Montana Wind Power Potential

I. Introduction
Recent concerns over both the environmental impact and the price of fossil fuels have led many to call for an increase in the production of renewable green energies in the United States. Though there are many windy places in the world, few locations are suitable for harvesting wind-based energy at economical prices. For wind power to become a commonly utilized form of energy, advocates must show potential investors that it can be extracted at reasonable prices.

This project aims to show how studies can be formulated to analyze wind-energy potential. Using Montana (Figure 1) as a case study, we explore how geography, infrastructure and land constraints influence a region’s energy extraction potential. We hope our analysis can help Montana determine where it can best produce wind-energy and also set up a framework of examination that other places can use to explore their own wind potential. To do this we formulate a cost and revenue approach, and calculate potential profit from 2MW wind turbines throughout the state. We then use our analysis to select the five incorporated cities with the best opportunity to utilize local wind energy.

Figure 1: The State of Montana
Flat in the east and mountainous in the west, Montana holds large green energy potential, as the winds of the Great Plains meet the Rocky Mountains. The towns and roads are found throughout the state, its largest towns are found in its south and southwest portions.
II. Methodology

We first determine which land in Montana is legally available for development. We then calculate the potential profit for 2MW wind turbines throughout the state, by calculating a site’s potential revenue, land costs and transmission costs. We then calculate the wind potential for every incorporated city in Montana. It’s important to note that any numbers on profit that we present are meant to exhibit site suitability, and do not necessarily reflect true measures of the finances behind wind farms.

1) Eliminate restricted land

Designated wilderness, wildlife refuges, national parks, state parks, special BLM lands and priority conservation areas are unlikely to allow development, and are therefore eliminated as potential locations for turbine sites or transmission lines (Figure 2).

![Areas Restricted from Development](image)

**Figure 2: Restricted Development**
These areas place high limits on development, and are therefore excluded from the analysis of potential sites.
2) Site revenue

Using data on classes of wind power throughout the state, the potential annual energy production for 2 MW wind turbines\(^1\) with 90m diameter blades and 40% efficiency is calculated\(^2\). Sites with wind power classes of four or higher are considered. Any sites classified lower is deemed economically unfeasible. Assuming energy prices at the Montana average of eight cents per kilowatt hour\(^3\), and taking away two cents for corporate costs, the potential annual revenue is calculated throughout the state (Fig. 3).

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**Figure 3: Site Revenue**
The highest revenue sites are located along the planes and where the planes meet the mountains.

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1. 2 MW Wind turbine parameters from Mitsubishi Heavy Industries at p://www.mhi.co.jp/en/products/pdf/vol41_no5.pdf
3) Site costs
We assume that the lowest site costs will be on flat federal or native land that is adjacent to roads. Our analysis focuses on relative land costs compared to this standard. Increased costs are measured as capturing a percentage of the site’s annual potential revenue. We use three categories of variables to serve as examples of the composition of a site’s cost: construction, royalties and public relations.

Construction Costs
Areas where the land cover is open water, perennial snow, manmade development or wetlands are deemed too expensive to build on. Sites with significant slopes are considered costlier than flatlands. As well, since the construction of a wind turbine is material intensive, accessibility to the road system is imperative. Therefore, sites lose revenue linearly, based on their distance from the road system, up to fifteen kilometers. Distances beyond this are deemed unfeasible.

Royalties
We assume that the lowest royalties will be on federal or native land. On private land\(^4\) (Fig. 4), our model pays 10% of revenue as royalties.

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Figure 4: Private Land
A large amount of the land in Montana is privately owned. If allowed, energy development on these lands is subject to royalty and easement payments.
Public Relations
Many individuals oppose wind-energy development due to its visual impact on landscapes. Developers face high litigation risks, and must spend large amounts persuading individuals and politicians to be in favor of their projects. To consider this factor two variables are used. Sites within view of the Lewis and Clark Trail (Fig. 5) or within 3km of BLM recreation sites (Fig. 6) loose proportions of their revenue.

Figure 5: BLM Recreation Sites
Development in view of popular recreation or historical sites increases public opposition. We use the Lewis and Clark Trail viewshed to illustrate this. Sites in view have increased costs, depending on the incidence of their visibility.

