,287
Total Initial Costs($)	2,186,195	1,703,198	2,245,396	2,363,578
Operating Cost ($)	185,344	174,115	185,093	175,309
Project Equity	655,859	510,960	673,619	709,073
Project Debt	1,530,337	1,192,239	1,571,777	1,654,504
Debt Interest Rate	8.5	8.5	8.5	8.5
Debt Term	10	10	10	10
Cost per kWh(cents/kWh)	6.15	7.57	6.86	8.21

For the first scenario there are 4 alternatives because the model calculated the energy production of E66 as 6,458 MWh and this amount is approximately the twice as the required energy for campus so this alternative is eliminated.

7.3.1.3 Selection of Turbine Type

Selecting a turbine type depends on various factors. These factors vary for different decision makers. For example, if the decision maker is a bank, the Internal Rate of Return or the Profitability of the project would be the decision criterion. If the developer is a small investor or a non-profit organization, than probably the simple payback period would be more important. Because he doesn't have much money and cost of money would be expensive for him.

As it is explained in the previous chapters, the IRR evaluation generates a percentage figure which is equal to the interest rate at which the project capital would have to be invested to generate the same series of annual cash flows that the project will generate.

And the NPV gives the value of the project in as dollar amount today. Each year's cash flow is discounted to the present at a predetermined discount rate, which reflects the project risk and the investors' minimum investment criteria. The NPV is the sum of these discounted annual cash flows. For most energy projects the required minimum IRR is 15%.

Although an entire project should not be judged by one or two summary numbers, if the IRR and NPV are used in conjunction with the annual cash flows, they are a powerful means of comparing and selecting investment opportunities. For these reasons, these two methods are used as the measure of the impact of assumptions in this thesis.

For all scenarios, IRR via Energy sales price would be our main criterion for selecting the turbine type. The IRR values are calculated for different sales prices and compared. Figure 7-6 shows the changes in IRR via sales price. Enercon E40-600kW has the lowest price, it is 11.12409 ¢/kWh, for IRR=15 (NPV=0) and it is the best alternative for autoproducer.

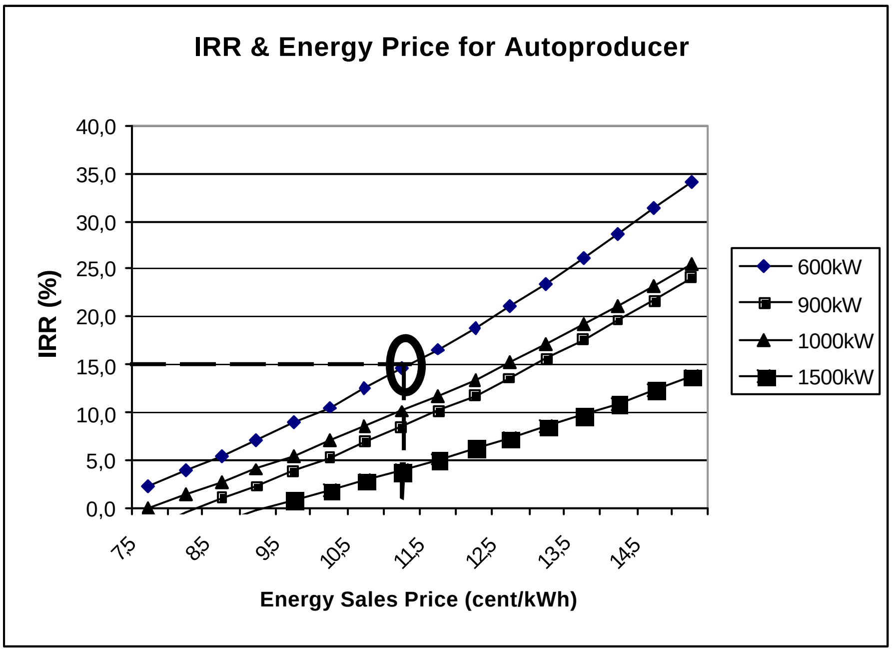


Figure 7-6 - IRR versus Energy Price for Autoproducer

7.3.1.4 Variance Analysis

Turbine type for autoproducer is selected according to the IRR & Energy Price values (Fig 7-6). Further analysis would be done for Alternative1- Enercon E40 and the "Base Case" parameters are shown in Table 7-9 and the percentages of the initial cost components are shown in Fig.7-7.

After having established a Base Case, it is important to determine how each of the major cost components of the project (revenue, capital costs, operating costs) influence its value. Sensitivity or variance analysis highlight's which variables have the greater impact on the project.

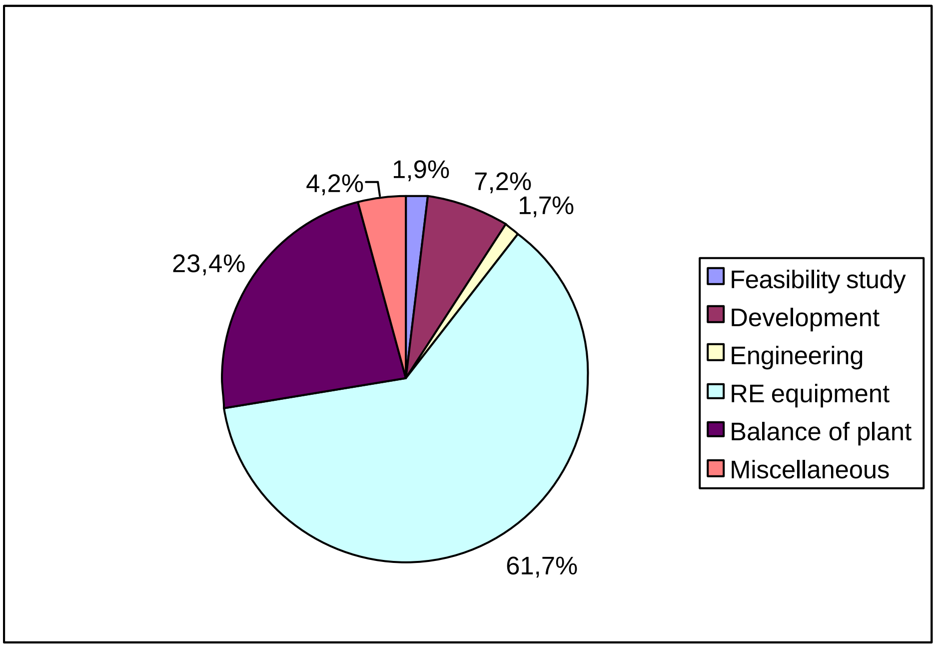


Figure 7-7 The cost component distribution of Enercon E40 600kW for Autoproducer

When plotted as a graph, the steeper the line, the greater the impact, or the greater the sensitivity of the project to the variable. The variables to which the project is most sensitive are those which should be most closely examined for accuracy and reliability. An example of a variance analysis is presented in Table 7-9 and Fig 7-8.

Table 7-9 Variance Analysis Summary for Enercon E40-600kW

Variable & Variance	IRR	15% NPV
Base Case	15%	$0
Price +20% -20%	25.3% 6.7%	$468,695 -$506,097
Op Cost +20% -20%	11.6% 18.7%	-$191,262 $185,928
Capital -20% +20%	23.1% 10.3%	$304,863 -$319,862

(Cont. on the next page)

Table 7-9 (cont.)

Inflation +2%	12.3%	-$131,421
+4%	7.5%	-$296,147
Debt 30%	12.1%	-$250,757
50%	13.2%	-$124,065
70%	15.0%	$0
90%	18.8%	$121,752
Repayment 1 year	11.5%	-$342,659
6 year	13.1%	-$131,042
10 year	15%	$0
12 years	16.2%	$54,948

The IRR and NPV are inversely proportional to capital costs and directly proportional to profit, as follows:

$$\text{IRR \& NPV} = \text{fn}\ \frac{(\text{Revenue - Operating Costs})}{\text{Capital Costs}} \qquad (7.6)$$

The extent of the impact of changes in these factors is determined by varying each factor individually over a likely range of values. Table 7-9 and Figure 7-8 show these impacts.

- Price and Revenue: Revenue is the only positive component of the cash flow. It is largely determined by selling price, but the change in production will also have a parallel effect. While the latter are usually fixed by technical considerations like good/detailed wind analysis, price is open to a broad range of interpretations and offers considerable scope for variance.
- Operating Costs: The cash flow is a direct function of the margin between revenue and operating costs, so operating costs exert a strong impact on the cash flow and the return.
- Capital: Capital is input at the very beginning of project and has a high negative influence on the discounted cash flow, since the positive cash flows which follow are discounted increasingly the further away they are in time.

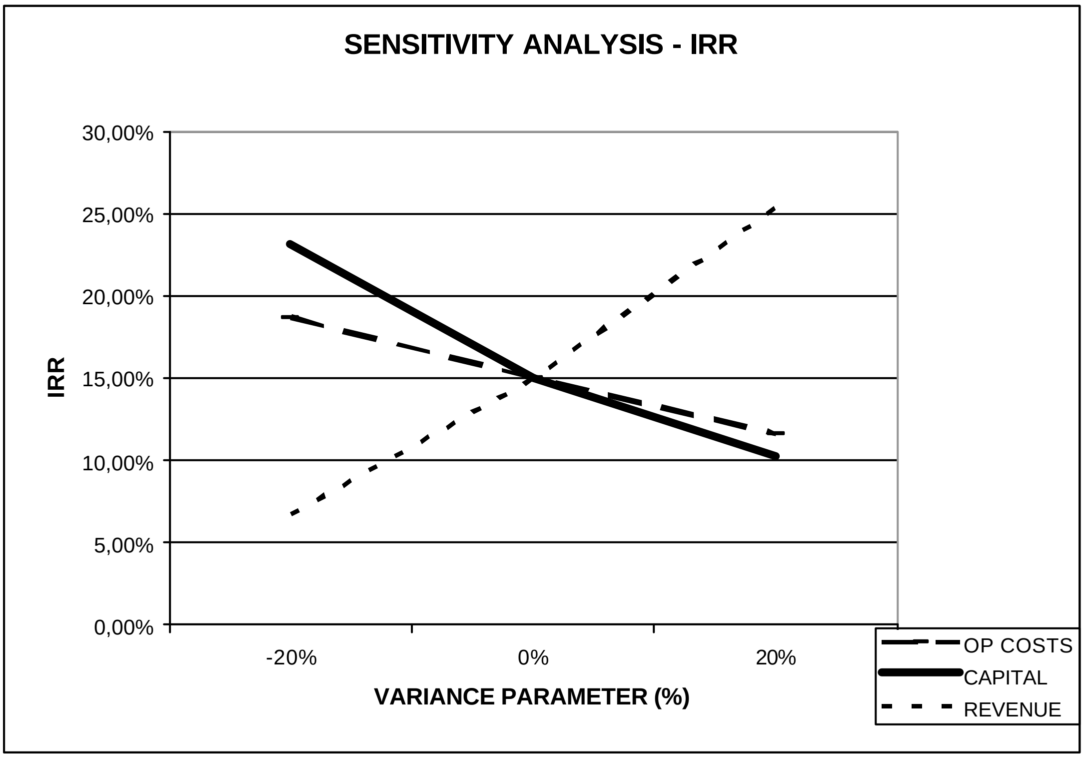


Figure 7-8 Sensitivity Graph for Autoproducer

Discount Rate

Discount rate is also important in project evaluation. The selection of the discount rate has already explained in the previous chapters.

