The Use of Wind Energy in India - Lessons learned.

"Boundless and ever glorious you might carry with you,

O showerers of blessed gifts on humanity,

And unlimited and unbeaten force…"

- Hymn on Marut, the God of Wind, from the *Rig Veda*.

Victor K. Mallet

Term Paper, Sustainable Energy, 10.391J

Spring 2001

Table Of Contents

1. Executive Summary

This paper will deal with the employment of wind energy as an alternative and renewable source of energy in India. The purpose of the paper is to give a clear idea of what kind of measures are needed in developing countries for alternative sources of energy such as wind to be a success.

It first introduces the notion of wind energy use in India. It follows by outlining the technology of energy generation from wind. Then, it goes on to look at the history and development of wind energy use in India since the early 1990's. The current state of wind energy in India is examined, looking specifically at the geographic distribution of wind farms and estimated wind capacity in various states as well as the current state of the market with regards to private sector companies active in the space. The paper will then examine specific economic measures, technical and social factors, infrastructural conditions and government policies that have allowed wind energy to succeed in (certain parts of) India. A similar framework is used to examine what problems were encountered and where some initiatives have failed. We will then make some broad recommendations for addressing the problems India is faced with in this respect. A brief foray will then be made into an alternative consideration for wind energy use in India. Finally, we shall arrive at a number of key lessons that policy makers, engineers and entrepreneurs in developing countries must take into account in considering wind energy employment in their country.

2. Introduction

India currently ranks fourth in the global wind energy installation list, with about 1271 MW installed capacity estimated on 28th February 2001, a figure placing it right behind Germany, Denmark and the United States. The Washington-based *Worldwatch Institute* recognizes India as a "Wind Superpower". A veritable wind energy boom began in the early 1990's with the transformation of the Department of Non-Conventional Energy Sources into the Ministry of Non-Conventional Energy Sources in 1992. India is probably the only country in the world with a full-fledged ministry dedicated to the production of energy from renewable energy sources.

As far back as 1950's wind energy was being used in India to pump water for domestic use and irrigation and as an alternative to diesel pump-sets. Then in the 6th National Five-Year Plan (NFYP) the Government of India introduced the National Windmill Demonstration Program, which, continued throughout the 7th NFYP (1985-1990), and saw the installation of hundreds of units of 12 PU-500 wind pumps for shallow water pumping. Today, India's energy demand is expected to require an extra 150, 000 MW of installed electricity by 2012 and the government is looking to wind energy to help solve that supply problem.1[1]

Current wind technology can be separated into three types. First there are wind pumps, which use mechanical energy from wind mainly for water-pumping purposes (used for drinking and irrigation). Then, there are wind energy generators (WEGS's), connected to turbines, which are used to produce electricity, to be distributed on electricity grids and are meant for rural and/or urban use. Lastly, there are wind-electric battery chargers that produce electricity and store it in batteries. **This paper on Indian use of wind energy will focus on WEG use and grid-intended electricity production and distribution.**

[1] India is a union of 26 States. Hence the legislative authority is split between the Union (Center) and the State governments with concurrent jurisdictions of both over electricity.

3. Wind Energy Technology – A Technical Overview

3.1 Background

In 1891, a Dane by the name of Poul LaCour built the first electricity-generating wind turbine. It was improved by Danish engineers and used to supply energy during energy shortages in World War I and World War II. The wind turbines built by the Danish company F.L Schmidt (now a cement machinery maker) in 1941-1942 can be considered the forerunners of modern wind turbines, and other companies, such as the American Palmer Putnam began building turbines as well, modifying the number of blades and tower height.

The actual technology has also improved in large spurts. By the end of 1989, a 300 kW wind turbine with a 30-m rotor diameter was state-of-the-art. Ten years later, 1500 kW turbines with a diameter of around 70m are available from many manufacturers. Though 4-5 MW are expected within the next 2 years, the 1.5 MW turbines remain state-of-the-art. In India, a typical wind turbine is of the 200 kW type.

Source: www.indianwindpower.com

3.2 The Physics of Energy Extraction from Wind

The power carried by a flowing mass of air that is called wind is the product of the cross-sectional area of the mass and the wind, the density of the wind, ρ , and the wind speed, v.

Wind Power, $P = ½ * A * v^3$ (Watts)

$ρ$ = Air density (kg/m3)

v = wind speed (m/s)

The air density is proportional to the air temperature and the air pressure, both of which vary with height above sea level.

The power in the wind cannot be completely converted to mechanical energy of a wind turbine. Otherwise the air mass would be stopped completely in the intercepting rotor area and would cause a "congestion" of the cross-sectional area for the following air masses.

The theoretical maximum of energy extraction from wind was discovered by Betz in 1926, and is written as

$P_{Betz} = ½ * ρ * A * v^3 * Cp_{Betz} = ½ * ρ * A * v^3 * 0.59$

Though this is not a hard and fast limit such as the Carnot efficiency it happens to be a useful rule-of-thumb estimate.

According to Betz, even if no losses occurred a wind turbine could utilize only 59% of the wind power. In addition when unavoidable swirl losses are included, this figure reduces to about 0.42. This happens to be observed as the current limit of well-designed turbines today.

