# WIND ENERGY POTENTIAL ASSESSMENT IN NEPAL

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ABSTRACT

Nepal is a mountainous country with a high potential for wind energy. The data base is poor and wind data are not sufficient to make a realistic assessment of the wind energy. The extreme wind speed is as high as 46.76 m/s, and 238 kW/m2 power density. The annual average energy potential is about 3.387 MWh/m2. The potential area of wind power in the country is about 6074 sq. km with wind power density greater than 300 watt/m$^2$. More than 3,000 MW of electricity could be generated at 5 MW per sq km. The commercially viable wind potential of the country is estimated to be only about 448 MW. For calculating wind load on individual structural elements NBC 104 :1994 (wind load) and the Indian standard IS :875 (part 3)1987 are followed. Every year storms kill many people, and destroy or damage properties worth hundreds of thousands of Dollars.

KEY WORDS: Wind Energy, Nepal National Building Code NBS 104:1994 (Wind Load), wind hazard, disaster.

## 1. INTRODUCTION

Nepal is a mountainous country lying along the middle part of the 2500 km long Himalayan range. It covers an area of about 147,181 sq km and is bounded by the northern latitudes 26$^0$ 22' and 30$^0$ 27' and the eastern longitudes 80$^0$ 04' and 88$^0$ 12'. Its length is about 885 km along the east-west direction and the width varies from 130 to 255 km. The country is under the influence of the strong SE monsoon climate. Winter is influenced also by a weak SW monsoon. Topography varies from nearly 100 m from msl at the northern edge of the Indo-Gangetic plains to high Himalayan ranges in the north with over 8000 m altitude.

Nepal started collecting data on wind speed only from 1967. There are 40 wind measurement stations installed all over the country run under the Department of Hydrology and Meteorology; however, presently only 29 stations are properly running (Fig 1). They measure average monthly wind speed data at particular time of the day, maximum hourly gust and maximum gust. Even among these stations many provide only discontinuous data. Out of the 29 stations, 7 are in the higher Himalayan region, 11 in middle mountain region and 11 in the Terai plains in the south. The average monthly wind speed data from 29 stations are presented in table 1 (DHM, 2008). However, the available database is inadequate both in terms of spatial distribution and duration for wind design structures. Modern wind design codes are based on the peak gust velocity averaged over a short interval of about 3 seconds with a 50 year returned period. The database is also insufficient to prepare the wind zone map.