The mathematics that is required to generate the NPV and IRR values is straightforward, but both methods require the definition of an appropriate discount rate to establish investment criteria. This rate is used as the discount rate in the NPV method, and the minimum rate for the IRR.

As mentioned before, it is possible to determine a discount rate that is appropriate for an individual project, on the basis of industry expectations for project returns (IRR), the risk factors associated with wind energy projects in general, and the risks related to the specific project.

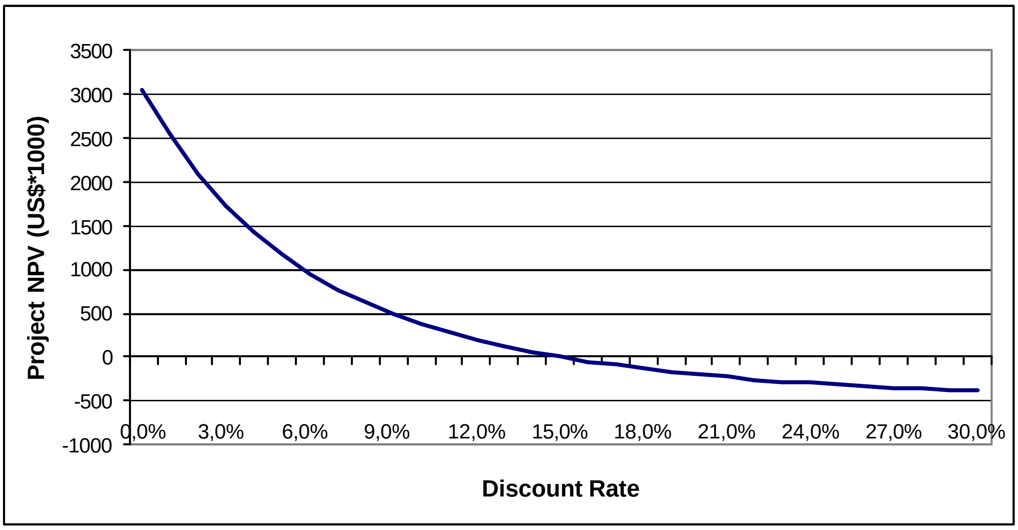


Figure 7-9 NPV versus Discount Rate for Autoproducer

Table 7-10 The effect of Discount Rate on IRR,NPV, Payback Time and Year to Positive Cash Flow

Parameter	Discount Rate			
	6%	8%	10%	15%
IRR (%)	15	15	15	15
Simple payback period(years)	7.1	7.1	7.1	7.1
Year to positive cash flow(years)	8.8	8.8	8.8	8.8
NPV (US$)	960,316	622,678	376,262	-894

Table 7-10 shows the changes in the economic parameters (like NPV) when discount rate changes with 11.12cents per kWh energy sales price.

Table 7-11 The effect of Interest Rate on IRR, NPV, Payback Time and Year to Positive Cash Flow

Parameter	Interest Rate					
	6%	7%	8%	8.5%	9%	10%
IRR (%)	17.1	16.2	15.4	15	14.6	13.8
Simple payback period(years)	7.1	7.1	7.1	7.1	7.1	7.1
Year to positive cash flow(years)	6.6	7.3	8.2	8.8	9.9	10.3
NPV (US$)	102,521	62,404	20,580	-894	-22,584	-66,692

Table 7-11 shows the influence of interest rate to economic parameters like IRR, NPV etc. when energy sales price is 11.124 cents per kWh and discount rate is 15%.

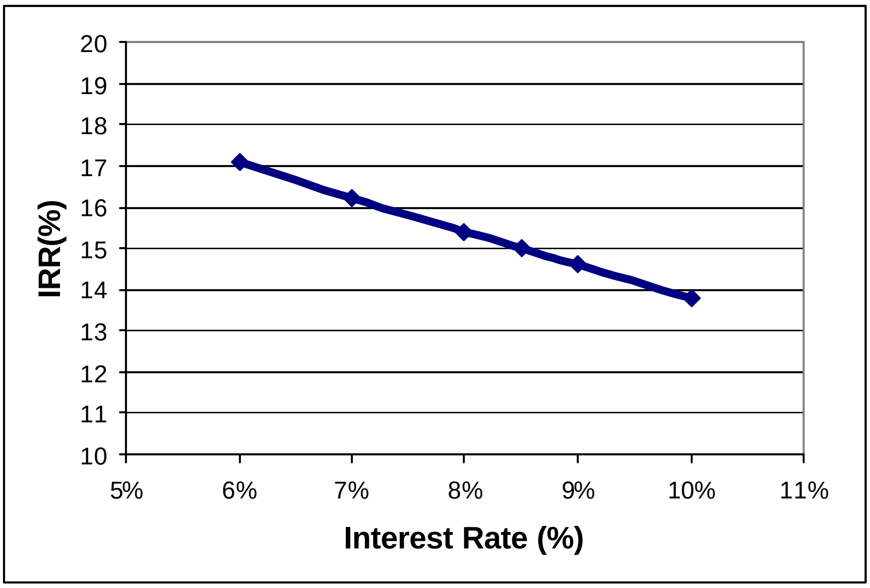


Figure 7-10 IRR via Debt Interest Rate for Autoproducer

Inflation:

Inflation is also an important parameter. First, it is excluded from the evaluations shown above, then to show the importance of it, IRR and net present values are calculated for different inflation rates.

Table 7-12 The effect of inflation on IRR and NPV

	Inflation Rate			
	0% (Base Case)	**2%**	**2.5%**	**3%**
NPV ($)	0	-131,421	-169,140	-208,878
IRR	15%	12.3%	11.4%	10.4%

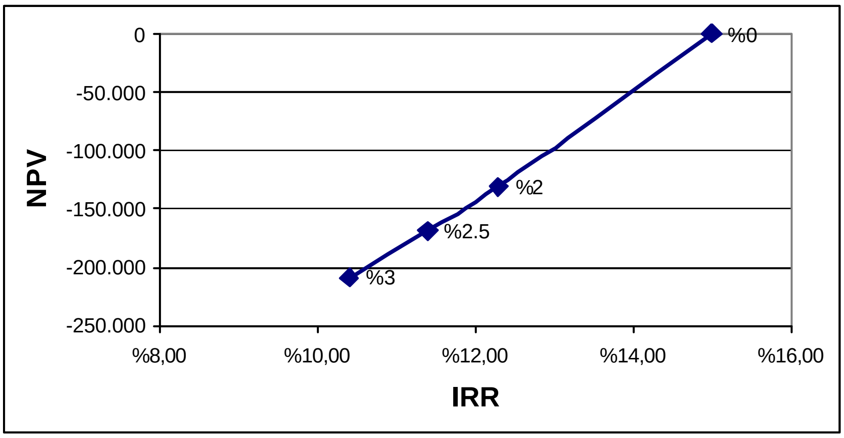


Figure 7-11 The effect of inflation on IRR and NPV

Table 7-12 and Figure 7-11 show the effect of inflation on NPV and IRR. The required IRR value decreased with inflation. To get the required IRR (15%) minimum energy sales price would be higher. Figure 7-12 shows required minimum sales price for IRR=15 with different inflation rates.

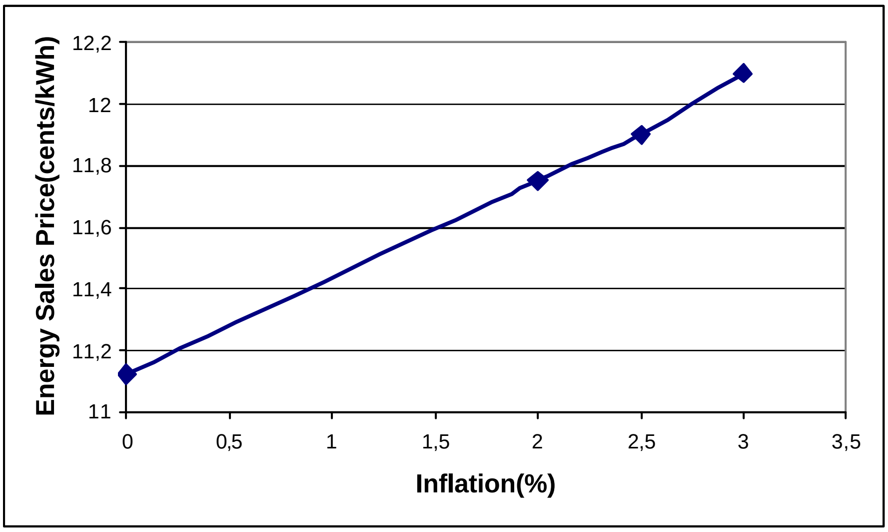


Figure 7-12 Inflation via required minimum sales price for IRR=15

For the base case, the minimum energy sales price is 11.12 cents/kWh for 15% IRR with 0% inflation rate. When the inflation rate is taken into consideration with 2%, 2.5% and 3%, the minimum energy sales price would be 11.75, 11.90 and 12.1 cents/kWh for 15% IRR, respectively.

