

Wind Farm Locational Analysis

Balancing Energy Efficiency and Sensitive Resources

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Oregon Renewable Energy Action Plan Objectives

- Risk Mitigation (oil & natural gas price fluctuations)
- Economic Development/Job Creation
- Environmental Benefits
- 10% renewable energy generation by 2012
- Current Power: 844.8 MW
- Power in Development: 1117 MW

Research Project

Identify optimal locations for potential wind-generated electric power on Bureau of Land Management land within the State of Oregon, considering factors such as energy output, topography, vegetative cover and road access, while avoiding disturbance to cultural and natural resources.

Initial Data Sources

- Initial Data Sources
 - Oregon DEM, 200 meters
 - BLM [Oregon Highways](#)
 - BLM [OR/WA Recreation Sites](#)
 - BLM [Oregon Surface Management Ownership](#)
 - BLM [Northern Spotted Owl Critical Habitat](#)
 - BLM [Wilderness Study Areas](#)
 - BLM [Areas of Critical Environmental Concern \(ACEC\)](#)
 - BLM [Visual Resource Management \(VRM\)](#)
 - NLCD Land Cover, 30 meter (USGS/USEPA)
 - Wind Power, NREL and AWS

Constraints

- Ownership
- Recreation Sites
- Spotted Owl Habitat
- Potential Wilderness Areas
- Areas of Critical Environmental Concern
- Visual Resource Management

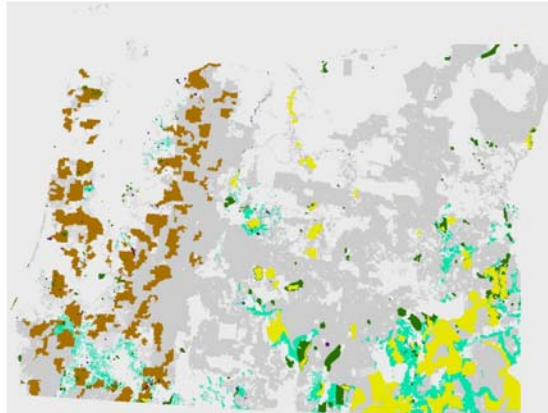
Ownership Constraint

Non_BLM Ownership
BLM Ownership



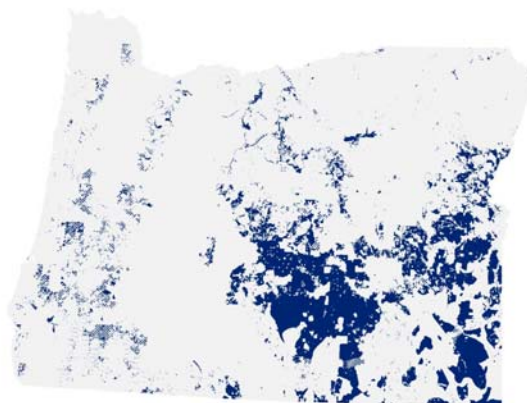
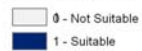
All Constraints