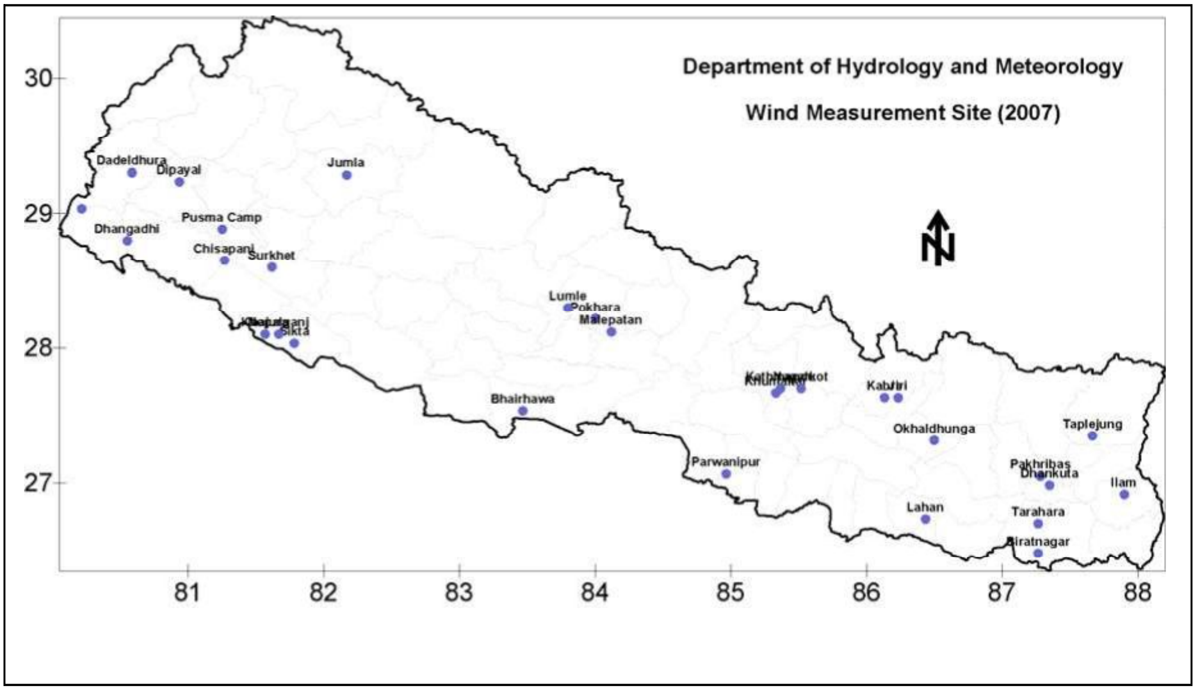



Fig. 1: Location of the 29 wind monitoring stations in Nepal in 2009

The Solar and Wind Energy Resource Assessment (SWERA) project run by the Alternative Energy Promotion Center (AEPC), provides a good overview on the wind resources assessment on Nepal.

Table 1: Wind speed data for last three years (2005-2007) (Wind Speed in Km/hr)

| Sr. No. | Index No. | Station | Elevation | Latitude | Longitude | Maximum monthly value 2005 | Maximum monthly value 2006 | Maximum monthly value 2007 |
|---|---|---|---|---|---|---|---|---|
| 1 | 104 | Dadeldhura | 1848 m. | 29 °18 ' N | 80 °35 ' E | 4.4 | 4.8 | 3.7 |
| 2 | 105 | Mahendra Nagar | 176 m. | 29°02 ' N | 80°13 ' E | 4.2 | 3.4 | 2.8 |
| 3 | 209 | Dhangadhi | 170 m. | 28 °41' N | 80° 36' E | 1.9 | 2.4 | 0.0 |
| 4 | 218 | Dipayal | 617 m. | 29 ° 15' N | 80 °57 ' E | 3.2 | 3.2 | 3.1 |
| 5 | 303 | Jumla | 2300 m. | 29 °17 ' N | 82 °10 ' E | 8.5 | 7.0 | 6.8 |
| 6 | 401 | Pusmacamp | 950 m. | 28° 53' N | 81° 15' E | 2.7 | 3.5 | 2.5 |
| 7 | 405 | Chisapani | 225 m. | 28° 39' N | 81°16' E | 14 | 12 | 13 |
| 8 | 406 | Birendra Nagar | 720 m. | 28 ° 36' N | 81° 37' E | 2.4 | 1.9 | 1.7 |
| 9 | 409 | Khajura | 190 m. | 28° 06' N | 81° 34' E | 3.5 | 2.8 | 3.0 |
| 10 | 419 | Sikta | 195 m. | 28 ° 02' N | 81° 47' E | 3.75 | 3.00 | 1.40 |
| 11 | 420 | Nepalgunj | 165 m. | 28° 06' N | 81° 40' E | 4.9 | 3.2 | 3.2 |
| 12 | 707 | Bhairahawa Agri. | 120 m. | 27° 32' N | 83° 28' E | 5.4 | 4.9 | 6.1 |
| 13 | 715 | Kanchikot | 1760 m. | 27° 56' N | 83° 09' E | 9.8 | 0.0 | 0.0 |
| 14 | 804 | Pokhara Airport | 827 m. | 28° 13' N | 84° 00' E | 3.1 | 3.1 | 2.9 |
| 15 | 811 | Malepatan | 856 m. | 28° 07' N | 84° 07' E | 0.6 | 0.8 | 0.9 |
| 16 | 814 | Lumle | 1740 m. | 28° 18' N | 83° 48' E | 1.8 | 1.6 | 2.2 |
| 17 | 911 | Parwanipur | 115 m | 27° 04' N | 84° 58' E | 4.8 | 3.9 | 1.9 |
| 18 | 1029 | Khumaltar | 1350 m. | 27° 40' N | 85° 20' E | 3.8 | 3.8 | 3.9 |
| 19 | 1030 | Kathmandu | 1337 m. | 27° 42' N | 85° 22' E | 1.3 | 1.2 | 1.2 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Airport | | | | | | |
| 20 | 1043 | Nagarkot | 2163 m. | 27° 42' N | 85° 31' E | 5.9 | 5.3 | 4.3 |
| 21 | 1103 | Jiri | 2003 m. | 27° 38' N | 86° 14' E | 4.2 | 4.2 | 3.9 |
| 22 | 1206 | Okhaldhunga | 1720 m. | 27° 19' N | 86° 30' E | 5.3 | 7.0 | 7.9 |
| 23 | 1215 | Lahan | 138 m. | 26° 44' N | 86° 26' E | 6.2 | 0.0 | 2.5 |
| 24 | 1304 | Pakhribas | 1680 m. | 27° 03' N | 87° 17' E | 1.9 | 2.1 | 2.0 |
| 25 | 1307 | Dhankuta | 1210 m. | 26° 59' N | 87° 21' E | 5.0 | 5.2 | 4.4 |
| 26 | 1319 | Biratnagar Airport | 72 m. | 26° 29' N | 87° 16' E | 3.5 | 4.0 | 9.7 |
| 27 | 1320 | Tarahara | 200 m. | 26° 42' N | 87° 16' E | 7.8 | 10.7 | 10.8 |
| 28 | 1405 | Taplejung | 1732 m. | 27° 21' N | 87° 40' E | 3.7 | 2.5 | 2.9 |
| 29 | 1407 | Ilam Tea Estate | 1300 m. | 26° 55' N | 87° 54' E | 1.7 | 2.3 | 1.6 |