7.3.2 SCENARIO 2: Autoproducer Group

Second scenario is also an autoproducer, which will meet the energy need of two facilities, campus and facility A. For the autoproducer group the consumption is the sum of IZTECH, which we calculated before, and the facility A which the consumption is about 3,000,000kWh/year. The autoproducer group annual energy consumption is about 6,500,000 kWh. (Eq 7.7).

$$3200000 + 3000000 = 6200000 * 1.05 = 6510000 \ kWh / year \quad (7.7)$$

Table 7-13 Cost related data of wind turbines used in the analysis.

Wind Turbine Type	Rated Output (kW)	Total Initial Cost (US$)	Tower Foundation & Erection Cost (US$)	Control Room Cost (US$)	O&M Cost (US$)
Enercon E40 -600kW	600	2,909,869	123,000	20,000	209,222
Neg Micon NM52 – 900kw	900	2,667,549	92,000	20,000	206,202
Enercon E-58/10.58 – 1000kW	1000	3,751,944	102,000	20,000	225,259
Neg Micon NM64C – 1500kW	1500	3,988,307	112,000	20,000	213,648
Enercon E-66/18-70 – 1800kW	1800	2,944,210	61,000	20,000	207,957

Table 7-14 Cost break down for Autoproducer Group (US$)

WECS:	0.6 MW		0.9MW		1MW		1.5MW		1.8MW	
Item	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
Equipment	2,004,520	68.9	1,802,520	67.6	2,835,208	75.6	3,052,480	76.5	2,099,540	71.3
Feasibility	40,600	1.4	40,600	1.5	40,600	1.1	40,600	1	40,600	1.4
Development	157,000	5.4	157,000	5.9	157,000	4.2	157,000	3.9	157,000	5.3
Engineering	36,100	1.2	36,100	1.4	36,100	1	36,100	0.9	36,100	1.2
Balance of Plant	553,000	19	522,000	19.6	532,000	14.2	542,000	13.6	491,000	16.7
Miscellaneous	118,649	4.1	109,329	4.1	151,036	4	160,127	4	119,970	4.1
O&M cost	209,222		206,202		225,259		213,648		207,957	

Because the capacity of the plant didn't changed a lot, the amount of money invested on feasibility, development and engineering components are taken exactly the same as the first scenario and also for the different types.

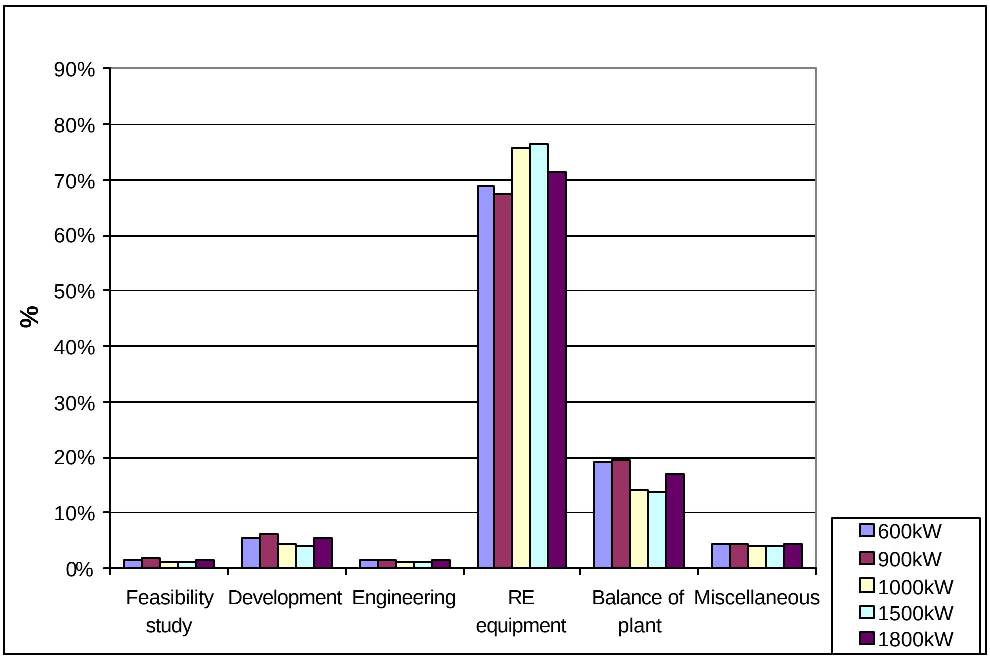


Figure 7-13 Comparison of Cost of Energy Components

The leading component of capital cost is, renewable energy equipment, followed next by the costs of balance of plant. Together, these two leading components represent about 88-90 percent of the total initial cost for autoproducer.

Table7-15 Summary of all alternatives

Autoproducer Group	**1**	**2**	**3**	**4**	**5**
Turbine Rated Power(kW)	600	900	1000	1500	1800
Manufacturer / Turbine Type	Enercon E40	NEG-Micon NM52	Enercon E58	NEG-Micon NM64	Enercon E66
Number of Turbines	3	2	2	2	1
Wind Plant Capacity(MW)	1.8	1.8	2.0	3.0	1.8
Estimated Energy Delivered (MWh)	6,655	6,399	8,011	6,574	6,458
Total Initial Costs($)	2,909,869	2,667,549	3,751,944	3,988,307	2,944,210
Operating Cost ($)	221,191	202,017	234,427	215,798	202,677
Project Equity	872,961	800,265	1,125,583	1,196,492	883,263
Project Debt	2,036,908	1,867,284	2,626,361	2,791,815	2,060,947
Debt Interest Rate	8.5	8.5	8.5	8.5	8.5
Debt Term	10	10	10	10	10
Cost per kWh(cents/kWh)	5.07	4.82	4.80	5.71	4.96

7.3.2.1 Selection of Turbine

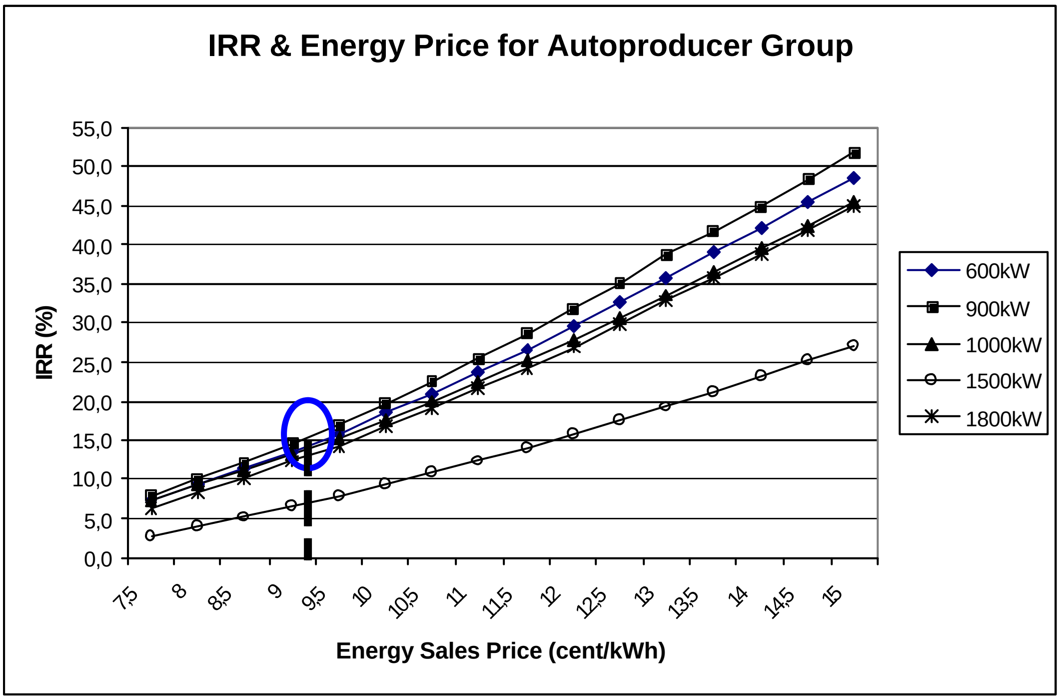


Figure 7-14 IRR versus Energy Price for Autoproducer Group

Although Enercon E58 has the minimum cost per kWh (Table 7-14), NEG-Micon NM52-900kW is chosen as the best turbine because of the sales price. According to the Figure 7-14 the best alternative is NEG-Micon NM52- 900kW for autoproducer group. And the minimum sales price is 9.08cents/kWh for IRR value of 15 %.

7.3.2.2 Variance Analysis

The turbine type is selected according to the IRR & Energy Price values. Further analysis would be done for Alternative2- NEG-Micon NM52-900kW and the "Base Case" parameters are shown in Table 7-16 and the percentages of the initial cost components are shown in Fig 7-15.

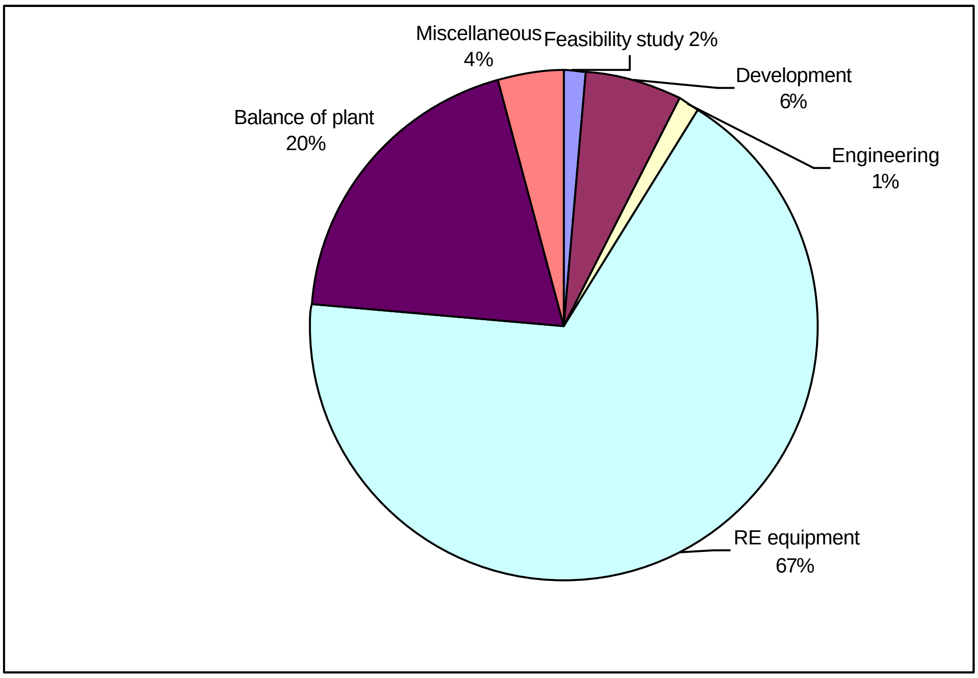


Figure 7-15 The cost component distribution of NEG-Micon NM52- 900 kW for Autoproducer Group

The graphics and tables explained below highlights which variables have the greater impact on the project.

