MORREN MONDIAL ASSOCIATES, INC.
BUSINESS DEVELOPMENT

Solving Dominican Republic energy problems with wind power

November 15, 2005

Wind *Power in the Province of Flefoland, the Netherlands (foto Justin Morren)*
***NL**: New capacity: 165 turbines / 199 MW   Decommissioned: 90 turbines / 29 MW.   Net increase: 75 turbines / 170 MW*

INTRODUCTION

Make a Personal Contribution to Safeguarding the Future....

One of the simplest ways you can have a direct impact on global warming and the environment is by powering your home with green energy.

Green power is generated from renewable energy sources like wind, sun, hydro, geothermal and some forms of biomass.

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Here are 4 straightforward reasons to make the switch

The Environmental Benefits include minimal, if any, byproducts of CO_2 and other pollutants such as carbon monoxide, sulfur dioxide, and lead in comparison to those produced in the creation of energy through fossil fuels.

Stimulating Our Hobbled Economy

In 2004, importing fossil fuels sent millions of dollars outside of the Dominican Republic. However, renewable energy resources can be developed at home. Furthering their development will keep millions of dollars in the Dominican Republic, creating more jobs for Dominicans.

The future of the Dominicans depends on the technological advancements of these energy sources. Two things we know for certain are that oil won't last forever and the sun will.

National Security is strengthened as our dependency for foreign oil is decreased. By moving toward renewable energies, we naturally shift toward freedom from unstable ground.

Where does Wind Energy come from?

All renewable energy (except tidal and geothermal power), and even the energy in fossil fuels, ultimately comes from the sun. The sun radiates 174,423,000,000,000 kilowatt hours of energy to the earth per hour. In other words, the earth receives 1.74×10^{17} watts of power.

1) About 1 to 2 per cent of the energy coming from the sun is converted into wind energy. That is about 50 to 100 times more than the energy converted into biomass by all plants on earth.

2) Temperature Differences Drive Air Circulation

The regions around equator, at 0° latitude are heated more by the sun than the rest of the globe.

Hot air is lighter than cold air and will rise into the sky until it reaches approximately 10 km (6 miles) altitude and will spread to the North and the South. If the globe did not rotate, the air would simply arrive at the North Pole and the South Pole, sink down, and return to the equator.

1) The power emission from the sun is 1.37 kW/m^2 on the surface of the sphere, which has the sun as its centre and the average radius of the earth trajectory. The power hits a circular disc with an area of of 1.27×10^{14} m^2. The power emitted to the earth is thus 1.74×10^{17} W.

2) On average, plant net primary production is about 4.95×10^{6} calories per square metre per year. This is global NPP, Global net primary production, i.e. the amount of energy available to all subsequent links in the food/energy chain. The earth's surface area is 5.09×10^{14} m^2 . The net power output stored by plants is thus 1.91×10^{13} W, or 0.011% of the power emitted to earth. You may find the conversion factor between the energy unit calories and Joule in the reference manual.

Wind Turbine Design: Basic Load Considerations

Whether you are building wind turbines or helicopters, you have to take the strength, the dynamic behavior, and the fatigue properties of your materials and the entire assembly into consideration.

Wind turbines are built to catch the wind's kinetic (motion) energy. You may therefore wonder why modern wind turbines are not built with a lot of rotor blades, like the old "American" windmills you have seen in the Western movies.

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Turbines with many blades or very wide blades, i.e. turbines with a very solid rotor, however, will be subject to very large forces, when the wind blows at a hurricane speed. (Remember, that the energy content of the wind varies with the third power (the cube) of the wind speed).

Wind turbine manufacturers have to certify that their turbines are built, so that they can withstand extreme winds which occur, say, during hurricanes.

To limit the influence of the extreme winds turbine manufacturers therefore generally prefer to build turbines with a few, long, narrow blades.

In order to make up for the narrowness of the blades facing the wind, turbine manufacturers prefer to let the turbines rotate relatively quickly.

Fatigue Loads (Forces)

Wind turbines are subject to fluctuating winds, and hence fluctuating forces. This is particularly the case if they are located in a very turbulent wind climate.

Components which are subject to repeated bending, such as rotor blades, may eventually develop cracks, which ultimately may make the component break. A historical example is the huge German Growian machine (100 m rotor diameter) which had to be taken out of service after less than three weeks of operation. Metal fatigue is a well known problem in many industries. Metal is therefore generally not favored as a material for rotor blades.