3.3 Factors affecting Wind Power Extraction

- Elevation of Blade Hub above ground – The higher above ground one is, the higher the wind velocity (to the 1/7th power) and since power is proportional to the cube of the velocity, an increase in hub elevation from 30m to 50m leads to an average wind speed 7.6% higher. This becomes a significant cost-benefit trade-off since taller hubs become more expensive.
- Spacing of Wind Turbines on Wind farms – Too far a spacing will prevent the maximum amount of wind to be intercepted. However, too close a spacing will lead to interference, and downwind units will be less productive.

Source: IndianWindpower.com - Turbines used in India

D = Diameter of Turbine

Area Required per Turbine = Approximately 5 acres.

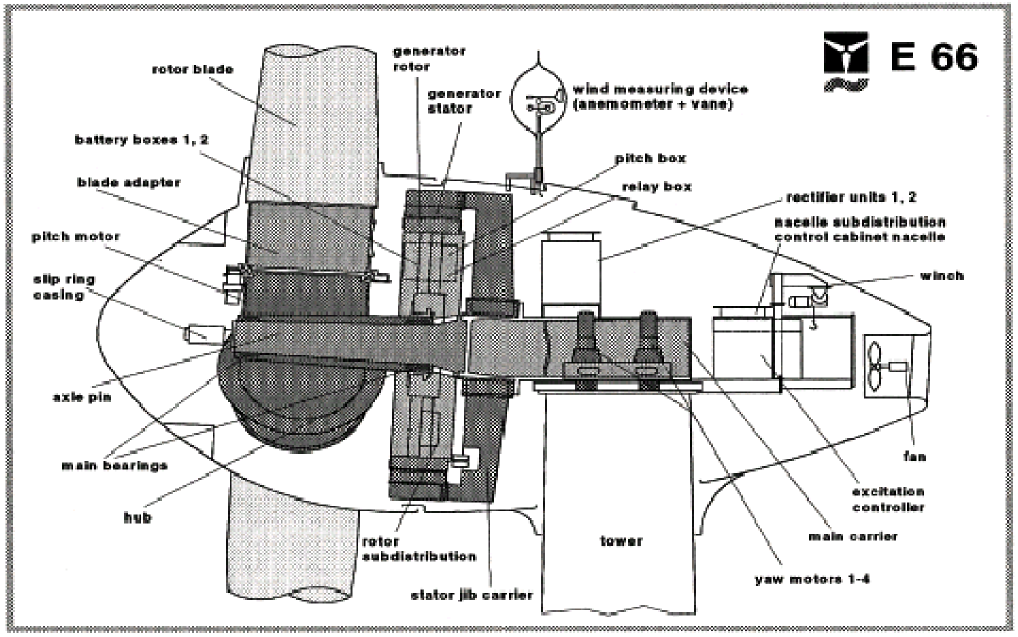
- Siting of Wind Turbine – Naturally not all locations are suitable for placement of wind turbines. In order to be economical, most sites have to have average wind speeds of about 10 m/s. This speed usually increases with height above ground.
- Air density – The higher the density of air, the more power carried by the wind, and as air density decreases with height above sea-level, usually sites in mountainous regions are less preferable than those at flat, sea-level locations. (For example, in "mile' high" Denver, air density is only 0.84 that at sea level which reduces the available wind-borne energy by as much as 6% in average wind velocity).

3.4 Major Components of a typical horizontal axis wind turbine

From an engineering standpoint, two types of wind turbines exist – those that use aerodynamic drag (used by the early Persians and Chinese), and those that utilize aerodynamic lift. Modern wind-turbines are based on those that use lift and these can be further divided into vertical axis and horizontal axis turbines. All the turbines we will be discussing will be the horizontal axis turbines and are by far the widest in use

A wind turbine generator usually consists of the following parts

1) **Tower** – Either steel lattice or tubular pole. The tubular towers are more popular among modern turbines because of their lower airflow interference and downstream turbulence creation. Also, they seem to be more aesthetically acceptable.
2) **Rotor Blades** - Current design uses either two- or three-bladed wind turbines, but the latter are becoming more popular and have a number of technical advantages. Two-bladed designs have the advantage that the hub is lighter and so the entire structure can be lighter. This is traded off by the fact that three-bladed designs are much better understood aerodynamically and also have a lower noise level than the two-bladed turbines. These blades are made of glass reinforced plastic (GRP).
3) **The nacelle** – This sits atop the tower and holds the rotor blades in place while housing the gearbox and the generator. On large turbines the nacelle with rotor is electrically yawed into or out of the wind.



Nacelle Bonus 1 MW (courtesy of BONUS Energy A/S Denmark)

Source: "Wind Energy Technology; current status and review" Renewable and Sustainable Energy Reviews 4 2000

