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ECONOMIC ASPECTS OF WIND POWERGENERATION

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Abstract: *Wind energy, commonly recognized to be a clean and environmentally friendly renewable energy resource that can reduce our dependency on fossil fuels. Its mature technology and comparatively low cost make it promising as an important primary energy source in the future. India ranks fifth in the world with an installed capacity of about 21421 MW till mid 2014. Many options can be effectively used to meet the future power needs of a country in ways which would be more economically viable, environmentally sound, and socially justified. A least-cost generation expansion planning study can be conducted to find the economic feasibility of large scale integration of wind farms in the main interconnected transmission system. This paper aims to provide an economic overview of world wind energy scenarios, the current status of wind turbine development, various financial aspects in developing the wind farms and a briefly focuses to their environmental impacts.*

Key Words: wind power aesthetics, investment-cost, running cost, discount-rate

I. INTRODUCTION:

Wind power is developing rapidly at both European and global levels. Over the past 25 years, the global installed capacity of wind power increased from around 2.5 GW in 1992 to just over 94 GW at the end of 2007 then 283GW in 2012 and approximate 350GW till mid 2014, an average annual growth of about 25 per cent. [1]
Owing to ongoing improvements in turbine efficiency and higher fuel prices, wind power is becoming economically competitive with conventional power production, and at sites with high wind speeds on land, wind power is considered to be fully commercial.
The work focuses on the economics of wind power. The investment and cost structures of land-based and offshore turbines are discussed. The cost of electricity produced is alsoconsidered, which takes into account the lifetime of turbines and O&M costs, and the past and future development of the costs of wind-generated power is analyzed.
Also, the importance of finance, support schemes and employment issues are discussed in short. The cost of wind-generated electricity is compared to the cost of conventional fossil fuel-fired power plants. Figure 1depicts the globally increasing trend for wind power generation every year.

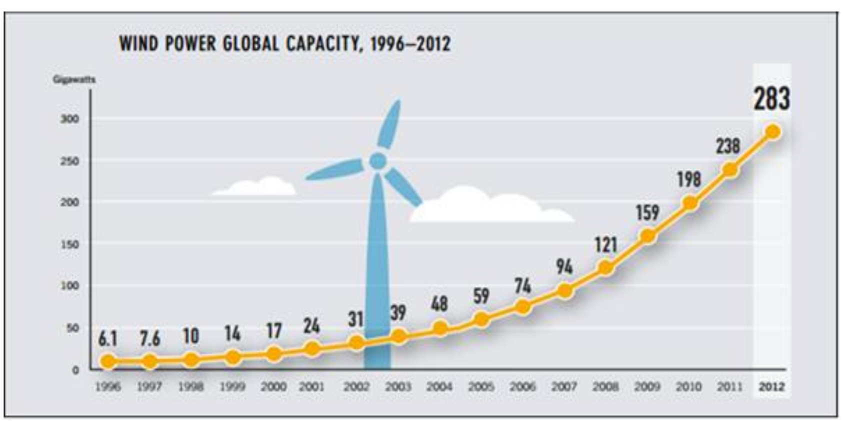

Fig. 1: Increasing global trends towards wind power generation global

Wind power is used in a number of different applications, including grid-connected and stand-alone electricity production and water pumping. The paper alsodescribes the economics of wind energy, primarily in relation to grid-connected turbines, which account for the vast bulk of the market value of installed turbines.

II. COST OF ON-LAND WIND POWER

The main parameters governing wind power economics includes following:

- Cost and Investment Structures,
- Investment costs, such as auxiliary costs for foundation and grid connection,
- Operation and maintenance costs,
- Electricity production/average wind speed,
- Turbine lifetime, and
- Discount rate.

The main parameters have been discussed one after another:

(i) Investment Costs:

The most important parameters are turbine electricity production and investment costs. As electricity production depends to a large extent on wind conditions, choosing the right turbine site is critical to achieving economic viability.