In Nepal, the wind velocities in low altitude valleys are lower in magnitude than those in the high altitude valleys and mountain ridges. This is evident from data observed in Kathmandu (low values) and Kaligandaki valleys (high values). Nepal national building code NBC 104 :1994 on wind load has divided the whole country into two regions:

a. The lower plains and hills generally include the southern plains (Terai), Kathmandu Valley and areas generally below 3000 m altitude. Here the basic wind velocity of 47 m/s is adopted.
b. The second zone lies above 3000 m. Here the basic wind velocity of 55 m/s has been adopted.

Based on the available data, a wind zoning map of Nepal has been prepared (Fig. 2).

## 2. NEPAL STANDARD ON WIND LOAD

Though the database on wind velocity within Nepal is not adequate, based on thee locally available data as well as the data from similar topographic zones of India; and also taking consideration of the Indian standard IS :875 (part 3)1987, code of practice for design loads (other than earthquake) for building and structures with amendments as set out on basic wind speed as (a) and (b), a Nepal standard on wind load has been prepared.

According to IS: 875 (part 3) -1987:
The design wind pressure at any height above mean sea level shall be obtained by the following relationship between wind pressure and wind velocity:

$$Pz = 0.6\,(Vz)^2$$

Where pz is design wind pressure in N/sq m at height Z and Vz is design wind velocity in m/sec at height Z.

### *2.1 Wind pressure and force on building*

The wind load on buildings shall be calculated for : (a) the building as a whole, (b) individual structural elements as roofs and walls (c) Individual cladding units including glazing and their fixings.

The wind load acting normal to a surface is obtain by multiplying the areas of that surfaces or its appropriate portion by the pressure coefficient and the design pressure at the height of the surface from ground. The average values of these pressure coefficients for some building shape are given in table 2.