3.5 Network Integration

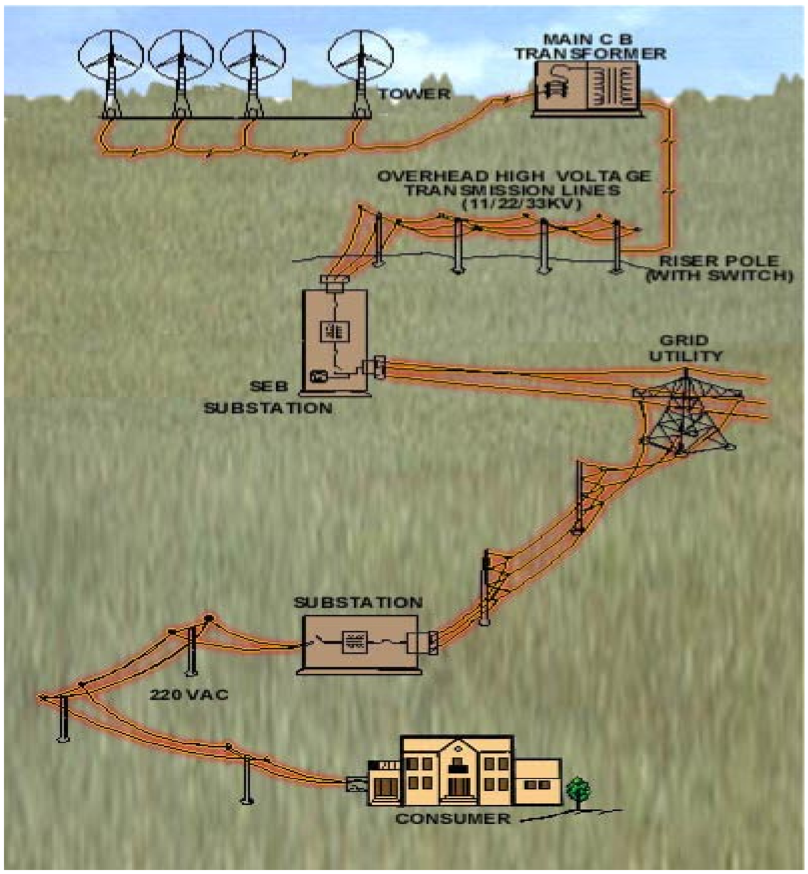
The interaction between the turbine and the grid it is connected is very important and both can be heavily influenced by how the other works.

Effect of Wind Turbine on Grid

The nature of wind energy extraction is such that it has fluctuating output due to variable wind speed. These lead to voltage and power fluctuations that may be evident as flicker effects, and voltage asymmetry, and generally affect the power quality of the network. Fixed-speed turbines produce a power pulsation emanating from the wind share over height. In order to avoid this, a number of measures can and are usually taken.

- Variable-wind speed turbines are able to absorb short-term power fluctuations by using immediate storage of energy on the rotating drive train.

- Having a large number of turbines active at a wind farm also eliminates irregularities because gusts of wind are not likely to affect all turbines at the same time and so a smoother overall output is achieved.
- The start-up of wind turbines may lead to an inrush of high current – pitch-regulated and variable wind speed turbines are able to achieve a more fluid transition.



Source: Indian Wind Turbine Manufacturers Association

Effect of Grid on Turbine

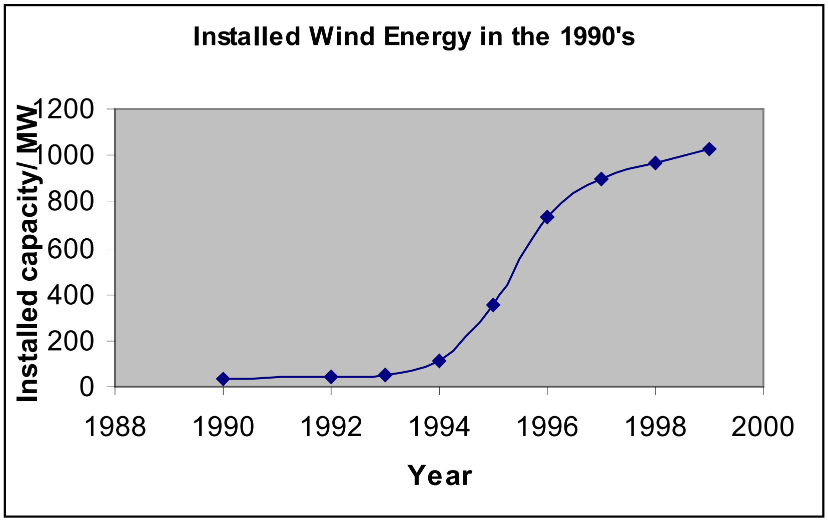
The grid also has numerous effects on the turbine performance itself. Weak grid-systems, that is those with long, low-loaded low-voltage transmission lines experience variations in voltage depending on the load they are experiencing. Such grids make it more difficult for wind turbines to be started up sometimes and so can seriously lower the "online" time of turbines.

4. Development of the Wind Sector in India

4.1 History

In 1985, the MNES conducted an extensive wind data collection program consisting of wind monitoring, wind mapping, and complex terrain projects, covering 25 out of India's 26 States/Union Territories. The wind resource potential calculated as a consequence of this study was 20, 000 MW. (8)