Figure 02 below depicts the main components and their percentage cost sharing. It considers the 05MW wind turbine. It was observed that the tower costs highest percentage of Approximate 26.30 followed by the rotor blades with 22.20% share in the overall cost.

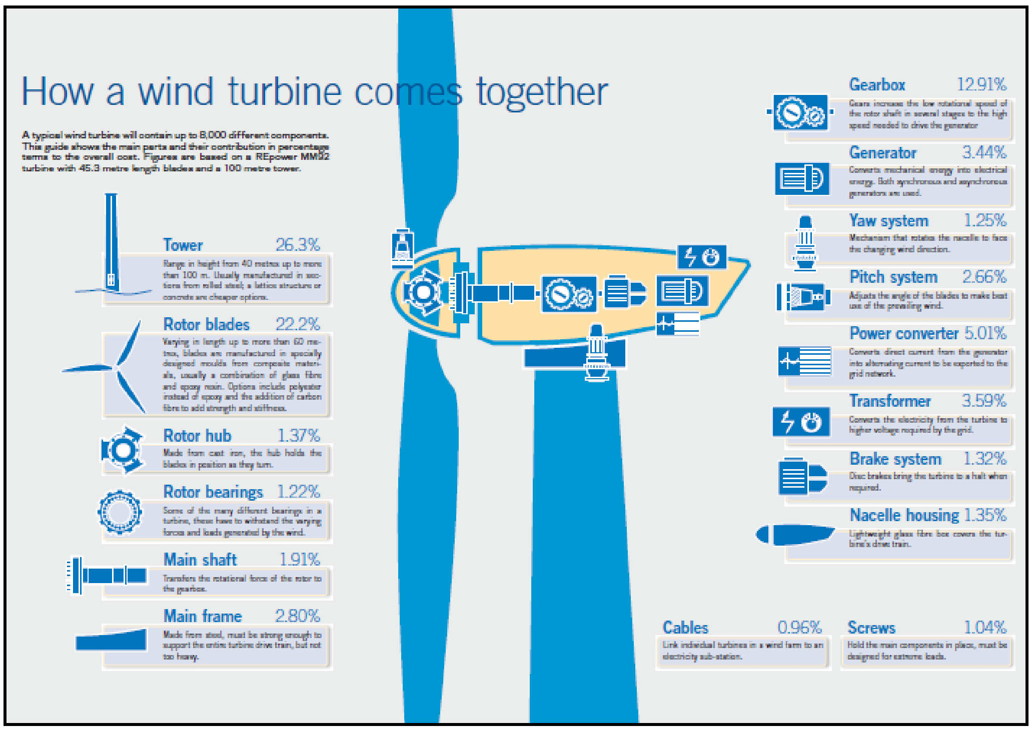

Fig. 2. The main components of a WTG set and their share to the overall cost (for the 05 MW RE Power machine)

The capital costs of wind energy projects are dominated by the cost of the wind turbine itself. An average turbine installed inEurope has a total investment cost of around €1.23 million/MW. The turbine's share of the total cost is, on average, around 76 per cent, while grid connection accounts for around 09 per cent and foundations for around 07 per cent. The cost of acquiring a turbine site (on land) varies significantly between projects. Other cost components, such as control systems and land, account for only a minor share of total costs.

The total cost per KW of installed wind power capacity differs between countries. The cost per KW typically varies from around €1000/kW to €1350/kW. The investment costs per kW were found to be lowest in Denmark and slightly higher in Greece and The Netherlands. For the UK, Spain and Germany, the costs in the data selection were found to be around 20–30 per cent higher than in Denmark.