Constraints



Combined Constraints

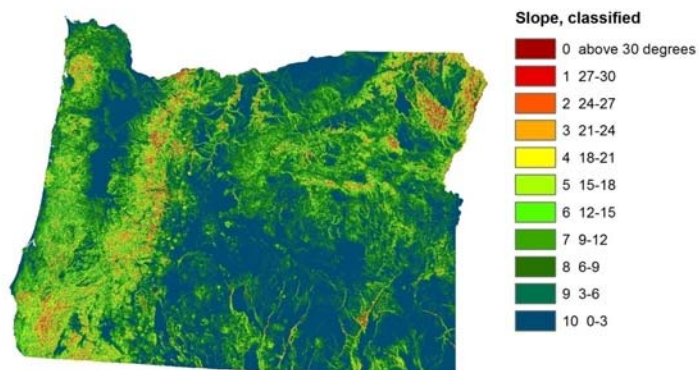
Constraints - Suitability on BLM land



Factors

- Slope
- Land Cover
- Distance to Highways
- Wind Power

Slope, classified



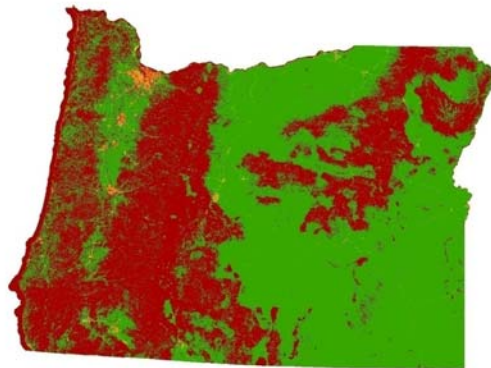
Land Cover



Legend

- Open Water
- Perennial Ice/Snow
- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land (Rock/Sand/Clay)
- Deciduous Forest
- Evergreen Forest
- Dwarf Scrub
- Shrub/Scrub
- Grassland/Herbaceous
- Pasture/Hay
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands
- 127

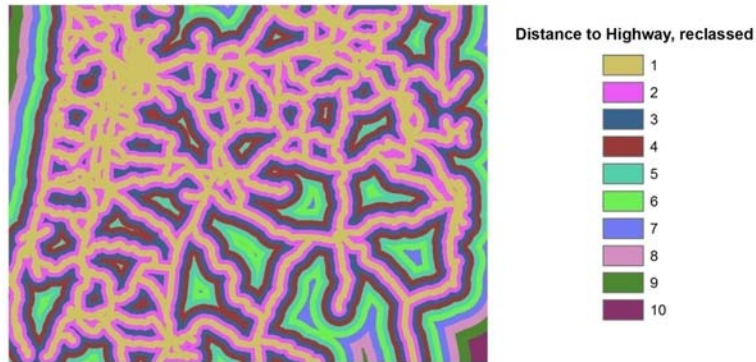
Land Cover, Classified into 5 categories



Land Cover Classified

- 0-Unsuitable
- 2-Poor
- 5-Fair
- 7-Good
- 10-Excellent

Distance to Highways, Classified



Wind Power Factor

Wind data sources (NREL)

- Free wind data available from the National Renewable Energy Laboratory (NREL).
- Wind power data available for 50 meter heights.
- Data resolution is 400 meters
- Data is classified using the standard wind power classification.

NREL Wind Power Classification
Average Annual Wind Resource 50m (1948)

Wind Power Class	Wind Power Density (W/m ²)	Wind Speed (mph)	Wind Speed (m/s)
1 Poor	0-200	0.0-12.3	0.0-5.5
2 Marginal	200-300	12.3-14.1	5.5-6.3
3 Fair	300-400	14.1-15.7	6.3-7.0
4 Good	400-500	15.7-16.8	7.0-7.5
5 Excellent	500-600	16.8-17.8	7.5-8.0
6 Outstanding	600-800	17.8-18.7	8.0-8.5
7 Superb	>800	>18.7	>8.5

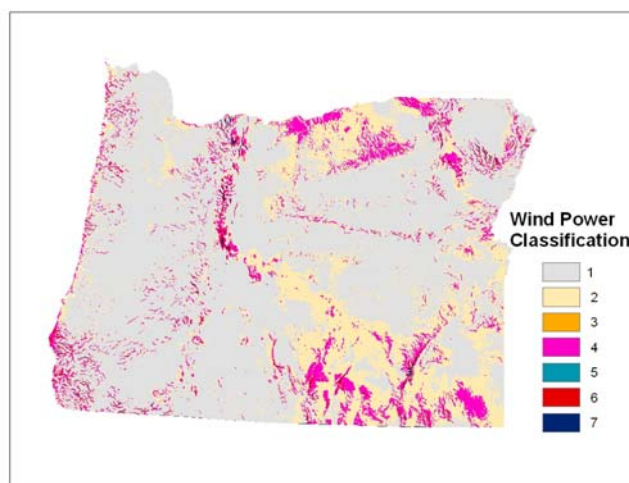
Wind Power Factor

Wind data sources (AWS)

- AWS wind data (private source)
- **Wind speed** data available at 30, 50, and 70 meter height.
- Data available at resolutions of 100meters, 200 meters, 400 meters.
- **Wind power** data available at 50 meter height only.