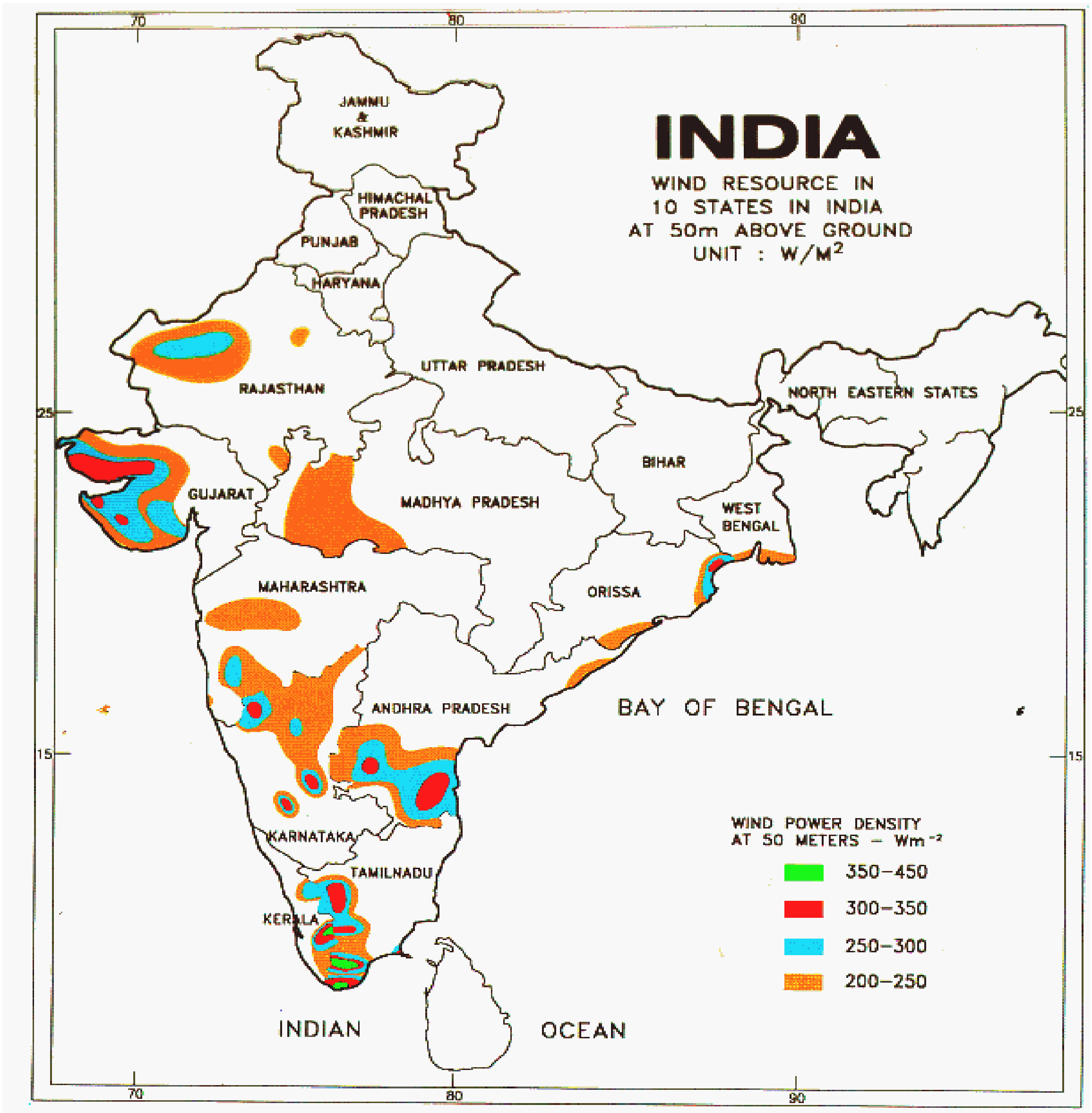
Consequently grid-quality wind power became the main focus of the MNES, and it opened up the wind energy sector to private enterprise, with giant success. Due to private sector investment, by March 1998, of the 968 MW of installed capacity, 95% had come from industries, entrepreneurs and businessmen (1). Lured by the incentives set up by the Ministry, wind farms had been set up by major industrial houses, including Madras Cement Limited and Dalmias, all over the country. A capacity of 230 MW was installed in 1994-95, 382 MW in 1995-1996 and 170 MW in 1996-1997. Between 1993 and 1997, growth in the wind energy sector represented approximately 6 per cent of new generating capacity installed in the country. And the government set an ambitious target of installing 3,000 MW generating capacity by 2003. The current 1025 MW that are in operation represent about 1% of India's total electricity consumption.



Source ("Down To Earth", Vol 18 No3 June 1999 - http://www.cseindia.org/html/dte/dte990630/dte_cover.htm)

4.2 Geographic Distribution

Tamil Nadu has the distinction of 719 MW (75% of total) wind farms at the end of September 1998 (2). Andra Pradesh has 58 MW (6%) and Gujarat has 168.64 MW, or 16% of the total capacity installed. See the map below for more details on wind-farm distribution.