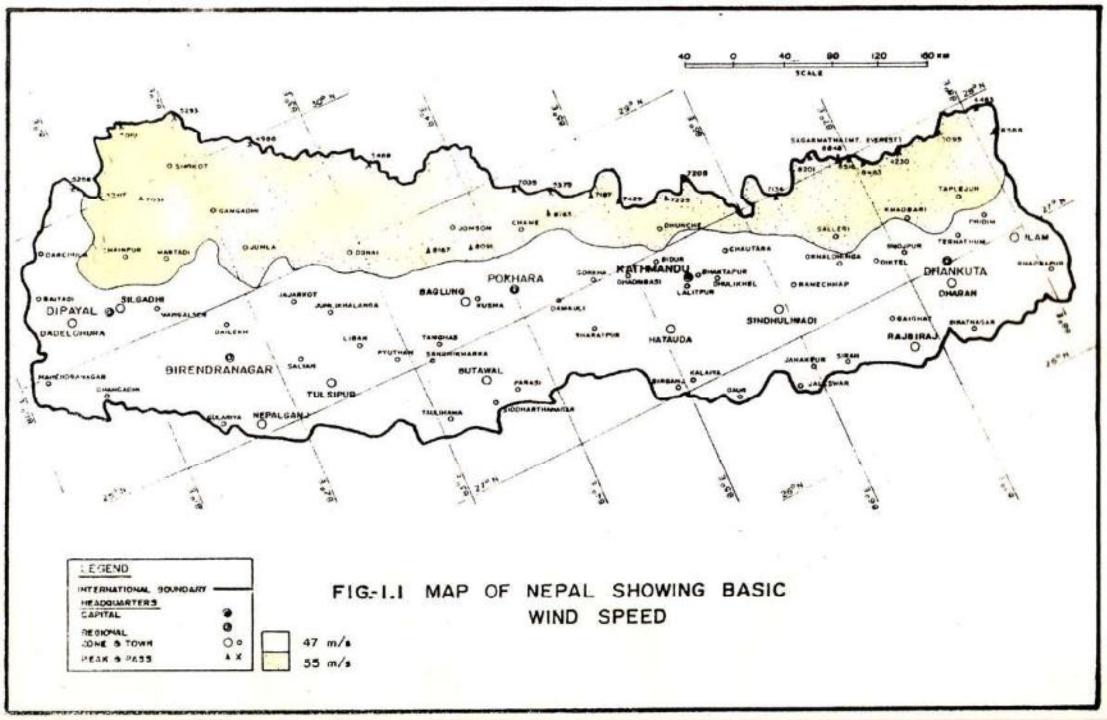


Fig. 2. Wind zoning map of Nepal.

Average values of the pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building, the total load should be calculated for each of the critical directions shown from all quadrants. In addition, areas of high local suction (negative pressure concentration) frequently occurring near the edge of wall and roofs are separately shown in table 2.

When calculating the wind load on individual structural elements such as roof, walls and individual cladding units and their fittings, the pressure difference between opposite faces of such elements or units are taken into account. The wind load F acting in direction normal to the individual structural elements or cladding unit is:

$$F = (C_{pe} - C_{pi})\, A\, p_a$$

Where, $C_{pe}$ - external pressure coefficient ,

$C_{pi}$ - Internal pressure coefficient,

A - Surface area of the structural elements or cladding unit

$p_a$ - design wind pressure

The Average external pressure coefficients for the walls of clad buildings of rectangular plan are given in table 3.

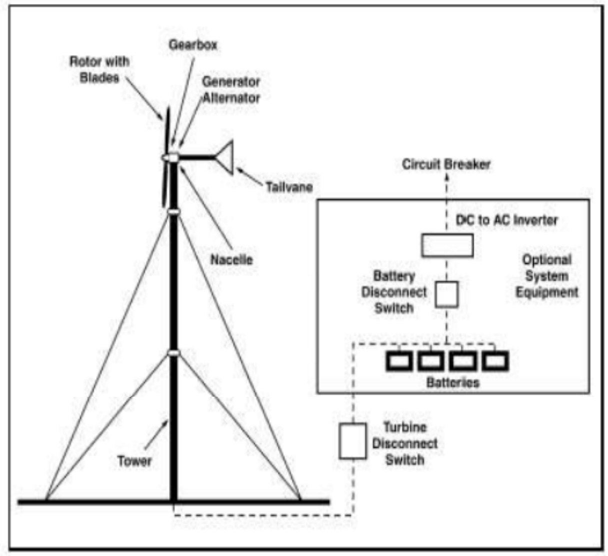
## 3. WIND ENERGY POTENTIAL OF NEPAL

Government of Nepal (HMG) established Alternative Energy Promotion Center (AEPC) in 1996 with an objective of disseminating and promoting renewable energy technology (RET) in the country. Nepal has a very short history of utilizing wind energy. The Solar and Wind Energy Resource Assessment (SWERA) project, a first of its kind in Nepal, was initiated by Alternative Energy Promotion Center in joint in-country Partnership with Center for Energy studies/ Institute of Engineering (IOE) with the support from United Nations Environment Program/ Global Environment Facility (UNEP/GEF) in 2003. The outcome of this project has

