

Techno economic evaluation of windmill for water pumping in coastal areas for aquaculture

M.JAYANTHI AND T. RAVISHANKAR

Central Institute of Brackishwater Aquaculture, 75, Santhome high road, Chennai

ABSTRACT

Wind energy industry is relatively new, rapidly expanding and offers the potential to substantiate sufficient amount of power without causing pollution to the environment. With the Kyoto protocol aimed at reducing the greenhouse gas emissions across the globe, wind energy sector assumes greater importance as an alternative source of energy. An attempt has been made to develop a framework for techno-economic evaluation of windmills for water pumping. The discharge rate of windmill and its performance at 3m, 4m and 5 m heads were evaluated. The highest discharge was $175.68\text{m}^3/\text{day}$ at 23 Km/hr at 3m head and the lowest discharge rate was $51.49\text{m}^3/\text{day}$ at 6km/hr at 5m head. The unit cost of water and energy delivered by the windmill were estimated. The monetary benefits that accrued to the end-user have been quantified in terms of the amount of diesel and electricity saved. The Net Present Value and Internal rate of returns for wter pumping using windmill, diesel pump and electric motor have been worked out to understand the efficiency of each sytem. The investment opportunities and support mechanisms were also highlighted.

Introduction

Energy consumption is an economic indicator that shows the level of development of the country. Supply of energy should be reliable, sufficient and timely to support and orient the targeted fiscal growth and societal developments. Adoption of unsustainable strategies of development coupled with the use of capital-intensive high energy consuming technologies has often created formidable environmental problems by making development unsustainable in the long run. In developing countries, energy consumption goes up rapidly in accordance with increase in economical growth. The world today consumes approximately ten times as much energy per person as it did hundered years ago

and most of this energy is of commercial one, which merely accelerates "global warming". This trend is expected to countinue in the future. The only known and viable solution to meet the energy demand without affecting the ecological balance is to use renewable energy sources which have added advantages such as being clean, environment friendly and inexhaustible.

In recent years, the possibility of utilization of the wind power for pumping water is drawing considerable attention among all user groups. Studies on wind data analysis have shown that installation of wind mills in various parts of the country may be favourable particularly in coastal areas where long spells of high wind speed are available.

The aspects of energy on which our future development will depend are making more energy available for useful work and making most efficient use of the available energy (Patel *et al.*, 1999).

Coastal aquaculture farms are mostly located in remote areas and the freshwater demand of these farms can be largely met by pumping water using wind pumps. Keeping this in view, a study was carried out to assess the techno-economic feasibility of the windmill for water pumping in aquaculture farms.

The power in the wind is proportional to the area of windmill being swept by the wind, the cube of the wind speed. Wind turbines transform the energy in the wind into mechanical power, which can then be used directly for many purposes. The wind power is calculated using the power in the wind as

$$\rho_w = 0.014AV^3$$

Where, ρ_w = Power in watts available from the windmill

A-Swept rotor area in square metres

V - Wind speed in Kilo metres per hour

The estimated potential wind power in India indicated that the available power ranged from 200-400 W/m² scattered over the country. Tamil Nadu, Gujarat and Andhra Pradesh had highest potential compared to Rajasthan, Karnataka and Madhya Pradesh.

Windmill pumping equipment is available with discharge capacities ranging from 1000 to 500 000 litres per day. It can lift water up to 90 meters vertically. The choice of pumping is usually decided by the source of the water supply. For pumping from bore wells, cylindrical pumps are used (Mike Harries, 2002).

Materials and methods

The windmill Type WF 305G was installed at Muttukadu experimental station at Central Institute of Brackishwater Aquaculture and evaluated for its performance at different heads. The windmill rotor diameter was 3m and tower height was 10m. The gear ratio was 3.29:1. The stroke length was 7.5". The pump suction diameter was made to 4 inches to get more output. The water source was a dug well with a diameter of 1m and depth of 3 to 6m. The minimum wind speed to operate the windmill was 6Km/hr. The discharge rate was measured to find out the delivery capacity of the windmill. The discharge obtainable from a windmill was calculated as

$$Q=0.09936 V^3 n/H$$

Q=Windmill discharge/sec

V- Wind speed in Kilo metres per hour

H - Total head metre

n-Overall efficiency of windmill

The diesel engine and electric motor of one H.P was compared with windmill to assess the discharge rate and cost energy. The Net Present Value, internal rate of returns for there water pumping systems such as windmill, electric pump and diesel pump were worked out.