Source: Ministry of Non-Conventional Energy Sources (www.mnes)

Vestas, V15s, Okha, Gujarat

Source: (Universal Sustainable Energy Services - http://www.uses.net/national/India/wind/windia.html)

160 sites have so far been identified in 13 states as showing promise of wind farm sites and the table below shows the installed capacities in various cities in India

SI No	State	Gross Potential (MW)	Technical Potential (MW)	Installed Capacity (MW)
	Andhra Pradesh	2200	1231	88
	Gujarat	3100	121	167
	Karnataka	4120	687	34
	Kerala	380	353	2
	Madhya Pradesh	3000	77	22
	Maharashtra	1920	2108	79
	Orissa	840	338	2
	Rajasthan	1210	397	2
	Tamil Nadu	900	1011	771
	West Bengal	180	775	-
	Other States	2150	-	2

	Total	20000	8946	1167

Source; MNES

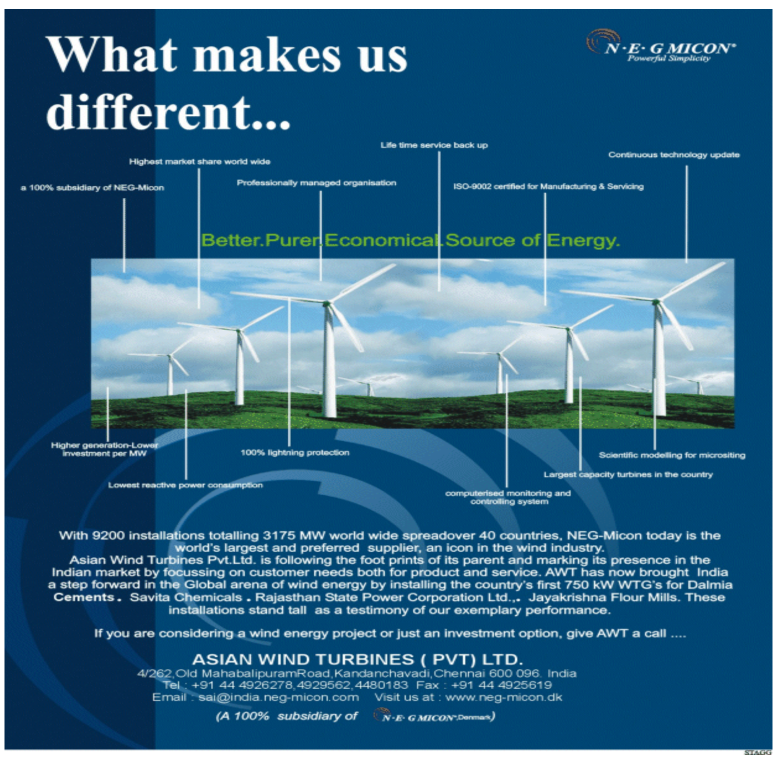
For Gross Potential: Assuming 0.5% of land availability for Wind Power generation in potential areas

For Technical Potential: As on March 31 1998, assuming 20% penetration.

Installed Capacity: As on March 31 2000

4.3 Market and Financial Aspect

Today there are over 30 companies involved in the wind energy sector in India. One really positive thing seen in India was the emergence of numerous private companies, which actually manufactured wind turbines and components. For example three companies that are in the business of wind turbine manufacturing are Rashron Energy and Auto Ltd, Energy Systems PvT and Windia Power. Another is NEG Micon, whose advertisement can be seen below.



The Indian private sector has also worked closely with foreign companies and agencies, from places like Denmark, Germany, the United States and over 25 manufacturers in India have tie-ups with these companies. This has enabled technology transfer that has benefited the Indian market, in that foreign designs could be adapted to meet local needs.

A comparison of wind energy with other renewable sources may serve to give an impression of the financial standpoint and appropriateness of wind energy to in India.

Source	**Capital Cost (Rs. Crores1[2]/MW)**	**Generation Cost (Rs/kWhr)**
Wind Power	**3.5**	**2.25**
Small Hydro	**3.5-6.0**	**1.50-3.5**
Co-Generation	**2.0-2.5**	**2.0-2.5**
Solar	**30.0**	**15.0-20.00**
Photovoltaic	**9.0**	**5.80**
Sea-Wave	**2.4**	**1.10**

Source: Indian Wind Turbine Manufacturers

*These numbers were in line with another report by S. Iniyani et al in 'Critical Analysis of Wind Farms for Sustainable Generation", where an optimal renewable energy model (OREM) was used to arrive at these numbers.

4.4 The Future

Despite the initial "wind-rush", after 1997 the wind sector experienced a serious slump, and the expectations of wind power have not been met despite the boom. Wind power plants have performed far below the expectations raised in feasibility studies, for numerous reasons. Investment in wind power has also ground to a halt. According to an article in the June 1999 edition of *Down to Earth,* a Science and Environment Fortnightly, *"The crores of rupees invested in the wind energy sector have largely gone to waste. Today, many*

[2] Current exchange rate is 1 $US = Rs. 46.87
1 lakh = 100, 000
1 crore = 100 lakhs = 10 million

wind farms are lying idle. And few that are working are falling far short of their generating capacities."

The Ministry of Non-Conventional Energy Sources is presently actively involved in setting up the Wind Energy Center (C-WET) which is to be located in Chennai, Tamil Nadu. This Center will cover R&D, technology upgrading, testing, certification and standardization in close association with the wind turbine industry.

5. The success of Wind Energy in India

The next section will try to examine the policies and measure that were implemented, as well as other reasons that have allowed India to move so quickly in terms of wind energy deployment. It will look at the government policies, economic incentives, some technical and social factors, and lastly the infrastructural factors, that allowed wind energy to take off with such a boom.

