Negative Impact of Wind Farms to the Environment

I. Introduction

Wind energy has attracted a vast amount of attention in recent years. It is one of the focal points of President Obama's energy plan. On the website of U.S. Department of Energy, it states "To help meet America's increasing energy needs while protecting our Nation's energy security and environment, the U.S. Department of Energy (DOE) is working with wind industry partners to develop clean, domestic, innovative wind energy technologies that can compete with conventional fuel sources. DOE's Wind Energy Program efforts have culminated in some of industry's leading products today and have contributed to record-breaking industry growth."[1]

On its report, "20% Wind Energy by 2030", "Energy prices, supply uncertainties, and environmental concerns are driving the United States to rethink its energy mix and develop diverse sources of clean, renewable energy. The nation is working toward generating more energy from domestic resources—energy that can be cost-effective and replaced or "renewed" without contributing to climate change or major adverse environmental impacts." [2]

With so many apparent benefits, however, the adverse environmental impacts of large-scale utilization of wind energy have not been thoroughly studied. It is the purpose of this paper to investigate a potential detrimental effect to climate of such usage of wind energy from the perspective of the direct movement of moisture rather than the perspective of equipment cost or energy conversion efficiency.

II. Estimated Amount of Energy

From the official report, "20% Wind Energy by 2030", "In its Annual Energy Outlook 2007, the U.S. Energy Information Administration (EIA) estimates that U.S. electricity demand will grow by 39% from 2005 to 2030, reaching 5.8 billion megawatt-hours (MWh) by 2030. To meet 20% of that demand, U.S. wind power capacity would have to reach more than 300 gigawatts (GW) or more than 300,000 megawatts (MW). This growth represents an increase of more than 290 GW within 23 years."[2]

III. Environmental Benefits

Environmental benefits of wind power generation have been fully explained in the report, "20% Wind Energy by 2030", "Wind energy is one of the cleanest and most environmentally neutral energy sources in the world today. Compared to conventional fossil fuel energy sources, wind energy generation does not degrade the quality of our air and water and can make important contributions to reducing climate-change effects and meeting national energy security goals. In addition, it avoids environmental effects from the mining, drilling, and hazardous waste storage associated with using fossil fuels. Wind energy offers many ecosystem benefits, especially as compared to other forms of electricity production. Wind energy production can also, however, negatively affect wildlife habitat and individual species, and measures to mitigate prospective impacts may be required. As with all responsible industrial development, wind power facilities need to adhere to high standards for environmental protection.

Wind energy generally enjoys broad public support, but siting wind plants can raise concerns in local communities. Successful project developers typically work closely with communities to address these concerns and avoid or reduce risks to the extent possible. Not all issues can be fully resolved, and not every prospective site is appropriate for development, but engaging with local leaders and the public is imperative. Various agencies and stakeholders must also be involved in reviewing and approving projects. If demand increases and annual installations of wind energy approach 10 gigawatts (GW) and more, the wind energy industry and various government agencies would need to scale up their permitting and review capabilities.

To date, hundreds of wind projects have been successfully permitted and sited. Although the wind energy industry must continue to address significant environmental and siting challenges, there is growing market acceptance of wind energy. If challenges are resolved and institutions are adaptive, a 20% Wind Scenario in the United States could be feasible by 2030. As noted by the Intergovernmental Panel on Climate Change (IPCC), under certain conditions, renewable energy could contribute 30% to 35% of the world's electricity supply by 2030 (IPCC 2007).
A primary benefit of using wind-generated electricity is that it can play an important role in reducing the levels of carbon dioxide (CO2) emitted into the atmosphere. Wind-generated electricity is produced without emitting CO2, the GHG that is the major cause of global climate change. "[2]

IV. Environmental Concerns

Environmental concerns of wind farms have also been addressed in the report, "20% Wind Energy by 2030", however, only in the following two aspects.

"Habitat disturbance and land use

Wind development also requires large areas of land, but the land is used very differently. The 20% Wind Scenario (305 GW) estimates that in the United States, about 50,000 square kilometers (km2) would be required for land-based projects and more than 11,000 km2 would be needed for offshore projects. However, the footprint of land that will actually be disturbed for wind development projects under the 20% Wind Scenario ranges from 2% to 5% of the total amount (representing land needed for the turbines and related infrastructure). Thus the amount of land to be disturbed by wind development under the 20% Wind Scenario is only 1,000 to 2,500 km2 (100,000 to 250,000 hectares)—an amount of dedicated land that is slightly smaller than Rhode Island. For scale comparisons, available data for existing coal mining activities indicate that about 1,700,000 hectares of land is permitted or covered and about 425,000 hectares of land are disturbed (DOI 2004). An important factor to note is that wind energy projects use the same land area each year; coal and uranium must be mined from successive areas, with the total disturbed area increasing each year. In agricultural areas, land used for wind generation projects has the potential to be compatible with some land uses because only a few hectares are taken out of production, and no mining or drilling is needed to extract the fuel.