| Building Height Ratio | Building Plan Ratio | Elevation | Plan | Wind Angle $\theta$ | $C_{pe}$ for Surface A | $C_{pe}$ for Surface B | $C_{pe}$ for Surface C | $C_{pe}$ for Surface D | Local $C_{pe}$ |
|---|---|---|---|---|---|---|---|---|---|
| | | | | degrees | | | | | |
| $\frac{h}{w} < \frac{1}{2}$ | $1 < \frac{l}{w} < \frac{3}{2}$ | | | 0 | +0·7 | −0·2 | −0·5 | −0·5 | −0·8 |
| | | | | 90 | −0·5 | −0·5 | +0·7 | −0·2 | |
| | $\frac{3}{2} < \frac{l}{w} < 4$ | | | 0 | +0·7 | −0·25 | −0·6 | −0·6 | −1·0 |
| | | | | 90 | −0·5 | −0·5 | +0·7 | −0·1 | |
| $\frac{1}{2} < \frac{h}{w} < \frac{3}{2}$ | $1 < \frac{l}{w} < \frac{3}{2}$ | | | 0 | +0·7 | −0·25 | −0·6 | −0·6 | −1·1 |
| | | | | 90 | −0·6 | −0·6 | +0·7 | −0·25 | |
| | $\frac{3}{2} < \frac{l}{w} < 4$ | | | 0 | +0·7 | −0·3 | −0·7 | −0·7 | −1·1 |
| | | | | 90 | −0·5 | −0·5 | +0·7 | −0·1 | |
| $\frac{3}{2} < \frac{h}{w} < 6$ | $1 < \frac{l}{w} < \frac{3}{2}$ | | | 0 | +0·8 | −0·25 | −0·8 | −0·8 | −1·2 |
| | | | | 90 | −0·8 | −0·8 | +0·8 | −0·25 | |
| | $\frac{3}{2} < \frac{l}{w} < 4$ | | | 0 | +0·7 | −0·4 | −0·7 | −0·7 | −1·2 |
| | | | | 90 | −0·5 | −0·5 | +0·8 | −0·1 | |

Table 2: External pressure coefficients ($C_{pe}$) for walls of rectangular clad buildings

shown that the potential area of wind power in the country is about 6074 sq. km with wind power density greater than 300 watt/$m^2$. From the total area of 6074 sq. km only 10 percent has been analyzed and it has been found that more than 3,000 MW of electricity could be generated with consideration of the installed capacity of 5 MW per sq km. The study also shows that the most potential areas lie in areas of high and middle mountains of the country. The commercially viable wind potential of the country is estimated to be only about 448 MW. Based on the data collected from a limited number of stations under the AEPC/SWERA/UNEP/GEF the twenty-six month long project that started in March 2003 and completed in April 2005, the extreme wind speed was found to be quite high (3 to 5 times) in all the stations in comparison to the average wind speed measured. The annual average energy potential is found to be 3.387 MWh/m2 at the locations where the measurement was taken. In a resource grid generated for 50 m height over the region shows very high (as high as 46.76 m/s) wind speed, and 238 kW/m2 power density in the Kagbeni region. The average wind data shows that there is not much difference to the average wind speed measured at the height of 10 m and 20 m. The diurnal variation of wind speed is very typical in all the regions in which it continuously rises up in the morning at 8-9 hours and reaches to the peak in 12-14 hours.




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $\frac{1}{2} < \frac{h}{w} \leqslant \frac{3}{2}$ | 0 | −0.8 | −0.6 | −1.0 | −0.6 | −2.0 | −2.0 | −2.0 | — |
| | 5 | −0.9 | −0.6 | −0.9 | −0.6 | −2.0 | −2.0 | −1.5 | −1.0 |
| | 10 | −1.1 | −0.6 | −0.8 | −0.6 | −2.0 | −2.0 | −1.5 | −1.2 |
| | 20 | −0.7 | −0.5 | −0.8 | −0.6 | −1.5 | −1.5 | −1.5 | −1.0 |
| | 30 | −0.2 | −0.5 | −0.8 | −0.8 | −1.0 | | | −1.0 |
| | 45 | +0.2 | −0.5 | −0.8 | −0.8 | | | | |
| | 60 | +0.6 | −0.5 | −0.8 | −0.8 | | | | |
| $\frac{3}{2} < \frac{h}{w} < 6$ | 0 | −0.7 | −0.6 | −0.9 | −0.7 | −2.0 | −2.0 | −2.0 | — |
| | 5 | −0.7 | −0.6 | −0.8 | −0.8 | −2.0 | −2.0 | −1.5 | −1.0 |
| | 10 | −0.7 | −0.6 | −0.8 | −0.8 | −2.0 | −2.0 | −1.5 | −1.2 |
| | 20 | −0.8 | −0.6 | −0.8 | −0.8 | −1.5 | −1.5 | −1.5 | −1.2 |
| | 30 | −1.0 | −0.5 | −0.8 | −0.7 | −1.5 | | | |
| | 40 | −0.2 | −0.5 | −0.8 | −0.7 | −1.0 | | | |
| | 50 | +0.2 | −0.5 | −0.8 | −0.7 | | | | |
| | 60 | +0.5 | −0.5 | −0.8 | −0.7 | | | | |