Table 7-16 Variance Analysis Summary for NM52-900kW

Variable & Variance	IRR	15% NPV
Base Case	15%	$0
Price -20%	%7	-$596,828
+20%	%24.9	$550,874
Op Cost -20%	%18.4	$204,676
+20%	%11.9	-$213,214
Capital -20%	%23.6	$390,183
+20%	%10.2	-$408,245

(Cont. on the next page)

Table 7-16 (cont).

Inflation +2%	%12.6	-$145,401
+4%	%8.5	-$327,393
Debt 30%	%12.1	-$305,968
50%	%13.2	-$151,382
70%	%15	$0
90%	%18.8	$148,559
Repayment 1 year	%11.5	-$418,106
6 year	%13.1	-$159,895
10 year	%15	$0
12 years	%16.2	$67,045

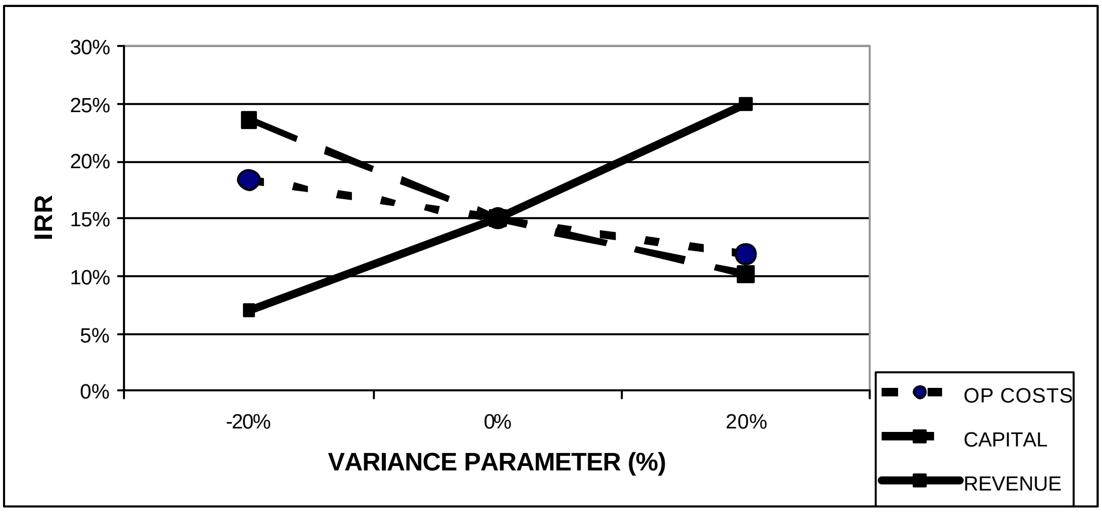


Figure 7-16 Sensitivity Graph for Autoproducer Group

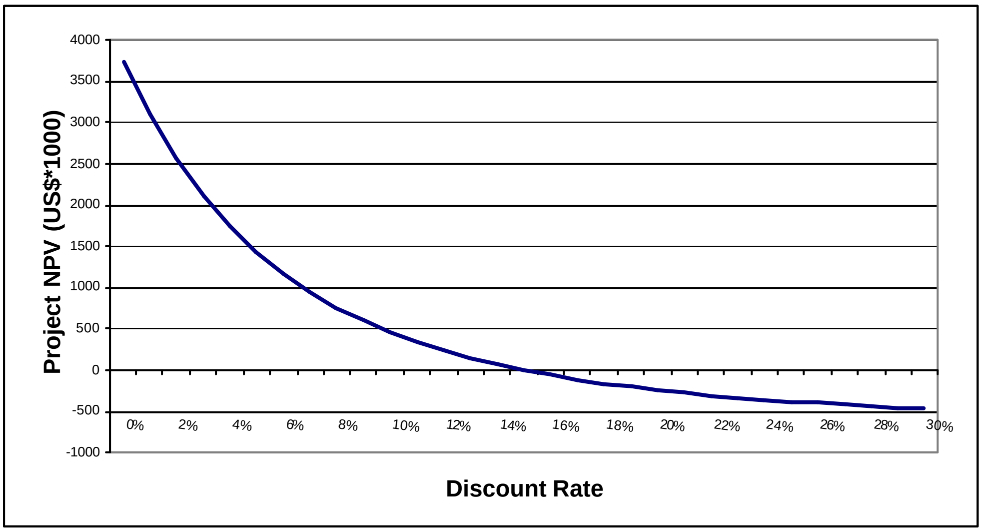


Figure 7-17 NPV versus Discount Rate for Autoproducer Group

Table 7-17 The effect of Discount Rate on IRR, NPV, Payback Time and Year to Positive Cash Flow

Parameter	Discount Rate			
	6%	8%	10%	15%
IRR (%)	15	15	15	15
Simple payback period(years)	7.1	7.1	7.1	7.1
Year to positive cash flow(years)	8.8	8.8	8.8	8.8
NPV (US$)	1,173,669	761,419	460,542	0

Table 7-17 shows the changes in the economic parameters when discount rate changes and energy sales price is 9.08cents/kWh.

Table 7-18 The effect of Interest Rate on IRR,NPV, Payback Time and Year to Positive Cash Flow

Parameter	Interest Rate					
	6%	7%	8%	8.5%	9%	10%
IRR (%)	17.1	16.3	15.4	15	14,6	13,8
Simple payback period(years)	7.1	7.1	7.1	7.1	7.1	7.1
Year to positive cash flow(years)	6.5	7.3	8.2	8.8	9.8	10.3
NPV (US$)	126,159	77,209	26,201	0	-26,467	-80,262

According to Table 7-18, interest rate have high effect on NPV and have small effect on IRR, simple payback period and year to positive cash flow.

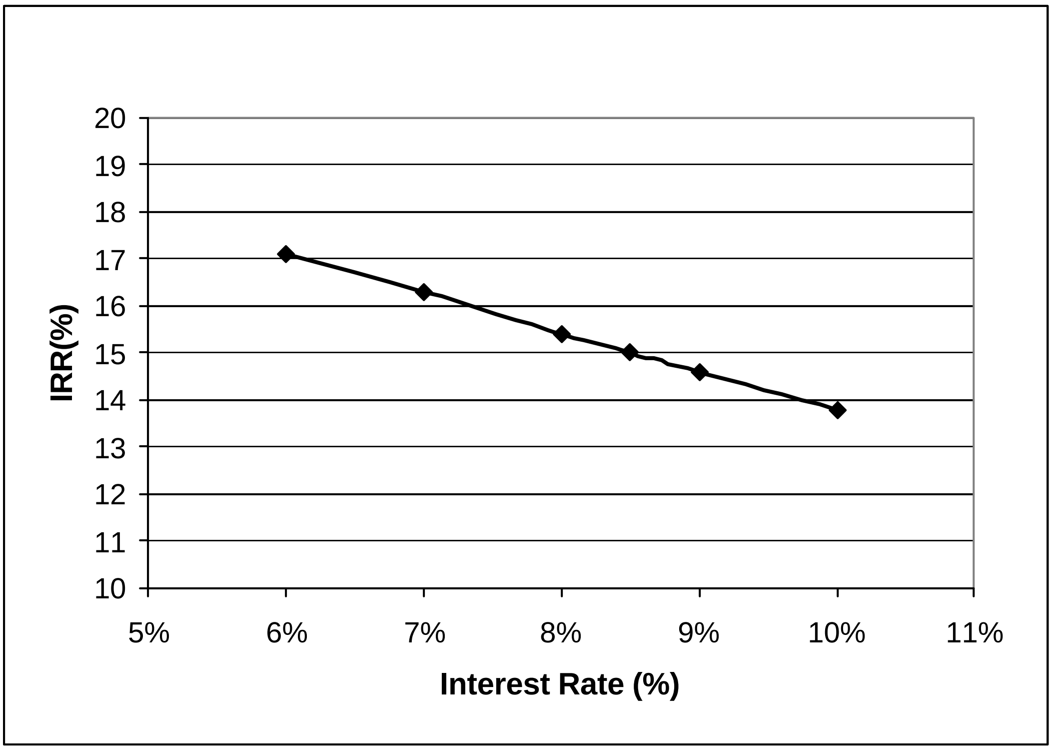


Figure 7-18 IRR via Debt Interest Rate for Autoproducer Group

Table 7-19 The effect of inflation on IRR and NPV

	Inflation Rate			
	0% **(Base Case)**	**2%**	**2.5%**	**3%**
NPV ($)	0	-145,401	-187,188	-231,211
IRR	15%	12.6	11.8%	10.9

According to Table 7-19 and Figure 7-19, inflation rate highly effects NPV and IRR.