Results and discussion

The energy requirements of the country increases day by day to commensurate with the rate of development. Looking at the requirements of energy for different activities, an earlier survey indicated that the major energy demand in India was for residential activities followed by the transportation industry. We need 56% of energy for residential activities followed by 27% for industrial activities and 12%

TABLE 1: *Estimated wind power potential in India*

State	Gross Potential (MW)	Demonstration Projects (MW)	Private Sector Projects (MW)	Total Capacity (MW)
Andhra Pradesh	8275	5.4	93.4	98.8
Gujarat	9675	17.3	184.7	202.0
Karnataka	6620	4.6	204.6	209.2
Kerala	875	2.0	0.0	2.0
Madhya Pradesh	5500	0.6	22.0	22.6
Maharashtra	3650	8.4	399.0	407.4
Orissa	1700	-	-	-
Rajasthan	5400	6.4	172.1	178.5
Tamil Nadu	3050	19.4	1342.2	1361.6
West Bengal	450	1.1	0.0	1.1
	45295	65.2	2418	2483.2

MW-Mega Watts

Source : MNES, Annual report, 2004

for transportation. But the worldwide consumption was more in industrial sector (37%) than residential activities (27.4%).

The state-wise wind energy potential and the projects that are under operation are given in Table 1. Among the states, Tamil Nadu and Maharashtra lead in

production of wind energy. India had 2483.2MW wind energy projects in the year 2004, out of which 65 MW was demonstration projects and 2418 was installed projects. Tamil Nadu contributed 1361.6MW capacity followed by 407.4 MW from Maharashtra, 209.2 MW from Karnataka and 202 MW from

Gujarat. There are wind pumps of various designs providing water for agriculture, afforestation and domestic purpose which are all scattered over the country. Wind energy accounts for 3% of the overall generation capacity in the power sector.

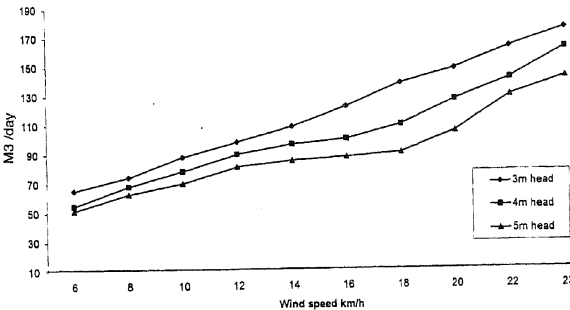


Fig.1. Discharge rate of wind mill at different head

The discharge rate measured at different wind speed and at different head

TABLE 2: *Economic analysis for three types of water pumping systems*

Year	Wind mill			Electric motor*			Diesel pump**		
	Cost Rs	Benefit Rs	Net cashflow	Cost Rs	Benefit Rs.	Net Cashflow	Cost Rs	Benefit Rs	Net Cashflow
1	65,750	17,500	-48250	32,700	21,874	-10826	32,000	21874	-10126
2	1,000	17,312	16312	14,500	21,579	7079	10,700	21579	10879
3	2,500	17,182	14682	14,750	21,296	6546	12,470	21296	8826
4	2,750	16,970	14220	18,900	22,624	3724	21,317	22624	1307
5	3,025	16,813	13788	15,750	22,329	6579	14,249	22329	8080
6	3,300	16,666	13366	16,750	22,046	5296	16,274	22046	5772
7	3,600	16,533	12933	22,250	23,371	1121	27,386	23371	-4015
8	4,000	16,408	12408	17,000	23,079	6079	16,500	23079	6579
9	4,400	16,292	11892	18,750	22,796	4046	17,625	22796	5171
10	4,850	16,183	11333	25,750	24,124	-1626	32,731	24124	-8607
		NPV	18038.87			11788.17			116150.05
		IRR	25.7748			52.7883			79.2994

* - Engine and Diesel cost

**-Motor and electricity cost

(Fig.1) indicated that the highest discharge rate was $175.68 \text{ m}^3/\text{day}$ at 23 km/hr wind speed at 3 m head. The lowest discharge rate was $51.49 \text{ m}^3/\text{day}$ at 6 km/hr wind speed at 5 m head. It can be seen that for all wind speed the delivery rate decreased as the head increased. The total functional days for the windmill was calculated as 250 days based on the wind speed data of previous years.