Table 3: The average external pressure coefficients and pressure concentration coefficients for pitched roofs of rectangular clad buildings

## 4. WIND ENERGY PROJECTS IN NEPAL

A 10 kw wind turbine generator was installed at Kagbeni in Mustang district, the trans Himalayan zone by Nepal electricity authority in 1985. But the turbine was broken by high wind after the installation and is now dismantled. Some of the recently completed micro-wind energy projects in Nepal are: (1) Kavre District (2 windmills with 400 watt capacity established in 2007. Fig. 3 and 4), (2) Biratnagar, Morang District (windmill for groundwater pumping), (3) Bhimdhunga, Dhading Besi, Dhading District and Timal Danda, Kavre District (measurement of wind speed and potential for electricity generation, established in 2008).

## 5. ACTIVITIES IN THE PAST TWO YEARS

Nepal government has realized that wind energy could become a major source of alternative energy to solve energy crisis in the country. It is planning to generate 20 MW wind power generation from Kathmandu Valley and the surroundings hills. Charus Development Nepal

Figure 3: 400 watt capacity wind mill at Kavre

Figure 4: schematic diagram of wind mill

Pvt. Ltd and two international companies, viz., Suzlon Energy Limited (India) and AGA Middle East Pvt. Ltd Singapore/Hong Kong have submitted proposals to the Government of Nepal for generating more than 200 MW wind energy. Charus Development Nepal Pvt. Ltd has already obtained from the Ministry of Environment, Science and Technology for survey license to carry out detail feasibility study in Annapurna areas for generating 400 MW of electricity. In addition, Suzlon Energy Limited (India) has plan to install wind mast of more than 30 meters high in Kagbeni, Mustang District to measure wind data for further detail study. AEPC has already invited AGA Middle East Pvt. Ltd Singapore/Hong Kong for detail feasibility study for wind potential areas of Nepal. The company has proposed to install vertical axis wind turbines and interested to invest for minimum 200 MW of wind energy.
In the last two years AEPC has established three more wind monitoring station at (1) Phakhel, Makawanpur district (2) Neta Hansapur, Pyuthan district, and (3) AEPC building at Kathmandu Valley. They are presently collecting data on (a) average wind speed of all stations (b) Average maximum and minimum wind speed (c) Durinal variation (d) seasonal variation (e) extreme values, and (f) monthly energy calculation from these stations. More than 30 small windmills up to 1,000 watt are planned or already installed in remote areas of Nepal with support from various countries.

## 6. WIND HAZARD IN NEPAL

Every year Nepal suffers from disaster due to storms which come with gusts. The disasters occur mostly during the months of February to June when the region is constantly under low pressure. Rural areas are more commonly affected than the urban areas. The main reason for disasters is due to the low quality building construction and most buildings do not follow the Nepal national building code on wind load. The wind disaster data from the year 1971 to 2005 available from the Ministry of Home Affairs is presented in table 4.

## 7. CONCLUSIONS

Nepal has a high potential for wind energy. However, it needs concerted efforts to survey the wind potential of the country to harness the energy. Due to its topographic condition, it needs a large number of wind stations distributed according to the altitude and locations and continue the survey for sufficiently long period. High altitude areas are yet to be surveyed.

Table 4: Wind disaster data from 1971 to 2005

| S.NO. | Affect | Unit | Strong wind | Storm | Snow Strom |
|---|---|---|---|---|---|
| 1 | Deaths | persons | 42 | 47 | 30 |
| 2 | Injured | persons | 121 | 154 | 8 |
| 3 | Houses destroyed | nos | 127 | 1016 | 67 |
| 4 | Houses damaged | nos | 995 | 487 | 11 |
| 5 | Affected | nos | NA | 1817 | 1432 |
| 6 | Education centre damaged | nos | NA | 15 | NA |

For development of the National building code on wind load these data are very important. Based on the new data, revised building code for Nepal has to be prepared. Although Nepal has a high potential for wind energy, only a insignificant amount of energy has been harnessed so far. Wind could be a very good alternative source of energy in remote and rural areas of Nepal where national grid of electricity will not reach in foreseeable future. Every year storms kill many people destroy or damage properties worth hundreds of thousands of Dollars. Therefore, low cost wind resistant building designs need to be designed for rural areas of lest developing countries like Nepal.

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