5.1 Economic and Financial instruments responsible for the wind energy boom

The most relevant and powerful fiscal incentives did not come about on their own. It was government policy that gave the private sector a really strong motivation to set up wind turbines and get into the renewable energy business. These were,

- 100% accelerated depreciation on investment on the capital equipment in the first year of installation itself
- Five year tax holiday on Income from sale of power generated by wind energy
- Industry status, entitling to capital subsidy in certain states
- Banking and Wheeling facility
- Buy back of power generation by State Electricity Board at a remunerative price and
- Third party sale of power generation in certain states. (8)

The 100% accelerated depreciation rule had the greatest effect in stimulating industry interest. What it meant was that if a company's taxable income (outside the wind power project) for the financial year was, for instance, Rs. 10,000, the company could show investments on WEG to the tune of Rs. 10,000 and get away by paying no tax at all. (W)

This meant that some of India's most prosperous businesses and industries, looking for tax breaks queued up in front of the MNES in order to sign installation contracts. The huge capital cost of wind-farm installation did not attract smaller entrepreneurs.

This was a deliberate move by the Ministry to heavily reward installation and capital cost acquisition, a barrier which usually prevents industries such as that of wind energy from taking off, and succeed it did.

Also, recognizing the limitations of conventional banks to shoulder large installation costs, the MNES created the IREDA (Indian Renewable Energy Development Agency) in 1987 in order to finance renewable energy technologies. (1). By 1997, IREDA gave out loans amounting to RS 676 million (US $16.2 M) which enabled the development of over 267 MW of wind power projects. This first confident move by the government spurred other groups to come forward to sponsor wind projects, such as the Gujarat Industrial Development Corporation Limited, the Industrial Development bank of India, and the Industrial Credit Investment Corporation of India.

Furthermore, the MNES streamlined the recognition and handling of wind-power plant financing by national and state-banks by drawing up "Guidelines for Clearance of Wind-Power Projects" in July 1995. It became mandatory for all State electricity boards and nodal agencies (which constitute the State bodies implementing wind-power development) to comply with conditions such

- Declare the schedule of envisaged capacity additions based on the power evacuation facilities at identifies windy sites every six months, and ensure grid compatibility.
- Seek Detailed Project Reports (DPR's) from independent consultants for (capacities above 1 MW) and verify project capital cost and generation against certified wind turbine power curves and wind data at the site before granting approval for projects. (1)

Outside the contribution of the MNES, bilateral development institutions from the Netherlands, Denmark, and loans from global institutions such as the World Bank through IREDA contributed to the flow of capital to fuel the development of wind energy

Other financially related aspects that are relevant are

- Power cuts (due to load shedding) during the summer months were a handicap for industries, especially in regions such as Tamil Nadu. Incidentally the wind generation during the summer months was at a peak and this incentivized both the TNEB and the local industries.
- The industries that invested heavily in wind energy came from the textiles and cement industry, which had earned huge profits and were eager to adopt wind energy to earn the 100% depreciation.

5.2 Technical And Social Factors

On the technical side, India has been fortunate in two ways. Firstly, they have discovered a good number of windy sites (recall that MNES identified 160 potential sites and 20, 000MW total available). Secondly, though they may not have previously been too familiar with wind technology, there are a large number of highly trained engineers and technicians who are graduates of institutions such as the IIT's (Indian Institute of Technology). These provide the technical expertise that has allowed adaptation of foreign wind turbines for local use and their deployment in different parts of the country.

Wind Energy adoption has had almost no social or environmentally charged backlash, as far as can be told from the wealth of information on the subject. Unlike the United States or Europe, neither the problem of noise nor avian death, have been significant obstacles that needed to be overcome. There has been widespread acceptance of the technology from the Indian public and environmental groups and this has undoubtedly been a factor enabling the rapid proliferation of wind turbine use.

5.3 Infrastructural Factors

A number of infrastructural situations have also spurred wind energy use. For this particular instance we shall look at the state of Tamil Nadu and analyze some of the characteristics that made it the leader among Indian states in installed capacity. Among these are

- The windy sites were close to towns for accessibility in bringing labor and providing accommodation for the personnel involved in the projects.
- The sites were well interlinked with highways.
- Grid network by Tamil Nadu Electricity board (TNEB) was well connected and mainly passing through the sites.
- Most of the wind turbine manufacturers/suppliers were located in Tamil Nadu and so gave investors confidence in the supply of machines and after-sales service of the machines.
- Chennai port of Tamil Nadu has excellent facilities for import of heavy machinery of the turbine components and this facilitated inter-state and international transportation.

5.4 Government Policy

This was perhaps the strongest initiator in promoting wind power adoption and investment. The policies adopted allowed all the other factors to flow together in a way that made wind energy very attractive to businesses and investors. Apart from the ongoing efforts of the MNES, which first of all instilled confidence in the technical and commercial viability of wind energy by performing the Demonstration Program, monitoring the entire country for windy sites, and putting the tax incentives in place, a few other policy initiatives by the State government of Tamil Nadu are also to be noted. These are,

- Active promotional steps were taken by TNEB and the Tamil Nadu Development Agency (TEDA). For example TNED took the first steps in setting up wind farms at sites like Muppandal, Kayathar and Kethanur to prove the viability of wind farms.
- TNEB extended all facilities for private entrepreneurs like consultancy services, processing of the application for issuance of No Objection Certificate (NOC), and other clearances, extending grid connections to wind farms and executing new dedicated sub-stations.