When designing a wind turbine it is extremely important to calculate in advance how the different components will vibrate, both individually, and jointly. It is also important to calculate the forces involved in each bending or stretching of a component.
This is the subject of structural dynamics, where physicists have developed mathematical computer models that analyze the behavior of an entire wind turbine.

These models are used by wind turbine manufacturers to design their machines safely.

Structural Dynamics:

An Example *)

A 50 meter tall wind turbine tower will have a tendency to swing back and forth, say, every three seconds. The frequency with which the tower oscillates back and forth is also known as the eigenfrequency of the tower. The eigenfrequency depends on both the height of the tower, the thickness of its walls, the type of steel, and the weight of the nacelle and rotor.

Now, each time a rotor blade passes the wind shade of the tower, the rotor will push slightly less against the tower.

If the rotor turns with a rotational speed such that a rotor blade passes the tower each time the tower is in one of its extreme positions, then the rotor blade may either dampen or amplify (reinforce) the oscillations of the tower.

The rotor blades themselves are also flexible, and may have a tendency to vibrate, say, once per second. As you can see, it is very important to know the eigenfrequencies of each component in order to design a safe turbine that does not oscillate out of control.

*) A very dramatic example of structural dynamic forces at work under influence of the wind (un-dampened torsion oscillations) is the famous crash of the Tacoma Bridge close to Seattle in the United States. You may find a short movie clip (700 K) on the disaster on the Internet.

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Roughness and Wind Shear

High above ground level, at a height of about 1 kilometre, the wind is hardly influenced by the surface of the earth at all. In the lower layers of the atmosphere, however, wind speeds are affected by the friction against the surface of the earth. In the wind industry one distinguishes between the roughness of the terrain, the influence from obstacles, and the influence from the terrain contours, which is also called the orography of the area..

Roughness of earth surface and its effect on windpower

In general, the more pronounced the roughness of the earth's surface, the more the wind will be slowed down.

Forests and large cities obviously slow the wind down considerably, while concrete runways in airports will only slow the wind down a little. Water surfaces are even smoother than concrete runways, and will have even less influence on the wind, while long grass and shrubs and bushes will slow the wind down considerably.

Roughness Classes and Roughness Lengths

Sheep are a wind turbine's best friend. In New Zealand, the sheep keep the roughness of the landscape down through their grazing.

In the wind industry, people usually refer to roughness classes or roughness lengths, when they evaluate wind conditions in a landscape. A high roughness class of 3 to 4 refers to landscapes with many trees and buildings, while a sea surface is in roughness class 0.

Concrete runways in airports are in roughness class 0.5. The same applies to the flat, open landscape to the left which has been grazed by sheep.

The proper definition of roughness classes and roughness lengths may be found in the Reference Manual. The term roughness length is really the distance above ground level where the wind speed theoretically should be zero.

Wind Shear

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The fact that the wind profile is twisted towards a lower speed as we move closer to ground level, is usually called wind shear. Wind shear may also be important when designing wind turbines. If you consider a wind turbine with a hub height of 40 meters and a rotor diameter of 40 meters, you will notice that the wind is blowing at 9.3 m/s when the tip of the blade is in its uppermost position, and only 7.7 m/s when the tip is in the bottom position. This means that the forces acting on the rotor blade when it is in its top position are far larger than when it is in its bottom position.

Wind Shear Formula

The wind speed at a certain height above ground level is:
v = v ref ln (z/z 0)/ln (z ref /z 0)
v = wind speed at height z above ground level.
v ref = reference speed, i.e. a wind speed we already know at height z ref . ln (...) is the natural logarithm function.
z = height above ground level for the desired velocity, v.
z 0 = roughness length in the current wind direction.
z ref = reference height, i.e. the height where we know the exact wind speed v ref .

In the above example, assume we know that the wind is blowing at 7.7 m/s at 20 m height. We wish to know the wind speed at 60 m height. If the roughness length is 0.1 m, then
v ref = 7.7
z = 60
z 0 = 0.1
z ref = 20 hence,
v = 7.7 ln(60/0.1) / ln(20/0.1) = 9.2966 m/s

*) = The formula assumes so-called neutral atmospheric stability conditions, i.e. that the ground surface is neither heated nor cooled compared to the air temperature.
Wind Turbines in the Electrical Grid: Wind Energy Variations.