Also, for 'other costs', such as foundations and grid connection, there is considerable variation between countries, ranging from around 32 percent of total cost in Portugal to 24 percent in Germany 21 per cent in Italy and only 16 per cent in Denmark. However, costs vary depending on turbine size as well as the type and its location.
Renewable sources have become the demand of the day for the welfare of humanity. Each country is trying to increase the contribution in this sector. Wind power being the prominent due to its large power production capacity is on the top. Figure 3 depictsthe market shared by the top 10 wind turbine manufacturer.[2][3]

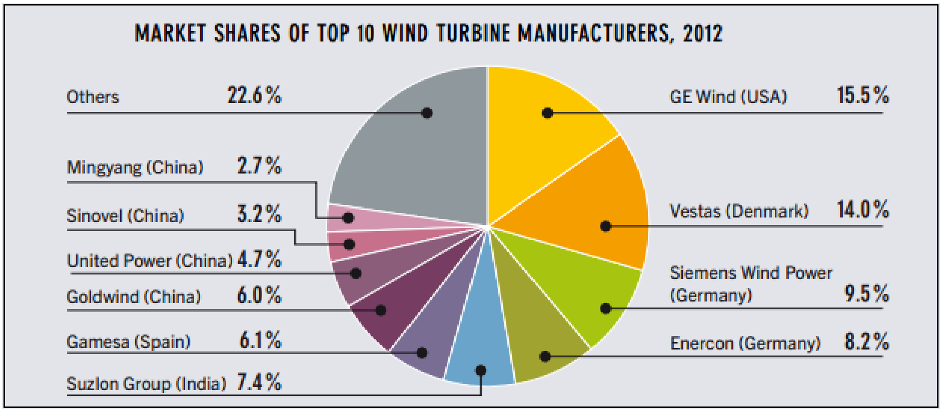

Figure 3: Market Trends in 2012

Approximate cost of main components of a typical wind farm (%) can be summaries as below:[4]

Turbine	928	75.6
Foundations	80	6.5
Electric	18	1.5
Grid	109	8.9
Control	4	0.3
Consultanc	15	1.2
Land	48	3.9
Financial	15	1.2
Road	11	0.9
Total	1227	100

(ii) Economics of Wind Power:

The wind regime at the chosen site, the turbine hub height and the efficiency of production determine power production from the turbines. So just increasing the height resulted in higher of turbines has resulted in higher power production. Similarly, the methods for measuring and evaluating the wind speed at a given site have improved substantially in recent years and thus improved the site selection for new turbines.

However, the fast development of wind power capacity in countries such as Germany and Denmark implies that the best wind sites in these countries have already been taken and that new on-land turbine capacity will have to be erected at sites with a marginally lower average wind speed.
The replacement of older and smaller turbines with modern versions is also becoming increasingly important, especially in countries which have been involved in wind power development for a long time, as is the case for Germany and Denmark.[5]

The development of electricity production efficiency, owing to better equipment design, measured as annual energy production per square meter of swept rotor area (kWh/m2) at a specific reference site, has correspondingly improved significantly in recent years. With improved equipment efficiency, improved turbine sitting and higher hub height, the overall production efficiency has increased by 02–03 per cent annually over the last 15 years.

(iii)Operation and Maintenance Costs of Wind-Generated Power:

Operation and maintenance (O&M) costs constitute a sizeable share of the total annual costs of a wind turbine. For a new turbine, O&M costs may easily make up 20–25 per cent of the total cost per kWh produced over the lifetime of the turbine. If the turbine is fairly new, the share may only be 10–15 per cent, but this may increase to at least 20–35 per cent by the end of the turbine's lifetime. [6]

As a result, O&M costs are attracting greater attention, as manufacturers attempt to lower these costs significantly by developing new turbine designs that require fewer regular service visits and less turbine downtime.O&M costs are related to following cost components:
• Insurance• Regular maintenance• Repair,•Spare parts and• Administration.

Some of these cost components can be estimated relatively easily. For insurance and regular maintenance, it is possible to obtain standard contracts covering a considerable share of the wind turbines total lifetime. Conversely, costs for repairs and related spare parts are much more difficult to predict. Although all cost components tend to increase as the turbine gets older, costs for repair and spare parts are particularly influenced by turbine age, starting low and increasing over time.Due to the relative infancy of the wind energy industry, there are only a few turbines that have reached with regard to the future development of O&M.