- TNEB established an effective system for registering the energy generation by each turbine and so enabled turbine owners to adjust their energy bill in accordance, or effect payment to those who sold to TNEB.

6. The Problems faced by Wind Energy in India

To a large extent, wind energy in India can be said to be as much of a failure as a success. There are many more problems that are being encountered with the implementation of the technology than there have been successes. We shall now take a scrutinizing look at some of the reasons for the failures.

6.1 Economic causes

One of the first things that are pointed to for being responsible for the slump in wind energy use is the introduction of the Minimum Alternate Tax (MAT). This was a new tax of 12.9% in the 1996/1997 budget for companies going for "zero-tax planning" and also reduction in the marginal corporate tariff tax to 35% from 46%. Companies that had used wind turbine installation as a tax-shelter were affected because MAT forced companies that had been going for this zero-tax planning to pay at least 12.9% corporation tax on their book profits. And so MAT made it slightly less financially beneficial to invest in wind.

Another reason for failure has been dire lack of financing institutions to back the huge capital cost investment that wind farms require. The wind power plant sector is still predominantly debt-based for 60-75% of the project cost. IREDA and the handful of other banks were not enough to meet the installation needs and so in many states, wind energy did not even take off.

However probably the most damaging factor for the wind industry was the very thing that really started the boom, namely the 100% accelerated depreciation. This rule had a number of negative impacts. Among these are

- Enabled large-company finance officers to make hasty decisions around the time of tax-filings to install wind plants. These hasty decisions often led to bad siting of machines and consequent low performance.
- The rule relies on the ability of promoters of the technology to absorb the tax benefits - this restricted the number of potential entrepreneurs to companies with huge profits, such as the textile and cement industries, which were actually big investors in the technology. Smaller entrepreneurs were not incentivized.

- Led to an increase in capital cost of locally made wind turbines, as they were "gold-plated". For example the rise in cost/MW in 96/97 over 92/93 was 27.5% with the rupee depreciating by 15.45 against the dollar. However the price of Danish machines for example has been falling and so import of machines is encouraged even though these may not be the optimal designs for Indian terrain.
- The worst impact this rule has had is that it placed no reward on the actual performance of wind turbines. Since this was not a part of the package that was rewarded by tax breaks, simply installation of wind turbines, whether they were well sited, efficient or not, was the only thing that counted. This led to very poor performance of the machines themselves.

6.2 Technical Problems

- Poor design of turbines (either local or foreign) led to rotor blade failures
- Disregard for the earthing regulations and lightning protection led to damage by lightning strike and unduly large breakdown of control systems resulting in expensive repairs and long "off-line" periods.
- Foreign cooperation sometimes led to a mismatch between locally manufactured components and imported parts, weakening the reliability of the entire system.

6.3 Infrastructural Challenges

- Grid problems: Wind turbines draw in a lot of power when starting up and so this sometimes caused the grids they were connected to experience voltage fluctuations – reducing power quality and having an undesirable effect on customer's appliances. These fluctuations weaken a grid and have a negative feedback on the wind turbines themselves. In 1996 grid abnormalities induced a 20% loss in potential revenue due to 'direct generation loss' (inability of wind plants to operate when the wind is blowing). Half of all these losses are due to weak grids in the region.

- There is a lack of servicing and maintenance expertise to handle wind farm upkeep.
- Utilities are suffering the burden of having wind farms connected to their grids. With the notable exceptions of the usual suspects Tamil Nadu, Andhra Pradesh and Gujarat, the other states view wind farms more as a nuisance than a benefit, due to the low reliability and non-dispatch ability. Government policy has placed them in the position where they have to pay higher prices for wind-generated electricity. This has caused them significant financial hardship and has not heightened their enthusiasm and support of the technology.

6.4 Government Policy

Government policy also has a few barriers to overcome.

- There are extensive bureaucratic procedures that discourage entrance into the sector. The Central government requires 22 clearances for wind power plant installation.
- There are no qualifying benchmarks for power plant entrepreneurs to meet. The only requirement that the MNES has stipulated is a wind speed of at least 5 m/s. This is not a factory speed for a wind turbine to be economical.
- There is a lack of standardization among wind turbine design and features. A large number of foreign and local manufacturers have made for difficulty in maintenance of wind turbines.
- With the exceptions of a few States, again, there has been a lack of active support for wind power development by the State nodal agencies and the State electricity boards.
- The biggest policy problem has been the lack of institutional infrastructure to support the booming wind industry. It is possible that the sector grew much faster than expected hence the institutional gap. This gap refers to the absence of authorities that are in charge of monitoring wind farms, certifying turbines, setting standards for designs and locations, research and development, funding institutions and so on.