Wind Turbines and the grid

The vast majority of the installed power of wind turbines in the world is grid connected, i.e. the turbines feed their electricity directly into the public electrical grid. Wind Turbines in the Electrical Grid:

Wind Energy Variations

The typical weather pattern is that winds are low at night, and higher during the day. This means that wind electricity generally fits well into the electricity consumption pattern, i.e. wind electricity tends to be more valuable to the electrical grid systems than if it were being produced at a random level.

Cost

Prices vary for each generator size. The reasons are e.g. different tower heights, and different rotor diameters. One extra meter of tower will cost you roughly 1 500 USD. A special low wind machine with a relatively large rotor diameter will be more expensive than a high wind machine with a small rotor diameter.

Economies of Scale

As you move from a 150 kW machine to a 600 kW machine, prices will roughly triple, rather than quadruple. The reason is, that there are economies of scale up to a certain point, e.g. the amount of manpower involved in building a 150 kW machine is not very different from what is required to build a 600 kW machine. E.g. the safety features, and the amount of electronics required to run a small or a large machine is roughly the same. There may also be (some) economies of scale in operating wind parks rater than individual turbines, although such economies tend to be rather limited.

Price Competition and Product Range

Price competition is currently particularly tough, and the product range particularly large around 1000 kW. This is where you are likely to find a machine which is optimized for any particular wind climate.

Typical 1000 kW Machines on the Market Today

Even if prices are very similar in the range from 600 to 750 kW, you would not necessarily want to pick a machine with as large a generator as possible. A machine with a large 750 kW generator (and a relatively small rotor diameter) may generate less electricity than, say a 600 kW machine, if it is located in a low wind area. The working horse today is typically a 1000 kilowatt machine with a tower height of some 60 to 80 meters and a rotor diameter of around 54 meters.
1 000 Dollars per Kilowatt Average

The average price for large, modern wind farms is around 1 000 USD per kilowatt electrical power installed. (Note, that we are not talking about annual energy production, yet.. Energy production is measured in kilowatt hours..

For single turbines or small clusters of turbines the costs will usually be somewhat higher.

Offshore Wind Turbines

Offshore wind energy is a promising application of wind power, particularly in countries with high population density, and difficulties in finding suitable sites on land. Construction costs are higher at sea, but energy production is also higher. The largest offshore wind farms are on Horns Rev by the west coast of Jutland and Nysted close to Lolland 160 and 158 MW respectively in Denmark. A tendering procedure for new offshore wind farms was commenced in late 2003.

The Danish energy plan, Energi21, from 1996 set up a target for 4,000 MW offshore wind power in 2030. These 4,000 MW are now producing 13.5 TWh per year equivalent to 40% of the Danish electricity consumption.

Did you know?

Wind turbines and economy

…that the European wind industry is the worlds largest.

…that the Danish wind industry has created 20,000 jobs in Denmark.

…that 90% of the production from Danish manufactures are sold abroad.

…that wind turbines can compete.

…growth expectations for the wind industry are greater than growth expectations for the Chinese economy.

Wind turbines and energy

…that energy in the wind more or less follows the human 24 hour power consumption cycle

…that wind power covers almost 40% of the Danish power consumption and will cover 65% in 2008

…that only a limited part of the potential wind energy is utilized

…that one 2 MW wind turbine on a good location can cover the electricity consumption for 2000 households per year

Wind turbines and people

…that wind turbines are popular in Europe and many other parts of the world

…that half the many turbines in Europe are owned by local wind turbine cooperatives

Wind turbines and nature

…that the sound from the wind turbine has the same sound level as ordinary speech.

…that birds fly past wind turbines.

…that offshore foundations increase the local variety of marine animals.

Wind turbines and landscape

…that wind turbines has a minimal effect on the surrounding area

…that a wind turbine takes up less than 1% of the area in a wind farm

…that wind turbines and wind mills has been a natural part of the northern European landscape for more than 800 years

Wind turbines and environment

…that wind turbines reduces CO2 emissions

…that during its life time a wind turbine delivers 80 times more energy than is used in its production, maintenance and scrapping.

***Facts and figures supplied by the Danish Wind Association**

For additional information on getting Windpower to your country or region, contact:

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