Figure 6: BLM Recreation Sites
We assume that attempts to develop within 3km of BLM will face opposition and therefore drive up costs.
4) Transmission Costs
Production sites must be connected to population centers by transmission lines (Fig. 7). These lines incur construction, legal and easement costs. We use several variables to measure the cost to build transmission lines throughout Montana. We then use this measurement to establish development regions for each incorporated city.

Figure 7: Existing Transmission Lines
Sites must be connected to population centers by transmission lines. We classify transmission lines as the cheapest line of movement for energy. Note that in reality, many existing transmission lines are at capacity, and may not be able to handle more electricity. As well, access to the grid requires a substantial permit process.
Measurement
The cost of the line per turbine is measured in dollars per 100m of line (Table 1). Once again, this measurement should be considered as an addition to a base price. Existing transmission lines (Fig. 7) are the lowest cost medium of travel.

Table 1: Transmission Costs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Additional yearly cost per 100m of line ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land cover</strong></td>
<td></td>
</tr>
<tr>
<td>Open Water</td>
<td>7</td>
</tr>
<tr>
<td>Perennial Ice/Snow</td>
<td>9</td>
</tr>
<tr>
<td>Developed</td>
<td>3</td>
</tr>
<tr>
<td>Barren</td>
<td>2</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>5</td>
</tr>
<tr>
<td>Evergreen Forest</td>
<td>4</td>
</tr>
<tr>
<td>Mixed Forest</td>
<td>5</td>
</tr>
<tr>
<td>Shrub/Scrub</td>
<td>2</td>
</tr>
<tr>
<td>Grassland/Herbaceous</td>
<td>2</td>
</tr>
<tr>
<td>Pasture/Hay</td>
<td>2</td>
</tr>
<tr>
<td>Cultivated Crops</td>
<td>2</td>
</tr>
<tr>
<td>Woody Wetlands</td>
<td>5</td>
</tr>
<tr>
<td>Herbaceous Wetlands</td>
<td>5</td>
</tr>
<tr>
<td><strong>Slope (degrees)</strong></td>
<td></td>
</tr>
<tr>
<td>10 - 15</td>
<td>3</td>
</tr>
<tr>
<td>15 - 20</td>
<td>4</td>
</tr>
<tr>
<td>20 - 25</td>
<td>5</td>
</tr>
<tr>
<td>25 - 30</td>
<td>7</td>
</tr>
<tr>
<td>30&lt;</td>
<td>unfeasible</td>
</tr>
<tr>
<td><strong>Private Land</strong></td>
<td>3</td>
</tr>
<tr>
<td><strong>Within 3km of BLM rec site</strong></td>
<td>5</td>
</tr>
</tbody>
</table>
Development Regions
To account for population differences between places, proportional buffers are applied to each city in which the cost of travel is considered to be zero. Next, the lowest cost path to an incorporated city is calculated. Finally, development areas are defined by the city to which each turbine’s cheapest transmission route is destined (Fig. 8).

**Figure 8: Development Regions**
This map shows the area of development for each town. Any turbine built in a city’s development area’s lowest transmission costs will be to that city. This was calculated using a cost allocation function.
5) Site Analysis
To calculate site value, potential revenue is multiplied by the site cost. From this product the site’s transmission cost is subtracted. The result (Fig. 9) gives an approximation of the suitability of each location.

![Site Suitability Map](image)

**Figure 9: Site Suitability**
This map shows the annual site profitability throughout the region. Numbers should be seen as indicators of relative site suitability, since we do not claim to have accurate data on the finances of wind turbine development.
6) City Analyses

The total wind potential for each development area was calculated by summing the profit potential throughout the area. This allows us to produce relative rankings of the wind potential for each incorporated city (Table 2, Fig. 10).