Wildlife risks

Wildlife—and birds in particular–are threatened by numerous human activities, including effects from climate change. Relative to other human causes of avian mortality, wind energy's impacts are quite small. "[2]

V. What Causes Wind

Wind is a movement of air caused by the difference in air pressure. The difference in air pressure is mainly the combined effect of temperature differences across the Earth's surface and temperature variation along the time. The temperature differences across the surface of the Earth are primarily the results of uneven distribution of the intensity of sunlight, for an example, during the day, the equatorial area which is perpendicular to direct sunlight receives much higher intensity of sunlight than the polar areas that are at skewed angles with sunlight.

VI. Wind Energy and Wind Farms

Wind energy that can be used to generate electricity can be expressed as:

$E=1/2\ mv_1^2 - 1/2\ mv_2^2$

Where v_1 is the wind velocity before the wind mill and v_2 is the wind velocity after the wind mill. Assume the best scenario that the wind energy is complete converted to electric energy, the conversion efficiency is 100 percent, no mechanical loss to friction, vibration or sound, and further assume that all the kinetic energy in the wind is captured, i.e., the velocity after the wind mill is zero, $v_2=0$.

"Modern wind turbines, which are currently being deployed around the world, have three-bladed rotors with diameters of 70 m to 80 m mounted atop 60-m to 80-m towers." "Generally, a turbine will start producing power in winds of about 5.36 m/s and reach maximum power output at about 12.52 m/s–13.41 m/s. The turbine will pitch or feather the blades to stop power production and rotation at about 22.35 m/s."[2] Assume the wind turbines operate at the optimum wind speed of 13.41m/s (30 MPH) and under non-stop continuous wind conditions. 300GW of electrical energy would translate into $3.34X10^9$kg/s or $2.78X10^9 m^3/s$ (using air density of 1.2 kg/m^3).

VII. The Moisture in Air

Water vapor pressure is a function of temperature. Apparently, the water vapor pressure is higher at a higher temperature, therefore, warmer air can hold more water than colder air. Air temperature drops with altitude. Combining these two factors, one can easily come to the conclusion that air at lower altitude contains more water than air at higher altitude overall. “The absolute humidity diminishes with the altitude, but the rate of reduction is not fully known.”[3]

VIII. Moisture Blocked by Wind Farms

As discussed in the above section, wind farms are sitting in an air layer that is richly laden with water moisture (absolute humidity). However, for the ease of discuss, the moisture content difference is ignored in the following calculations. If all wind turbines are located near a water body, for example, coast-line or near a river or a lake, and on a water body such as off-shore, further assuming the average annual temperature for all the locations is 59^oF, then $2.78X10^9 m^3/s$ (from section VI) of air that is blocked by the wind farms contains $3.57X10^7 kg/s$ water. Water vapor density is considered to be $12.83 g/m^3$ at 59^oF for saturated vapor.[4]

Annually, that is $1.13X10^{15}$ kg of water If the water is assumed to transform into rain falling on 10 percent of the land of contiguous United States (about 5 states, $0.766X10^{12} m^2$)[5], it is equivalent of 1.47 m or 58 inches of rainfall annually that is blocked by the wind farms.

IX. Conclusion

The above calculation assumes 100 percent efficiency of energy conversion by the wind turbines. Any inefficiency such as friction, noise, or vibration will result in lower exit wind speed, hence increase the amount of moisture being retained. It is also assumed optimum wind speed of 13.41m/s (30 MPH), any deviation from the optimum speed will exponentially increase the quantity of moisture retained. On the other hand, not all wind farms are located at coast-line, by a river, or near a lake, the fact that absolute moisture content is not always be the saturated vapor pressure will decrease the amount of moisture retained by the wind mills. Wind mills are by no means a water-proof air-tight seal. Wind direction plays a role too. Wind not always blows land-inbound. Land-outbound wind will reduce the amount of water retained.

The moisture retaining effect is further intensified by different distances of the moisture being projected at the two different wind speeds. Obviously, higher wind speed can project the moisture farther, wind mills reduces the wind speed, therefore, shorten the distance.

Large-scale utilization of wind energy by wind farms is promising, but, it can have disastrous environmental effect too. All the factors needs be included in the assessment of the value of wind energy. Although not all moisture in the wind will change into rain, with huge amount of water moisture blocked by the wind turbines, the possibility of inland drought can not be ignored. It should at least be included into the consideration when choosing the site for a wind farm.

Reference

1. U.S. Department of Energy, Wind and Hydropower Technologies Program, 2008.
http://www1.eere.energy.gov/windandhydro/

2. U.S. Department of Energy, 20% Wind Energy by 2030, 2008.
http://www1.eere.energy.gov/windandhydro/wind_2030.html

3. John Brocklesby, Elements of meteorology, With Questions for Examination, Designed for School and Academies, 2008, p.39.
http://books.google.com/books?id=8pLzzidDzNUC&pg=PA33&lpg=PA33&dq=altitude+and+absolute+humidity&source=bl&ots=ikpD0EXbmN&sig=Hsz7xkL_VdKw-u_ZCHEfadagmRk&hl=en&ei=JRrAScCLIKDFtgf4i-1P&sa=X&oi=book_result&resnum=4&ct=result

4.Department of Physics and Astronomy, Georgia State University, Hyperphysics,
http://hyperphysics.phy-astr.gsu.edu/HBASE/kinetic/watvap.html

6. Wikipedia, Contiguous United States, 2009,
http://en.wikipedia.org/wiki/Contiguous_United_States