(iv)The Cost of Energy Generated by Wind Power:
The total cost per kWh produced (unit cost) is calculated by discounting and leveling investment and O&M costs over the lifetime of the turbine and then dividing them by the annual electricity production. The unit cost of generation is thus calculated as an average cost over the turbine's lifetime. In reality, actual costs will be lower than the calculated aver- age at the beginning of the turbine's life, due to low O&M costs, and will increase over the period of turbine use. The turbine's power production is the single most important factor for the cost per unit of power generated. The profitability of a turbine depends largely on whether it is sited at a good wind location. Figure 4 represents the Cost of generated power as compare to conventional power plants.

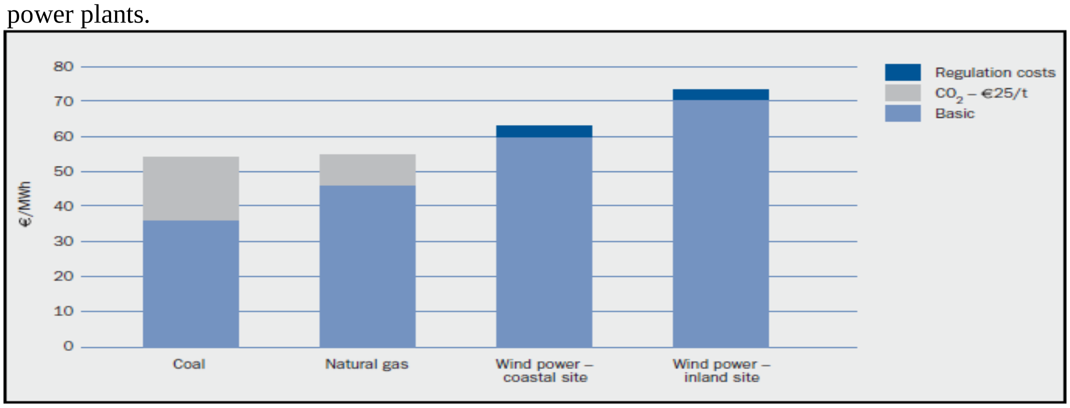

Figure 4: Cost of generated power as compare to conventional power plants

Other assumptions include the following:
• Calculations relate to new land-based, medium- sized turbines (1.5–2 MW) that could be erected.
• Conventional fossil fuel-fired technologies, such as natural gas power plants, where as much as 40–60 per cent of total costs are related to fuel and O&M costs. For this reason, the costs of capital (discount or interest rate) are an importantfactor for the cost of wind-generated power, which varies considerably between the countries.

(v)Development of the Cost of Wind-Generated Power:

The rapid European and global development of wind power capacity has had a strong influenced on the cost of wind power over the last 20 years. To illustrate the trend towards lower production costs of wind- generated power, a case that shows the production costs for different sizes and models of turbines is presented in Figure 5 .