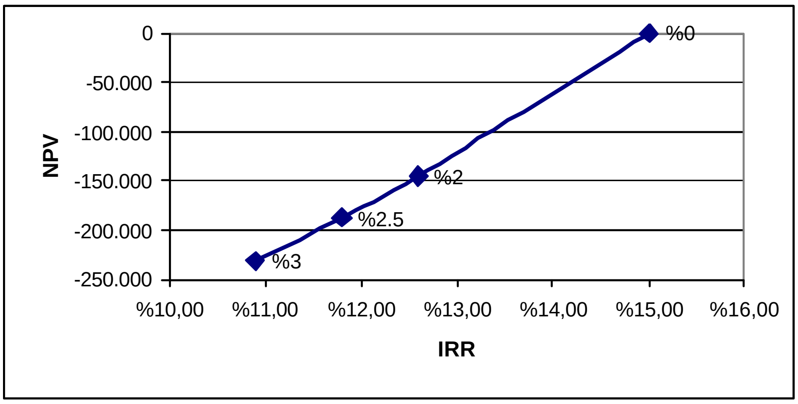


Figure 7-19 The effect of inflation on IRR and NPV

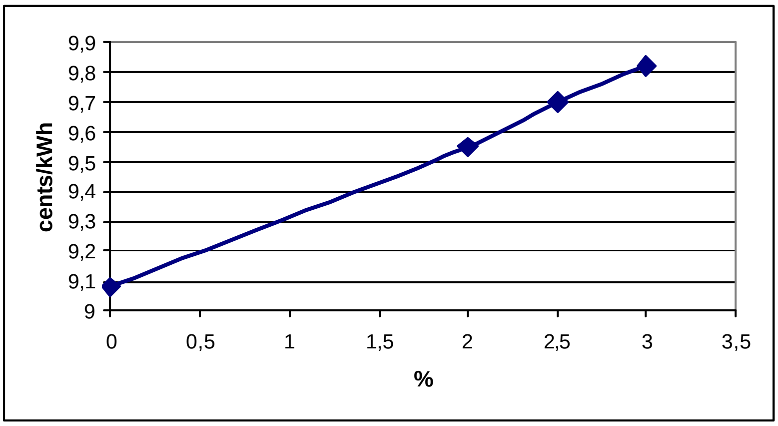


Figure 7-20 Inflation via required minimum sales price for IRR=15%

Figure 7-20 shows the rise in energy sales price for reaching 15% IRR requirement. For the base case, the minimum energy sales price is 9.08 cents/kWh for 15% IRR with 0% inflation rate. When the inflation rate is taken into consideration with 2%, 2.5% and 3%, the minimum energy sales price would be 9.55, 9.7 and 9.82 cents/kWh for 15% IRR, respectively.

7.3.3 SCENARIO 3 : Independent Power Producer (IPP)

Under the land and grid considerations the installed capacity of the IPP can be maximum 12MW. Same calculations and evaluations were also done for the third scenario.

Table 7-20 Cost related data of wind turbines used in the analysis

Wind Turbine Type	Rated Output (kW)	Total Initial Cost (US$)	Tower Foundation & Erection Cost (US$)	Control Room Cost (US$)	O&M Cost (US$)
Enercon E40	600	15,967,072	820,000	20,000	581,200
Neg Micon NM52/900	900	14,030,155	598,000	20,000	552,523
Enercon E-58/10.58	1000	19,572,178	612,000	20,000	619,506
Neg Micon NM64C/1500	1500	14,491,437	448,000	20,000	394,115
Enercon E-66/18-70	1800	16,931,131	427,000	20,000	589,941

Table 7-21 Cost break down (thousand US$)

WECS:	0.6 MW		0.9MW		1MW		1.5MW		1.8MW	
Item	Cost	%	Cost	%	Cost	%	Cost	%	Cost	%
Equipment	13,146,800	82.3	11,506,380	82	16,821,248	85.9	12,099,920	83.5	14,466,780	85.4
Feasibility	59,000	0.4	59,000	0.3	59,000	0.3	59,000	0.4	59,000	0.3
Development	390,500	2.4	390,500	2.8	390,500	2	390,500	2.7	390,500	2.3
Engineering	158,000	1	158,000	1.1	158,000	0.81	158,000	1.1	158,000	0.9
Balance of Plant	1,590,000	10	1,368,000	9.8	1,382,000	7.1	1,218,000	8.4	1,197,000	7.1
Miscellaneous	622,772	3.9	548,275	3.9	761,430	3.9	566,017	39	659,851	39
O&M cost	581,200		552,523		619,506		394,115		589,941	

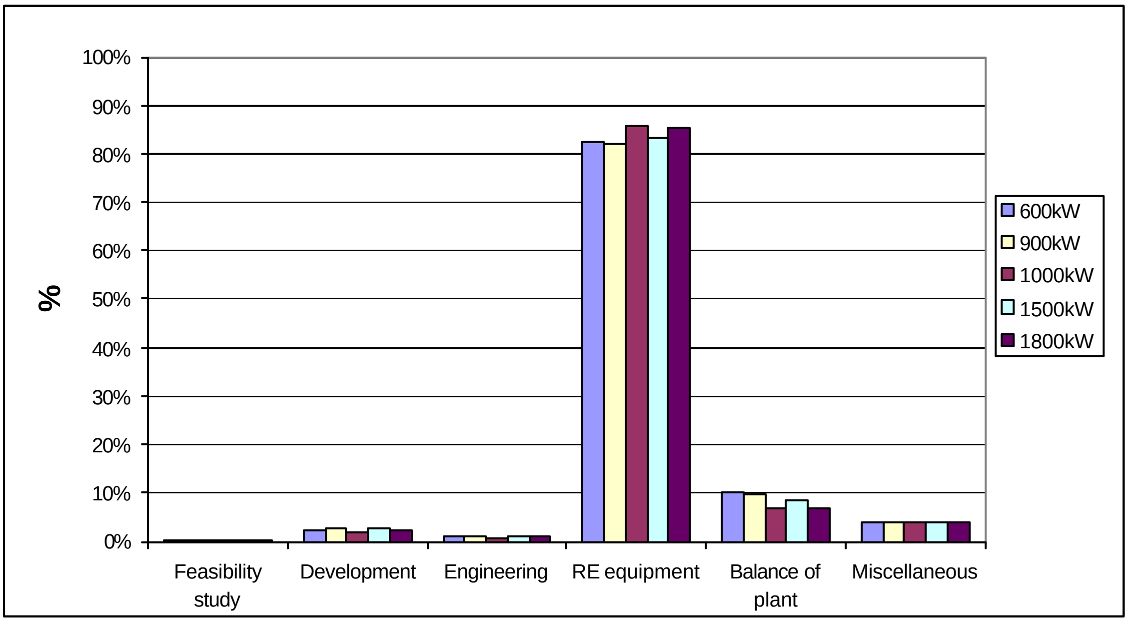


Figure 7-21 Comparison of Cost of Energy Components

The leading component of capital cost is still, renewable energy equipment, followed next by the costs of balance of plant. Together, these two leading components represent about 91-93 % of the total initial cost for IPP. The share of the other components like feasibility study and development decreased rapidly.

Table 7-22 Summary of all alternatives

12MW	**1**	**2**	**3**	**4**	**5**
Turbine Rated Power(kW)	600	900	1000	1500	1800
Manufacturer / Turbine Type	Enercon E40	NEG-Micon NM52	Enercon E58	NEG-Micon NM64	Enercon E66
Number of Turbines	20	13	10	8	7
Wind Plant Capacity(MW)	12.0	11.7	12.0	12.0	12.6
Estimated Energy Delivered (MWh)	44,365	41,596	48,064	26,298	45,209
Total Initial Costs($)	15,967,072	14,030,155	19,572,178	14,491,437	16,931,131
Operating Cost ($)	581,200	552,523	619,506	394,115	589,941
Project Equity	4,790,122	4,209,047	5,871,653	4,347,431	5,079,339
Project Debt	11,176,950	9,821,109	13,700,525	10,144,006	11,851,792
Debt Interest Rate	8.5	8.5	8.5	8.5	8.5
Debt Term	10	10	10	10	10
Cost per kWh(cents/kWh)	2.75	2.68	2.92	3.70	2.80

7.3.3.1 Selection of Turbine

Neg Micon NM52-900kW has the lowest sales price-6.12cents/kWh- at 15% IRR rate.

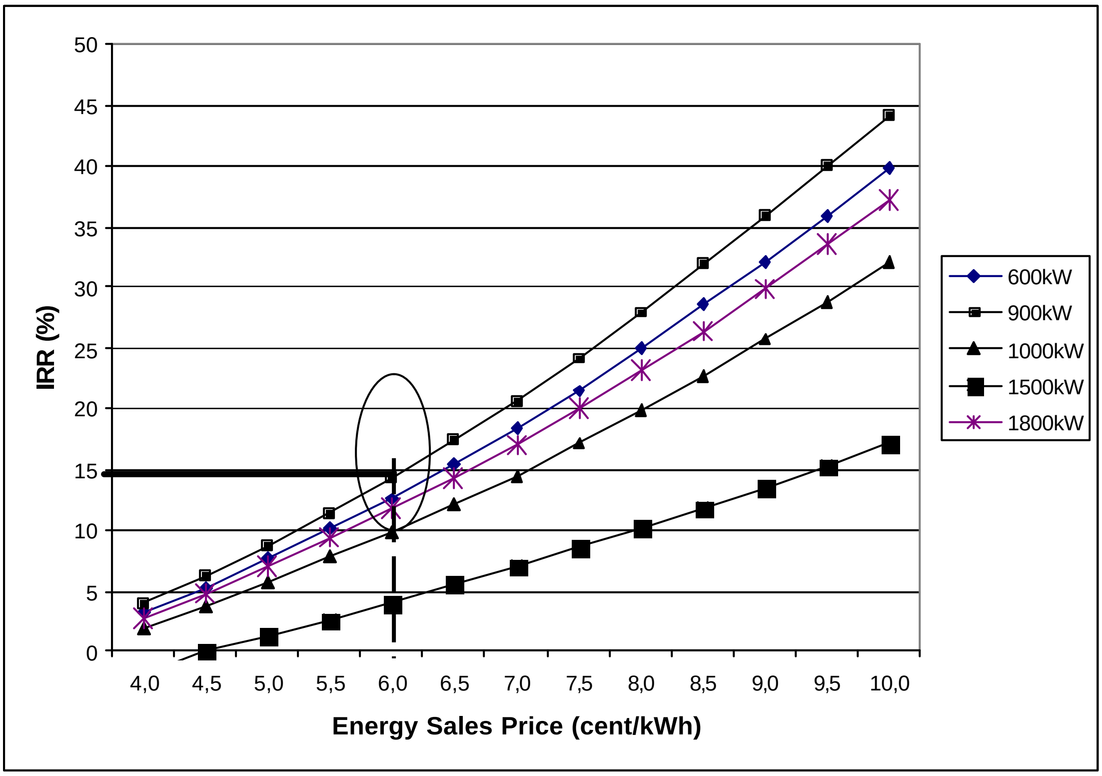


Figure 7-22 IRR versus Energy Price for IPP

7.3.3.2 Variance Analysis

We had selected our turbine type according to the IRR & Energy Price values. Further analysis would be done for Alternative 2- NEG-Micon NM52-900kW and the "Base Case" parameters are shown in Table 7-23.