<table>
<thead>
<tr>
<th>Potential Energy Rankings</th>
<th>Site Profit &gt; $100,000</th>
<th>Site Profit &gt; $250,000</th>
<th>Site Profit &gt; $350,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cut Bank</td>
<td>Cut Bank</td>
<td>Livingston</td>
</tr>
<tr>
<td>2</td>
<td>Shelby</td>
<td>Livingston</td>
<td>Red Lodge</td>
</tr>
<tr>
<td>3</td>
<td>Great Falls</td>
<td>Red Lodge</td>
<td>Billings</td>
</tr>
<tr>
<td>4</td>
<td>Harve</td>
<td>Billings</td>
<td>Cut Bank</td>
</tr>
<tr>
<td>5</td>
<td>Fort Benton</td>
<td>Big Timber</td>
<td>Fort Benton</td>
</tr>
<tr>
<td>6</td>
<td>Harlowton</td>
<td>Fort Benton</td>
<td>Thompson Falls</td>
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<tr>
<td>7</td>
<td>Conrad</td>
<td>Harve</td>
<td>Helena</td>
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<tr>
<td>8</td>
<td>Big Timber</td>
<td>Bozeman</td>
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<td>9</td>
<td>Chinook</td>
<td>Belt</td>
<td>Walkerville</td>
</tr>
<tr>
<td>10</td>
<td>Billings</td>
<td>Helena</td>
<td>Townsend</td>
</tr>
</tbody>
</table>

Table 2: City Rankings

This chart shows the relative rankings of cities based on profit potential considering different sized sites. The analysis examining only large site profits shows short term wind development potential, while the analyses also considering lower profit sites have longer term development potential, since efforts should first focus on high profit sites.

Figure 10: City Potential
Wind potential in the most suitable cities.
III. Results
To determine the top five cities, we relied on our calculated potential energy rankings, potential development site characteristics and town population. We determined the top five cities to be Cut Bank, Livingston, Billings, Fort Benton, and Harve.

Cut Bank (Population 3329)

Cut Bank Development Area
This city has very high wind potential, both nearby the city, and in the mountains to the west. It also has close proximity to transmission lines. Over the long term, this town should focus on becoming a major exporter of wind energy. We identified one possible development site west of the city.
Cut Bank Potential Development Site

Cut Bank Wind Farm
High wind areas on this mountain could produce high profit wind. As well, a short spur line could connect the site to the State’s transmission infrastructure. This site would likely receive large amounts of opposition however, due to its proximity to conservation areas and Glacier National park.

Cut Bank Wind Farm Viewshed
The site has relatively high visibility. As well, it can be seen from Glacier National Park. This may inhibit its development.
Livingston (Population 6701)

Livingston Development Area
Located in southern Montana, this town is located very close to a high profit wind source. This town has the highest short term development potential.

Livingston Wind Farm
Located on a hill to the southwest of town, a wind farm could easily be connected to the town. The downside is that it is located near a wilderness area, and it would be in view of the town and highway.
Billings Development Area

Billings has several well-suited wind development areas, all within close proximity to transmission lines. We identified one potential site on a mountain to the south. This is the highest population town that we identified as having very good wind potential.
Billings, Potential Development Site

Billings Wind Farm
Located about 40 miles south of the city, this site has excellent wind potential, is located next to a road, and could be connected to existing transmission lines with a short spur. On the downside, it is located near a recreation area, and special lands. However, the special lands are protecting a herd of wild horses, so it would probably not inhibit development.

Billings Wind Farm Viewshed
The site does not have very high visibility within forty miles. As well, it cannot be seen from the national recreation areas. Though it is in view further to the north, at that great of a distance it would probably not be a significant problem. This site’s development should be explored further.
Harve (Population 10,322)

This town has very good long term wind potential, within close proximity to the town. As well, transmission lines run through the town. Though no individual sites were identified, this city should plan for long-term wind energy development.
Fort Benton (Population 1653)

**Fort Benton Development Area**

The smallest of the towns we examined, this site has large amounts of long term wind potential, and one high potential short term site to the south of town. The downside of this site is it would require a 30 mile transmission line to reach the city.

**Fort Benton Wind Farm Viewshed**

The site has moderate visibility, mostly in low population areas.
IV. Conclusion
This report outlines a basic process of examination to determine a region’s wind energy potential. To move forward on development, several things must occur. First, on site surveying and measurement should take place. Second, capital must be raised to support construction costs. Third, community forums should be established to persuade individuals on the benefits of wind development.

Due to time and data constraints, our results presented here are severely limited. Future research should focus more upon the constraints and parameters of our model. It’s also important to recognize that our research is only as accurate as the data provided, so future research should ensure the accuracy of the data. Finally, no decisions should be made from this research without further in person site analysis.