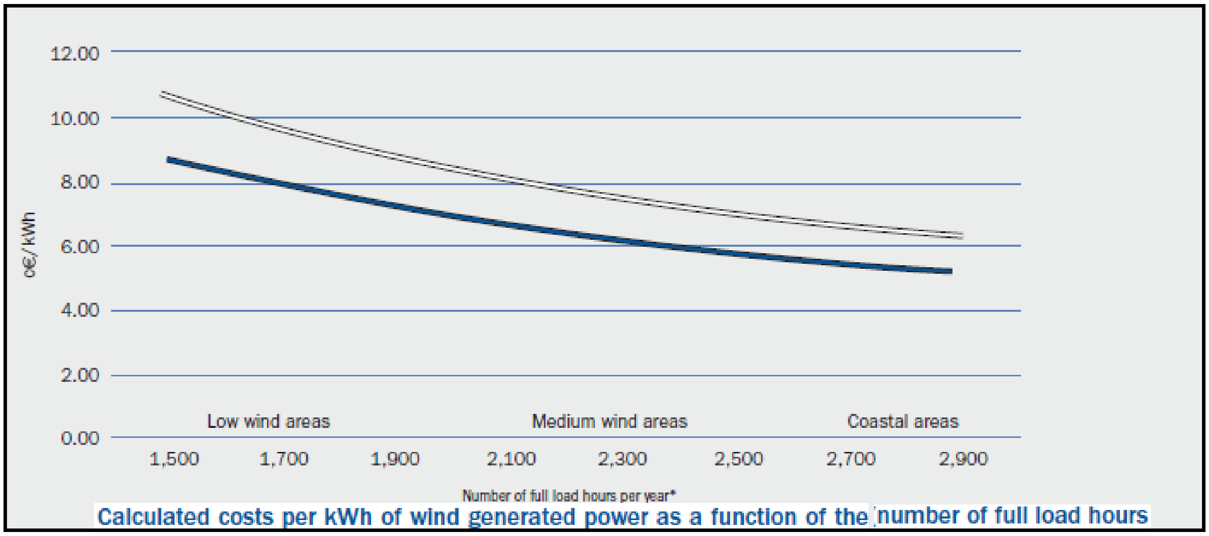

Figure 5: Cost of per kWh as a function of full load hours

Figure 5 shows the calculated unit cost for different sizes of turbine, based on the same assumptions used in the previous section: a 20-year lifetime is generally assumed for all turbines and the discount rate of 7.5 per cent per annum is considered. Turbine electricity productions are estimated for two wind regimes a coastal and an inland medium wind position [7].

III. FUTURE EVOLUTION OF THE COSTS OF WIND-GENERATED POWER

The future development of the economics of wind power is illustrated by the use of the experience curve methodology. The experience curve approach was developed in the 1970s by the Boston Consulting Group which relates the cumulative quantitative development of a product to the development of the specific costs.

Thus, if the cumulative sale of a product doubles, the estimated learning rate gives the achieved reduction in specific product costs.

The experience curve converts the effect of mass production into an effect upon production costs, without taking other causal relationships into account. Thus changes in market development or technological breakthroughs within the field may change the picture considerably.[8]

Wind power capacity has developed very rapidly in recent years, on average by 25 to 30 per cent per year over the last ten years. At present, the total wind power capacity doubles approximately every three to four years.

The present price-relations are approximate. The reason why no price reductions are foreseen is due to a persistently high demand for new wind turbine capacity and sub- supplier constraints in the delivery of turbine components.

In comparison to land-based turbines, the main differences in the cost structure are related to two issues:

Foundations are considerably more expensive for off- shore turbines. The costs depend on both the sea depth and the type of foundation being built. For a conventional turbine situated on land, the foundations' share of the total cost is normally around 05–09 per cent. However, since considerable experience will be gained through these two wind farms, a further optimization of foundations can be expected in future projects.

Transformer stations and sea transmission cables increase costs. Connections between turbines and the centrally located transformer station, and from there to the coast, generate additional costs. For the various sites the average cost share for the transformer station and sea transmission cables is 21 percent of which a small proportion (05 per cent) goes on the internal grid between turbines.[9]

Environmental analyses, includes an environmental impact investigation, graphic visualizing of the wind farms, as well as additional research and development. The average cost share for these analyses accounts approximately 06 per cent of total costs.

IV. THE COST OF ENERGY GENERATED BY OFFSHORE WIND POWER

Although the costs are higher for offshore wind farms, they are somewhat offset by a higher total electricity production from the turbines, due to higher offshore wind speeds. An on-land installation normally has around 2000–2300 full load hours per year, while for a typical offshore installation this may reach more (fig.6).

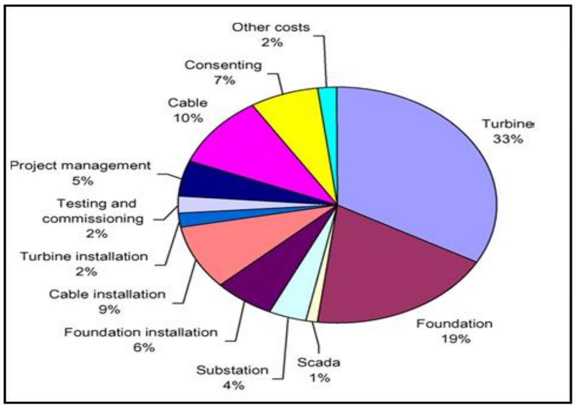

Figure 6: Estimation of capital cost for an offshore wind farm.