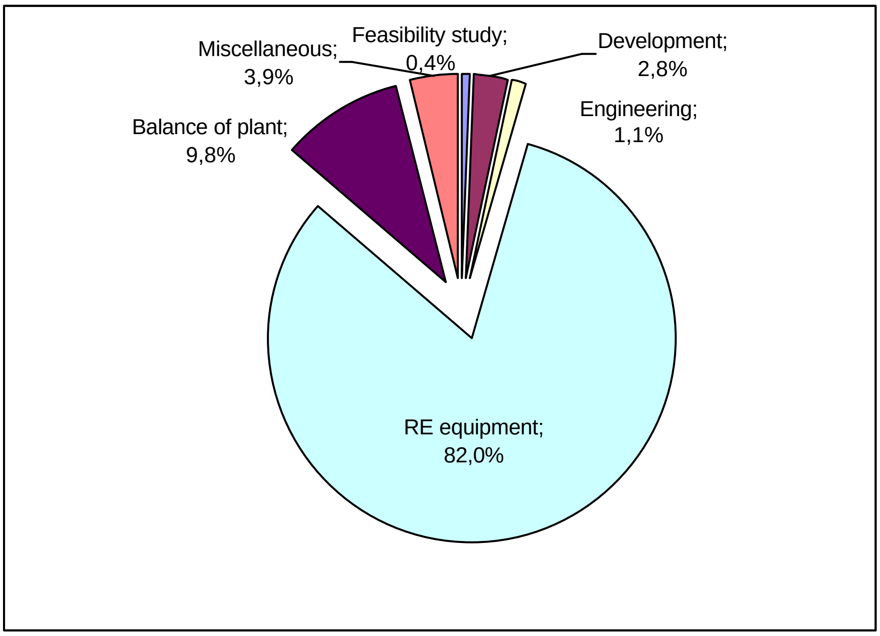


Figure 7-23 The cost component distribution of NEG-Micon NM52- 900 kW for IPP

The graphics and tables explained below highlights which variables have the greater impact on the project.

Table 7-23 Variance Analysis Summary for NM52-900kW

Variable & Variance	IRR	15% NPV
Base Case	15%	$0
Price -20%	8.2%	-$2,587,913
+20%	23.1%	$2,434,692
Op Cost -20%	16.7%	$572,104
+20%	13.3%	-$580,104
Capital -20%	23.6%	$2,061,582
+20%	10.3%	-$2,053,424
Inflation +2%	13.8%	-$400,337
+4%	12.1%	-$897,817

(Cont. on the next page)

Table 7-23 (cont.)

Repayment 1 year	11.5%	-$2,199,047
6 year	13.1%	-$840,967
10 year	15%	$0
12 years	16.2%	$352,641

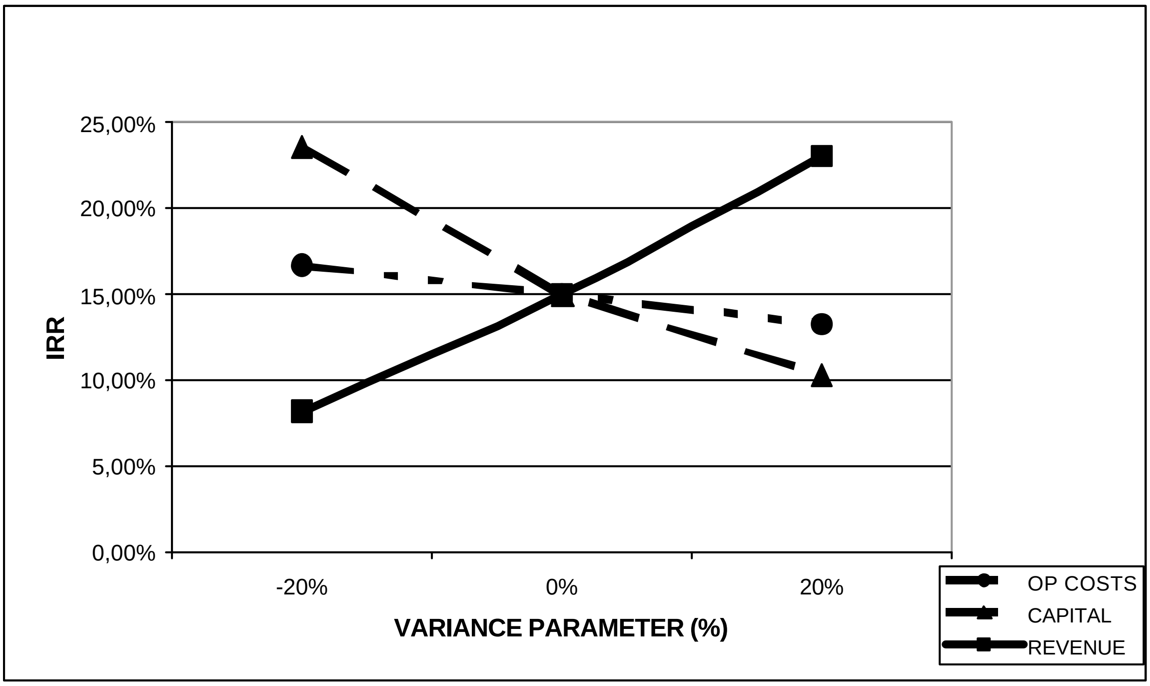


Figure 7-24 Sensitivity Graph for IPP

Sensitivity analysis can project how changes in the selected cost items would impact on the cost analysis of the different turbine options under consideration.

On the one hand, sensitivity analysis would allow decision makers to formulate specific policies with a view of the consequences of their decisions.

On the other hand, the use of sensitivity analysis allows investors/planners to investigate how their investment would respond to changes in economic conditions, as well as enabling them to study the impact of an anticipated change in the regulatory framework.

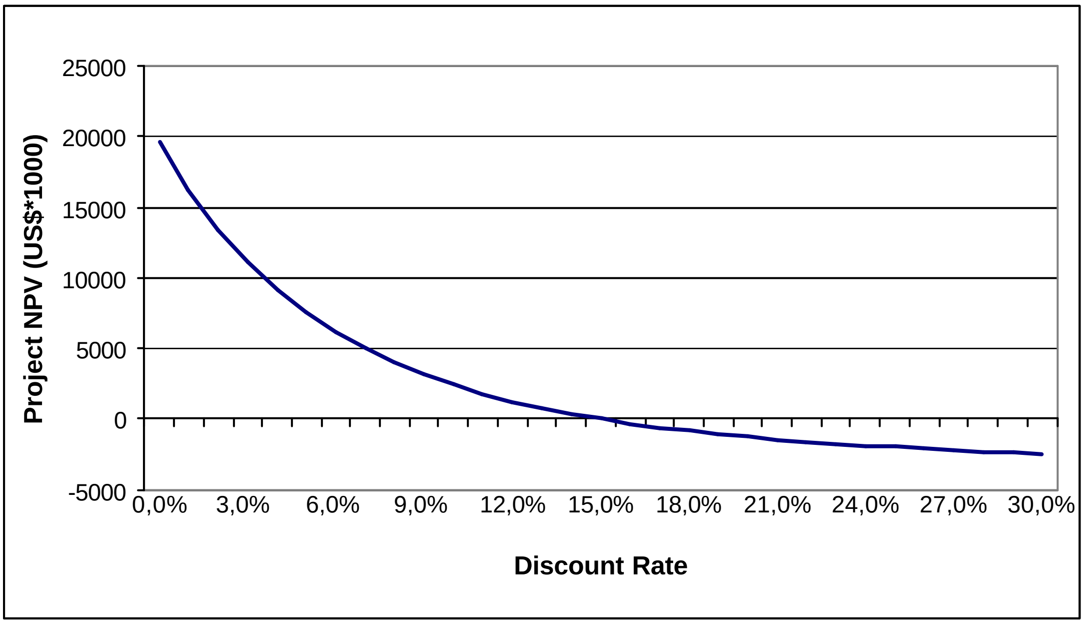


Figure 7-25 NPV versus Discount Rate for IPP

Table 7-24 The effect of Interest Rate on IRR,NPV, Payback Time and Year to Positive Cash Flow

Parameter	Discount Rate			
	6%	8%	10%	15%
IRR (%)	15	15	15	15
Simple payback period(years)	7.1	7.1	7.1	7.1
Year to positive cash flow(years)	8.8	8.8	8.8	8.8
NPV (US$)	6,173,014	4,004,752	2,422,267	0

Table 7-25 The effect of Discount Rate on IRR, NPV, Payback Time and Year to Positive Cash Flow

Parameter	Interest Rate					
	6%	7%	8%	8.5%	9%	10%
IRR (%)	17.1	16.3	15.4	15	14.6	13.8
Simple payback period(years)	7.1	7.1	7.1	7.1	7.1	7.1
Year to positive cash flow(years)	6.6	7.3	8.2	8.8	9.9	10.3
NPV (US$)	663,552	406,096	137,817	0	-139,193	-422,131

