Montana is the fourth largest state in the United States, seventh least populous, and (somewhat accordingly) exports more energy than it uses. Most of this energy comes from coal (64%) and hydroelectric (34%). Straddling numerous mountain ranges within the Rockies and the vast eastern expanse of the Great Plains, Montana boasts very high wind potential, rated at 6th in the nation, yet is only 16th for wind power production.

This report examines the potential for wind farm development, locating five cities near which suitable wind farm sites could be created. The process begins with looking for specifics on where we "could" develop (this being places that either are developable or not); then where we "should" develop (which areas are better than others); and then finally where we "would" develop (these are specific locations that use all of the criteria to assess the most suitable places).

**Montana: Towns, Roads, and Wires in a Giant Landscape**

All data for report was collected by Middlebury Geography Department.
WHERE CAN we BUILD? - CONSTRAINTS

Before deciding the best place for windmills, it is important to determine what possible locations will actually be possible to build on. These layers give a "yes" or "no" as to whether or not we can develop there.

**Protected Areas**
- Wildlife Refuge
- National Park Service
- Agricultural Research Area
- Wildlife Management Area
- Designated Wilderness

These are places that may not be developed on, no negotiation. They represent either state or federal protection agencies - but more importantly represent wildlife areas that might best be left undisturbed anyway.

**Undevelopable Slope: > 15%**

These areas have a slope of greater than 15 percent. Most building ordinances state that this amount of slope is too much for effective construction.

**Undevelopable Landcover**

This is a conglomeration of different land cover restraints. Areas included are: open water, perennial ice and snow, already developed land, cropland, and all wetlands.

**Windpower Potential**

These are areas that would not yield enough power to warrant the construction of a wind farm. An index was used to determine average wind speed and the corresponding Watts that could be generated.

**Combined, Possible Locations**

When these layers are added together, the end result is a "yes" or "no" indicator that will help determine the best (and possible) sites in the final analysis.
**Where Should We Build? - Physical**

These criteria demonstrate either how suitable or unsuitable the physical parts of the landscape are for building sites. Each element is assigned a value on how beneficial it would be to build there.

**Landcover Suitability 33%**

These were organized in terms of how inexpensive developing would be. As done before, wetlands, croplands, ice, water, and developed areas are cancelled out. Forest was rated as less desirable, for instance, while Grassland was rated as more so.

**Gradient Suitability 33%**

0 - 5% Gradient is the most desirable, and anything over 15% is undesirable.

**Windpower Suitability 33%**

Using a windpower index, the areas were rated as being most desirable and least desirable, according to the potential energy of each spot. Insufficient energy potential is omitted.

**Physical Suitability**

These criteria demonstrate the areas of highest suitability in Montana. This will be used to assess the final suitability in the last analysis.
Recreational and Aesthetic Concerns

Recreational resources are a benefit to the state in terms of tourism, and important to the aesthetics of the natural landscape. Many consider wind farms a garish mark on the land and would rather not see them. Performing a viewshed analysis, we can look at which areas would be most suitable to put windmills in order to preserve recreation aesthetics.

Viewshed and View Distance

This viewshed (on the right) shows what areas can and cannot be seen from the trails and recreational spots. The unseen places (cyan) are the most ideal, but it would be unlikely for there to be absolutely invisible wind farms. So, to account for this, another layer has been added that puts visibility at a further distance more acceptable. If “recreators” see them at a distance, that might be considered more positive.

Viewshed Suitability

This final map shows the suitability assuming that it would be best to have the wind mills NOT seen from recreational sites. This data will be used in the end for the overall suitability analysis.
WHERE SHOULD we build? - Proximity

One of the largest factors in deciding where to put a wind farm should be: What is it close to? The proximity of the farm to different features should be take into account. What follows is a weighted interpretation of what the possible sites would ideally be near.

Because a power infrastructure is already in place, the wind farm sites would ideally be built near existing links. If the grid is overloaded, these will be the least expensive places to build more powerlines.

**Places and Networks**

Population Centers

- Thousands: 81, 12, 2, 1
- Transmission Lines
- Highways
- Secondary Roads

**Incorporated Cities 30%**

This shows how it would be better to build near existing cities, as it is more efficient to supply the network near population (consumption) centers.

**Power Plants 10%**

Whereas it would be ideal to be near consumption sources, it would be more ideal to diversify the location of the power sources. Perhaps this would create job opportunities and help prevent an overload of the power grid in one area.

**Transmission Lines 30%**

Existing transmission lines are desirable locations because they would be the easiest and least expensive areas to build more power lines into. Proximity to these is a plus.

**Road Networks 30%**

Road networks, like transmission lines, would not be difficult to use as transportation corridors. Included here are Highways and Secondary Roads.

**Places 40%**

This is the combination of the proximity suitability for towns and power stations. Weights are shown as a percent of the total suitability below.

**Networks 60%**

This is the combination of the proximity suitability for roads and transmission lines. Weights are shown as a percent of the total suitability below.

**Proximity Suitability**

High

Low

Together, these different criteria compose a suitability analysis for proximity. This will be used again later when assessing an overall suitability index for a building site.

The most suitable areas here largely follow corridors between population centers, and an existing infrastructure.
WHERE **W**OULD **WE** **BUILD?** - **OVERALL **SU**ITABILITY**

Now that each factor has been weighed independently, it is time to look at them together. With reference to each preceding page, let’s look at what where we could and should build, now with specific respect to where we would build.

**Physical Suitability**
50%

**Proximity Suitability**
30%

**Viewshed Suitability**
20%

**Overall Suitability 100%**

**Constraints Minus:**

- 100% Not Developable
- 0% Developable

This is the final compilation. Both where we can and can’t build, and where we should build. Following are several possible sites.
After putting a 10 kilometer "buffer" around each town, we can find the highest scoring areas. Using the suitability surface, GIS can perform a function that analyzes the statistics of each zone. These were the five highest scoring areas: Shelby, Havre, Chinook, Harlowton, and Big Timber. Here's an up close look at each:
When looking at these sites it is important to remember that a windmill needs a physical 2/3 of an acre in space, and they need to be staggered in succession so the wind shadow caused by each doesn't affect the others. As the high scoring areas are in a 400 meter grain, you can see that each pixel represents a very large tract (about 40 acres). More importantly, now that these regions have been distinguished as highly amenable to development, field research on each local area is a must. This, as well as a small-grain, detailed analysis on each individual area would prove very useful.
Final Considerations

As indicated on the site maps, it is crucial to gain local opinion and knowledge of the areas. Though public opinion may not offer much constructive spatial information, sensitivity concerning the "NIMBY" (Not In My Back Yard) attitude is useful to be aware of. Because windfarms only require 2/3 of an acre, they can be split into different areas. With local knowledge, or a closer study of each site, a windfarm could be created in multiple regions and make them somewhat versatile in dealing with unforeseen constraints.

A site visit would also help ground truth some of the error inherent with GIS work. The raster analysis generalizes everything, from elevation to landcover to boundaries. The evaluation was also made through several Multi-Criteria Evaluations. These are inherently subjective, and while I attempted to be as transparent as possible (listing weights and showing my process), a different set of weights might yield a very different result.

Finally, what follows are two important, yet slightly overlooked parts to my analysis. Although none of the sites that I have selected interfere with a Native American Reservation, this should be considered as a potential factor in future work as Reservations act as semi-sovereign states. Laws and land ownership differ depending on where you are. Also, socioeconomics can play a role in unfair land acquisition. Make sure that this is treated with sensitivity, and create a moral framework if you plan on adding it to an analysis.

Other Social Factors to Consider

Ben Meader

Less than 600 words (not including captions).