Over the last couple of decades, the vast majority of commercial wind farms have been funded through project finance. Project finance is essentially a project loan, backed by the cash flows of the specific project. The predictable nature of cash flows from a wind farm means they are highly suited to this type of investment mechanism.[10]
These days as an increasing number of large companies have become involved in thissector.There has been a move towards balance-sheet funding, mainly for construction. This means that the owner of the project provides all the necessary financing for the project, and the project's assets and liabilities are all directly accounted for at company level.
At a later date, these larger companies will sometimes group multiple balance sheet projects in a single portfolio and arrange for a loan to cover the entire portfolio, as it is easier to raise a loan for the portfolio than for each individual project.

V. THE WIND FARM PROJECT FINANCE:

Project finance is the term used to describe a structure in which the only security for a loan is the project itself. In other words, the owner of the project company is not personally, or corporately, liable for the loan. In a project finance deal, no guarantee is given that the loan will be repaid; however, if the loan is not repaid, the investor can seize the project and run or sell it in order to extract cash.

This process as rather like a giant property mortgage, since if a homeowner does not repay the mortgage on time, the house may be repossessed and sold by the lender. Therefore, the financing of a project requires careful consideration of all the different aspects, as well as the associated legal and commercial arrangements.
It is expected that before investment, any project finance lender will carefully check if there is any risk that repayment will not be made over the loan term.

VI. TECHNOLOGICAL RISKS FOR WIND POWER MARKET:

The present 'sellers' market', characterized by the shortage in supply of wind turbines, has introduced a number of new turbine manufacturers. Many of them are not financially strong and have a poor substantial track record.
Therefore, technology risk remains a concern for the banks. Thus the old-fashioned way of mitigating these risks is through extended warranties. It is resisted forcefully by both new and experienced manufacturers.
Hence technology risk has increased recently, rather than diminishing over time. However, some banks are still showing significant interest in lending to projects that use modern technology but with relatively little operational experience.
Offshore Wind Farm Economics:
Offshore wind farms are now more common in Europe. The first few projects were finance by large companies with substantial financial clout. The initial involvement of banks was in the portfolio financing of a collection of assets, one of which was an offshore wind farm. Banks were concerned about the additional risks associated with an offshore development. This approach allowed the risks to be diluted somewhat.
Approximate estimation of the offshore wind turbines are compared below:

	INVESTMENT COSTS, MILLION €/MW			O&M	CAP. FACTOR
	Min	Average	Max	€/MWh	%
2006	1.8	2.1	2.4	16	37.5
2015	1.55	1.81	2.06	13	37.5

Although there are still relatively few offshore wind farms, banks are clearly interested in both (i) term loans, associated with the operational phase of offshore wind farms, and (ii) the provision of construction finance. This clearly demonstrates the banks' appetite for wind energy lending.

It is too early to define typical offshore that for the equivalent onshore farm, at least until the banks gain greater confidence in the technology. The risk of poor availability as well as poor accessibility is a major concern.[11]

VII. CONCLUSIONS

The nature of wind energy deals is changing throughout the world. Although many small, privately owned projects remain, there has been a substantial shift towards bigger, utility- owned projects. This change brings new money to the industry, reduces dependence on banks for initial funding and brings strong sponsors.

Projects are growing and large-scale offshore activity is increasing. Since banks favor larger projects, this is a very positive change. If the economic picture deteriorates, it may give rise to certain misgivings concerning project finance. The political and environmental support for renewable energy means that the funding of wind energy remains a very attractive proposition.

It is hoped that obtaining financing for the large-scale expansion of the industry will not be a problem. It is also assumed that wind energy in all forms is going to serve the generations ahead. At the same time India is also trying to increase its contribution in this market through the great political, industrial, environmental and individual willingness.

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