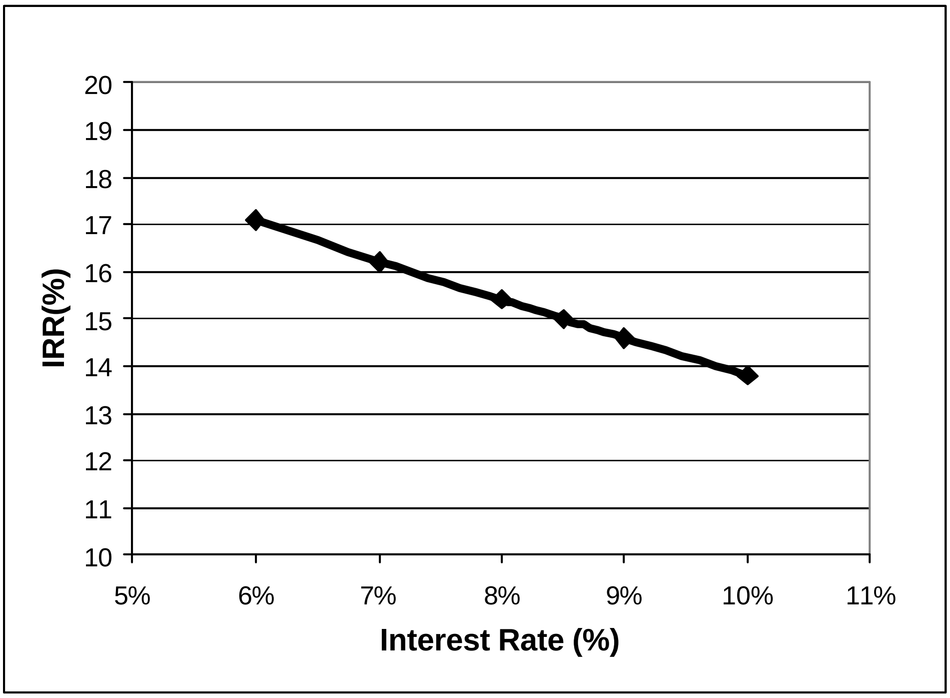


Figure 7-26 IRR via Debt Interest Rate for IPP

Table 7-26 The effect of inflation on IRR and NPV

	Inflation Rate			
	0%(Base Case)	**2%**	**2.5%**	**3%**
NPV ($)	0	-400,337	-513,862	-634,069
IRR	15%	13.8	13.4	13

According to Table 7-26, Figure 7-27 and Figure 7-28 inflation rate highly effects NPV, IRR and minimum energy sales price in all cases.

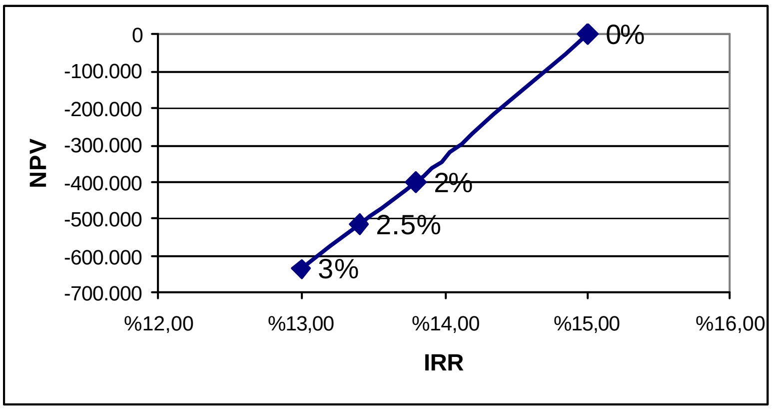


Figure 7-27 The effect of inflation on IRR and NPV

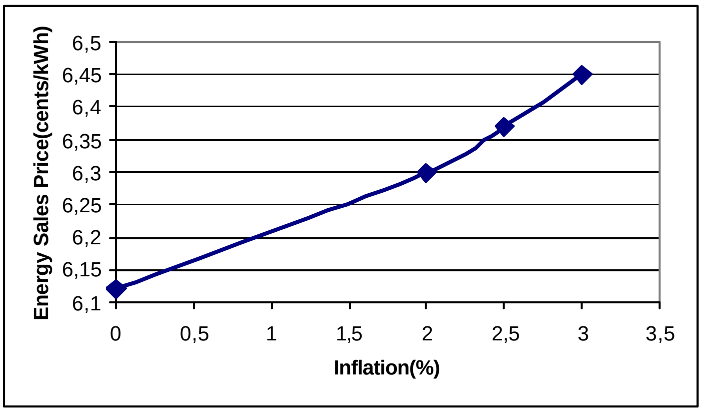


Figure 7-28 Inflation via required minimum sales price for IRR=15%

For the base case, the minimum energy sales price is 6.12 cents/kWh for 15% IRR with 0% inflation rate. When the inflation rate is taken into consideration with 2%, 2.5% and 3%, the minimum energy sales price would be 6.30, 6.37 and 6.45 cents/kWh for 15% IRR, respectively.

7.3.3.3 Sequence of Events in Wind Energy Projects

The projects follow a logical and more or less chronological scheme. During the initial project stage, aspects must be examined that require official authorization. Such as building permissions, grid access, approval of Ministry of Environment and Ministry of Energy.

One of the milestone to finalize the project is project financing. Only once the funding is secured, a proper project process and time schedule can be drawn up. The funding step sparks initial measures at the site. (at least 1 year data with the calibrated anemometer) Financing and approvals are the primary and extremely time consuming milestones of the project. These issues have to be sorted out at the start of the project.

After this step, the entire infrastructure must be prepared for the erection of turbines. Usually the erection of turbines takes within 6 months from when the binding order is placed.

Five points are important:

- Access and suitable position for the crane,
- Foundation,
- Transformer and transfer station,
- Low and medium voltage cabling,
- Data transmission,

In addition to procuring stations with the correct specifications it also takes time to build the foundations. So the delivery date for foundation parts has to be coordinated with the builder at an early stage.

The access roads have to be in line with specifications for crane and transport of the turbine parts by trucks. If access and crane position would be sufficiently fortified, (the gradient too high, curves too narrow,... etc.) the transportation of the parts and crane are no longer safe.

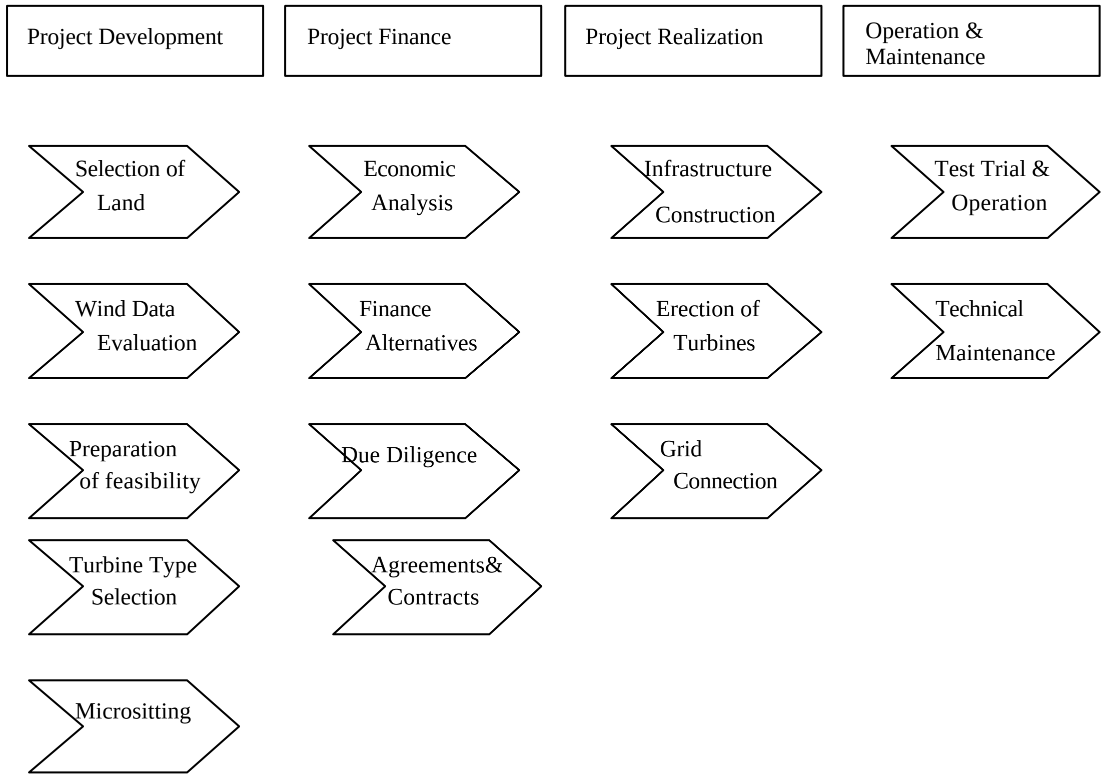


Figure7-29 Structure of building a wind energy project [64]

Chapter 8

CONCLUSION

Most of the world energy demand is met by fossil fuel generated electricity. The fact that the fossil fuels are going to be ended in 21st century, the energy sources have to be verified. Wind energy is a good chose for verification. Another reason for using renewable energy source is to lower dependency on foreign oil imports. Lastly, the green house gasses and Kyoto Protocol are good reasons for renewable energy generation.

In most countries, hydro electricity generation is still the most dominant among all Renewable energy technologies. Wind power generation took off in the mid 90s due to technical progress and political incentives. Today, it is the most promising renewable energy source (RES) in terms of market growth.

Also, wind energy is mature compared with many of the other renewables. Even at today's cost levels, it is close to being competitive with other power generation technologies in some circumstances, and may even be cheaper at good sites as fuel prices rise.

The electricity supply industry is highly capital intensive. It is probably more capital intensive than any other sector, particularly in developing countries. Therefore, planning and proper financial and economic evaluation of projects are important for rationalizing investment and achieving economic efficiency. It is crucial that a more detailed feasibility analysis has to be done after a potential cost-effective wind energy project has been identified through the RETScreen.

According to the previous study, IZTECH campus has a mean speed of 8.14m/s at 30m. which is indicating "excellent" zone. The prevailing wind direction is North and North Northeast. As far as wind potential of IZTECH site is acceptable, the economic evaluation can be done for the site.