7. Some Recommendations for India

A number of reports have analyzed the situation, most notably those by B. Rajsekhar and A. Jagadeesh, and the following recommendations were arrived at

- Create electricity-production based incentives such that performance and reliability also receive more attention from the actual wind farm operators.
- Take financial burden off the State utilities by subsiding the higher cost of wind energy. The source of this money could come from bilateral institutions such as the World Bank. There have also been calls for the establishment of a wind fund, which could serve this purpose.
- Another financial move must be the bringing down of the equipment cost. The "gold-plating" practice must be stopped (by a certifying government body) and local production must provide affordable machines to entrepreneurs.
- The establishment of regional service stations, in proximity to a cluster of wind farms, in order to provide maintenance and upkeep of the equipment. This is another area that entrepreneurs may be able to tap into once more incentives are given to actual performance of the turbines and investors want to ensure the smooth running and reliability of their machines. In having these stations close to a number of wind farms there will be significant savings on personnel cost.
- A central governing body must be established responsible for certification, standardization of design and features, monitoring of wind farms and technological R&D. The GOI has already recognized this need in the establishment of C-WET (Wind Energy Center) at Chennai.

8. An Alternative Consideration for Wind Energy Use

This paper has so far focused on the WEG (wind energy generators). These are important but do not constitute the only way wind power can be employed, especially not in highly agrarian developing countries.

In the early 1990's 850 water-pumping windmills were installed under the National Demonstration Program (mentioned in the introduction). 120 of these were geared type well wind pumping systems. The remainder were 12-PU-5 type, and after a few years these particular windmills were shown to be below par in terms of performance. The entire project had been heavily subsidized, and was a failure for two main reasons. The equipment that was being used was not adapted for Indian circumstances (hence broke down and could not be fixed by locals) and communities involved had no sense of ownership in the project. However a useful lesson can be learned from this example. It is that these wind pumps have a big role to play in a decentralized rural community, and that the previous two mistakes need to be avoided.

9. Conclusion, or Lessons Learned

The example of India can be a very instructive one because as a developing country it has seen both the tremendous promise of wind energy as a substitute to coal and oil and has stumbled across real problems. There are lessons to be learned both in the success of wind in India and in examining how it needs to overcome these stumbling blocks.

First and foremost the initiative for wind power adoption must come from the government. The energy sector needs to be highly deregulated to allow alternate energy producers to shoulder most of the financial burden and also to really encourage the development using a market-based approach. The government of the country must make a long-term, dedicated and highly active approach to get the technology off the ground. As we can see in the case of India, it has taken them over a decade, with consistent efforts beginning in the early 1990's, to reach where they are today. Development has been hampered by unnecessarily bureaucratic procedures but all in all, the heart of the government was "in the right place". The government must make the first move in order to carry out wind mapping activities to determine the best windy sites for installation, and build private sector confidence in wind energy. It must provide the right fiscal incentives, in the form of tax breaks for example, as India did, in order to spur installation.

The second major thing that needs to occur is for the institutional infrastructure to be established as early as possible. As described before, these institutions must be responsible for the certification of wind turbines and the setting up of national standards that are appropriate to the terrain of the country, and the available local technical expertise. The last point is important because as seen with India, a highly subsidized approach in which foreign equipment is predominantly used is not sustainable – the technical expertise for the upkeep and maintenance of machines will not be available, forcing the project to resort to expensive foreign consultants. Also, with local production of wind equipment, and the involvement of the community that the technology will be serving, there will be a sense of ownership that is crucial to the survival of such projects.

A third point would be that as well as rewarding capital investment, there must be corresponding reward for actual generation of electricity, else performance of turbines will be low, and will both cause financial loss for the entrepreneurs and burden the local electricity boards, whose grids will suffer as a consequence.

Lastly, the essence of wind energy technology must be recognized by government policy. This essence lies in its *decentralized nature* and the ability to supply remote areas with electricity. These areas may be connected in a local area grid (LAG), much like a Local Area Network, or LAN, in computer systems, so that power lines from rural areas do not need to be constructed to the remote area. Also, wind pumps have great potential - not for electricity production but for pumping of water for irrigation or for drinking water. This is especially important in rural areas where access to clean drinking water or irrigation water is a huge public health problem. These pumps can power Wells that reach deep into the ground to tap into ground water. This decentralized is an aspect of wind energy that spurred Indian policy-maker's adoption of the technology and this philosophy needs to be remembered by other governing bodies in the developing world.

References

B Rajsekhar, F Van Hulle, J.C Hansen, "Indian Wind Energy Programme; performance and future directions" Energy Policy 27 1999 669-678.

A Jagdeesh, "Wind energy development in Tamil Nadu and Andhra Pradesh, India Institutional Dynamics and barriers", Energy Policy 28 2000 157-168.

Thomas Ackermann, Lennart Soeder, "Wind Energy Technology and current status: a review", Renewable and Sustainable Energy Review 4 2000 315-374.

Indian Wind Turbine Manufacturers Association, http://www.indianwindpower.com.

R Abrutat, "Unleashing business opportunities for wind energy", Renewable Energy 22 (2001) 403-410.

M.F Trivedi, "Environmental factors affecting wind energy generation in western coastal region of India", Renewable Energy 16 (1999) 894-898.

S Kumar, "Wind Energy – India Overview", Renewable Energy 16 (1999) 961-964.

S Iniyani, L. Suganthi, R Jagdeesan, "Critical Analysis of Wind Farms for Sustainable Generation", Solar Energy Vol 64 Nos 4-6 pp. 141-149, 1998.

Mridula Chetri, "Gone with the Wind", Down to Earth, Vol 8 No3 June 30 1999.

Universal Sustainable Energy Services.
http://www.uses.net/national/India/wind/windia.html

10.391J Class Notes on Wind Energy.