Normally, the requirement of water at the start of aquaculture is very high. The total water requirement to maintain 70 cm water depth in 0.5 ha pond is 3500 m^3 . Considering the freshwater requirement to bring down 1 m^3 of the 30 ppt water to 15 ppt is 0.5 m^3 , the quantity of fresh water needed will be 1750 m^3 . Each windmill is capable of feeding at least two 0.5 ha ponds and it can be effectively used in high saline remote areas. The expected energy from the wind lies in the medium range which could be used as an alternative source of energy, specially in the summer months when the energy is most needed (Som and Ragab, 1993).

Recently most of the farms are shifting towards zero water exchange. Even if such a system needs water exchange, it will be an easy task to maintain water level. As the windmill delivery totally depends on wind speed, the average delivery rate was uncertain. It is better to construct the storage tank to store the water pumped by the windmill and also to facilitate unattended pumping during night hours. The storage tank should have sufficient capacity to meet the freshwater requirement and, if needed filtration and prior treatment can be done before letting the water into the farm.

For assessing the economic feasibility of windmill, comparison was made with other water pumping systems like diesel engine with pump and electric motor

with pump. It was assumed that the reduction in discharge rate was 2.5% every year and the water cost is same for all systems as Rs. 500 for 12 T capacity.

The cost of windmill, electric motor and diesel pump were Rs. 65,750,3500 and 8500 respectively. Life time and delivery rate for windmill was 10 years and 18.2 T/day . The delivery rate was the same as 2500 l/h for both diesel pump and electric motor. To calculate returns, the price range was fixed for each unit of water lifted. For ten trips, by 12 t tanks, the rent will be Rs.500. Every year, addition of Rs. 250 will compensate the other maintenance cost. The cost of pumping was Rs.41.66/ m^3 . From the analysis output, (Table 2) the Net Present Value was 18038.87, 11788.17, 116150.05 and Internal Rate of Returns (IRR) was 25.77%, 52.78%, 79.29% for windmill, electric motor and diesel pump, respectively.

As the initial cost of installation was high in case of windmill, the diesel engine with pump is economically suitable. But for the places where the resources are not available and an unattended pumping is required, windmill can be the best remedy. Since, the demand for conventional resources is increasing and availability is becoming a problem, non-conventional resources like windmill should be encouraged. At macro level, burden on exchequer on account of subsidized electricity generation will be lessened with windmill. In due course of time, by installations of more and more windmills, the production cost per unit of windmill is likely to come down.

India Renewable Energy Development Agency (IREDA) was formed in 1987 to provide assistance in obtaining loans from World Bank, Asian Development Bank, and Danish International Development Agency

(DANIDA) for renewable energy projects. IREDA acted as a conduit for World Bank loans totaling \$78 million, specifically for wind energy projects. India has a large wind assessment program with over 600 stations in 25 states to provide information about the best sites for development. This capacity is concentrated in the states of Tamil Nadu and Gujarat. Tamil Nadu and several other state electricity boards have agreed to purchase wind power with the following discounts. Five-year tax holidays on income from sales from renewable energy; accelerated depreciation on investment in capital equipment in the first year; excise duty and sale tax exemptions for wind turbines; import duties on a variety of components waived; moving towards a production tax incentive to encourage performance.

Wind energy enjoys an accelerated depreciation benefit of 80 per cent and it has brought a large amount of investment in recent years. All the installations have been based on balance sheet financing by the companies whose wind energy investments have been a part of their tax planning strategy.

Wind energy is not yet generally competitive with alternate sources such as fossil fuels. Thus, it is dependent on non-market support for development to take place. With the Kyoto protocol aimed at reducing the greenhouse gas emissions across the globe with effect from 16.02.2005, the need of wind energy sector assumes greater importance. Renewable energy technologies are capital intensive and require high initial investment, which investors could not mobilize in the absence of financial support including capital subsidy from the government. Research and development to improve efficiency of the devices for generation of wind energy and to bring down the cost should be

encouraged. Due to the high initial cost, it is not possible to generate sufficient demand for these items, though people are aware of the advantages. Private investment should be encouraged and promoted in renewable energy through suitable policy initiatives at state level. Field units should be established at local level.

Energy efficient buildings that will conserve energy to meet energy requirements from naturally available resources should be encouraged (Nagwa, 1994). Since the discharge of windmill is low, attention is paid to increase the efficiency and longer life. Appropriate and suitable extension strategies and methods should be employed for effective dissemination / transfer of renewable energy technologies like Participatory Rural Appraisal (PRA); Self Help Group approach (SHG); Cyber Extension to create awareness among rural people. The windmill can be recommended, if wind conditions are reliable, unattended pumping is required for long periods, when there is no other power source and also user requires environmentally clean power.

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