The economically feasible potential site is evaluated using estimations for the average cost of electrical energy produced by each turbine and taking into account all the cost parameters affecting the economics of Renewable Energy Technologies(RET)'s such as installation cost, O&M costs, cost of grid interface, cost of civil works, etc. The influence of each cost parameter (installation, O&M, network, civil works) to the final cost of energy is also estimated.

The illustration is done for three scenarios. According to the results of the pre-feasibility studies, it can be concluded that the projects are feasible for the autoproducer, autoproducer group and IPP respectively, with 600kW, 900kW and 900kW turbines.

	IYTE Autoproducer	Autoproducer Group	Independent Power Porducer (IPP)
Turbine Type	Enercon E40 -600kW	NEG-Micon NM52 – 900kW	NEG-Micon NM52 – 900kW
Wind Plant Capacity (MW)	1.2	1.8	11.7
Estimated Energy Delivered (MWh)	4,437	6,399	41,596
Total Initial Cost	2,186,195	2,667,549	14,030,155
Cost per kWh(cents/kWh)	6.27	4.82	2.68
Min. energy sales price with IRR 15% (cents/kWh)	11.12	9.08	6.12
Min. energy sales price with IRR 15%, 3% inflation (cents/kWh)	12,1	9,82	6,45

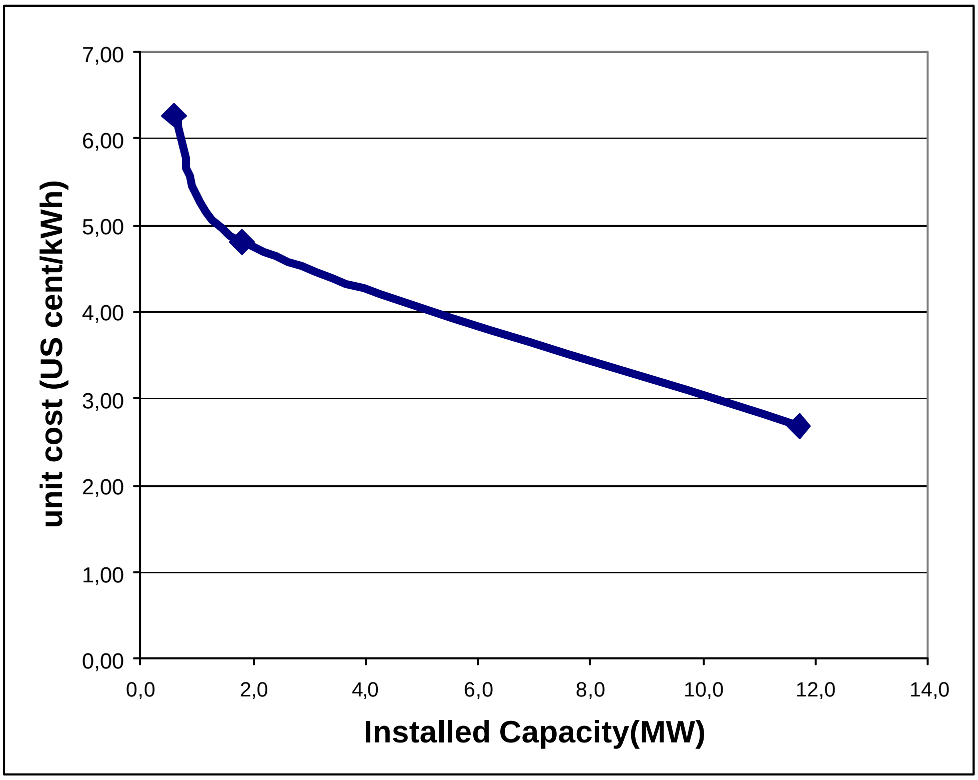


Figure 8-1 Energy price versus installed capacity

All three scenarios are promising in respect to cost per kWh and IRR. But the best scenario for the campus area is IPP case. Therefore, the developer should consider to build a wind farm as an IPP, firstly. While good opportunities for the deployment of the renewable already exist in Turkey, obstacles to invest, related to investor perception and institutional limitations as well to structural issues in the renewable sector, impede the realization of such opportunities. Project financing and syndicated loan credit can play a role in accelerating the deployment of wind energy projects in Turkey. Both financial mechanisms can also be applied to IZTECH scenarios. On the other hand, the uncertainty in renewable energy in Turkey makes financing harder. There has to be an incentive mechanism for renewables. The public acceptance and political support have to be ensured.

Wind power must be included in our fuel mix if a sustainable energy future is to be achieved. It is expected that driven by the momentum of sustainable development and concerns for global warming, renewable energy will continue to experience strong growth.

Turkish electricity market has to make necessary regulatory arrangements for the obligations of Kyoto Protocol.

The implementation of wind energy as a renewable energy source would reduce the current national energy insecurity associated with the production and use of fossil fuels. The immediate priority of Turkey should be to speed the transition from the reliance on non-renewable fossil fuels to reliance on renewable energy sources.

In order to achieve this goal, governmental support is needed, and then legislative system has to be formed. Technical progress of renewable energy generation technologies and increasing cost of power generation from conventional energy sources are the other factors that drive growth and value in the renewable energy market.

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APPENDIX

RETScreen - Renewable Energy Technology Screen

RETScreen International was developed by Natural Resources Canada's (NRCan) CANMET Energy Diversification Research Laboratory (CEDRL) with the contribution of several experts from industry and government. RETScreen is funded in part by NRCan's Renewable and Electrical Energy Division (REED) through the Renewable Energy Deployment Initiative (REDI). RETScreen is being further developed in collaboration with the United Nations Environment Programme's (UNEP) Division of Technology, Industry and Economics (DTIE) and the National Aeronautics & Space Administration's (NASA) Earth Science Enterprise Program.

RETScreen is a pre-feasibility analysis software for renewable energy projects. The software can be used to evaluate the annual energy production, costs and financial viability of the following renewable energy technologies (RETs):

Wind energy
Small hydro
Photovoltaics
Solar air heating
Biomass heating
Solar water heating
Passive solar heating
Ground source heat pumps

This model can be used world-wide to easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for central-grid, isolated-grid and off-grid wind energy projects, ranging in size from large scale multi-turbine wind farms to small scale single-turbine wind-diesel hybrid systems.

RETSCREEN WIND ENERGY PROJECT MODEL

Each RETScreen renewable energy technology model (e.g. Wind Energy Project, etc.) is developed within an individual Microsoft® Excel spreadsheet "Workbook" file. The Workbook file is in-turn composed of a series of worksheets. These worksheets have a common look and follow a standard approach for all RETScreen models.

Five worksheets, Energy Model, Equipment Data, Cost Analysis, Greenhouse Gas (GHG) Emission Reduction Analysis, Financial Summary Worksheets, are used for the evaluation.

Energy Model

The Energy Model worksheet is used to help the user calculate the annual energy production for a wind energy project based upon local site conditions and system characteristics. Results are calculated in common megawatt-hour (MWh) units for easy comparison of different technologies.

Equipment Data

The Equipment Data worksheet is used to specify the wind equipment for the project. The results of this worksheet are transferred to the Energy Model worksheet. The user should return to the Energy Model worksheet after completing the Equipment Data worksheet.

Cost Analysis

The Cost Analysis worksheet is used to help the user estimate costs associated with a wind energy project. These costs are addressed from the initial, or investment, cost standpoint and from the annual, or recurring, cost standpoint.

Greenhouse Gas (GHG) Emission Reduction Analysis

A GHG Analysis worksheet is provided to help the user estimate the greenhouse gas emission reduction potential of the proposed project. This common GHG emission reduction analysis worksheet contains four main sections: Background Information, Base Case System (Reference), Proposed Case System (Mitigation) and GHG Emission Reduction Summary. This is an optional analysis - inputs entered in this worksheet will not affect results reported in other worksheets, except for the GHG related items that appear in the Financial Summary worksheet.

Financial Summary

As part of the RETScreen Renewable Energy Project Analysis Software, a Financial Summary worksheet is provided for each RET project evaluated. This common financial analysis worksheet contains five sections: Annual Energy Balance, Financial Parameters, Project Costs and Savings, Financial Feasibility and Yearly Cash Flows. The Annual Energy Balance and the Project Costs and Savings sections provide a summary of the Energy Model, Cost Analysis and GHG Analysis worksheets associated with each project studied. In addition to this summary information, the Financial Feasibility section provides financial indicators of the RET project analyzed, based on the data entered by the user in the Financial Parameters section. The Yearly Cash Flows section allows the user to visualize the stream of pre-tax, after-tax and cumulative cash flows over the project life. The Financial Summary worksheet of each RET Workbook file has been developed with a common framework so the task of the user in analyzing the viability of different project types is made simpler. This also means the description of each parameter is common for most of the items appearing in the worksheet.

One of the primary benefits of using the RETScreen software is that it facilitates the project evaluation process for decision-makers. The Financial Summary worksheet, with its financial parameters input items (e.g. avoided cost of energy, discount rate, debt ratio, etc.), and its calculated financial feasibility output items (e.g. IRR, simple payback, NPV etc.), allows the project decision-maker to consider various financial parameters with relative ease.

DATABASES

Product Data

Some of the product data requirements for the model are provided in the RETScreen Online Product Database. To access the product database the user may refer to "Access to the Online User Manual, Product and Weather Database." The product database provides information on the equipment associated with the Wind Energy Project. From the Online Product Database dialogue box the user may obtain product specification and performance data, as well as company contact information.

Weather Data

This database includes some of the weather data required in the model. To access the weather database the user may refer to "Access to the Online User Manual, Product and Weather Database." While running the software the user may obtain weather data from ground monitoring stations and/or from NASA's satellite data. Ground monitoring stations data is obtained by making a selection for a specific location from the Online Weather Database dialogue box. NASA's satellite data is obtained via a link to NASA's Website from the dialogue box.

Cost Data

Typical cost data required to prepare RETScreen studies are provided in the RETScreen online cost database and in the online manual. This database is built into the "right-hand column" of the Cost Analysis worksheet. Data are provided for Canadian costs with 2000 as a baseline year. The user also has the ability to create a custom cost database.