Wind Data Sources

Oregon Wind Power Resources at 50 meter height (NREL)



The MesoMap System

- Composed of several data models.
- **MASS (Mesoscale Atmospheric Simulation)**
 - Embodies the fundamental physics of the atmosphere including conservation of mass, momentum, and energy, as well as the moisture phases, and it contains a turbulent kinetic energy model that accounts for the effects of viscosity and thermal stability on wind shear.
- **WindMap**
 - High resolution mass-consistent wind flow model
 - Mainly at greater scales to increase the spatial resolution of MASS simulations.

(Brower, True Wind Solutions LLC, AWS Scientific, 2003)

Databases used by the MesoMap System

- **Reanalysis database**
 - A gridded historical weather data set produced by the US National Centers of Environmental Prediction (NCEP), and National Center for Atmospheric Research (NCAR)
 - Data provides snapshots of atmospheric conditions around the globe at all levels of atmosphere at 6 hours intervals.
 - MesoMap creates simulations of weather conditions over 366 days selected from a 15 year period.

(Brower, True Wind Solutions LLC, AWS Scientific, 2003)

Wind Power

- Wind speed measured in m/s
- Wind power measured in W/m²
- $Wp = Ws^3$ (Robert, Hewson, 1978)
- $Wp = Ws^3 * \text{Air Density}$

Assumptions

- Air density is dependent of temperature and humidity, but these two variables do not greatly affect the calculation of wind power.

Air Density

- Geographic altitude formula

$$z = \frac{(6359km * H)}{6359km - H} \rightarrow H = \frac{z}{\left(1 + \frac{z}{6359km}\right)}$$

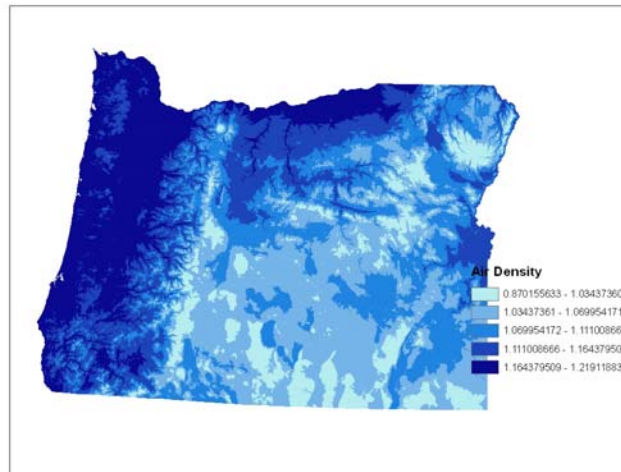
- Geopotential altitude formula used by airplanes

$$H = 44.3308 - 42.2665 * D^{0.234769}$$

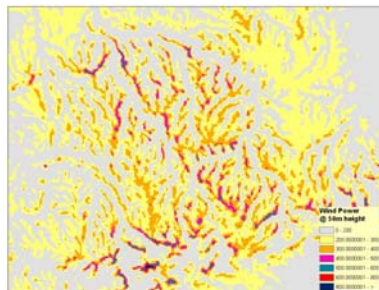
- Solving for density

$$D \frac{kg}{m^3} = \sqrt[0.234769]{\frac{(H - 44.3308)}{-42.2665}} \rightarrow D \frac{kg}{m^3} = \frac{\left(\frac{z}{\left(1 + \frac{z}{6359km}\right)} - 44.3308\right)^{\frac{1}{0.234769}}}{-42.2665}$$

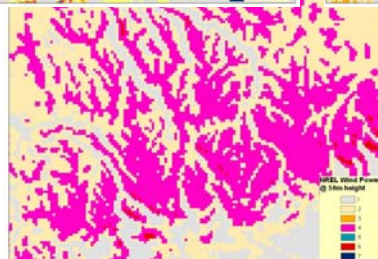
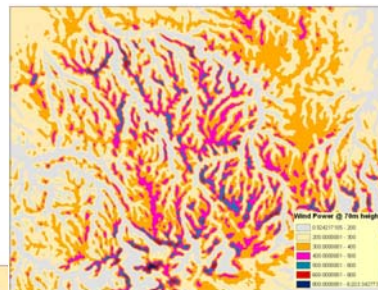
Calculated Air Density



Calculated Wind Power at 50 meter height



Calculated Wind Power at 70 meter height



NREL Power at 50 meter height

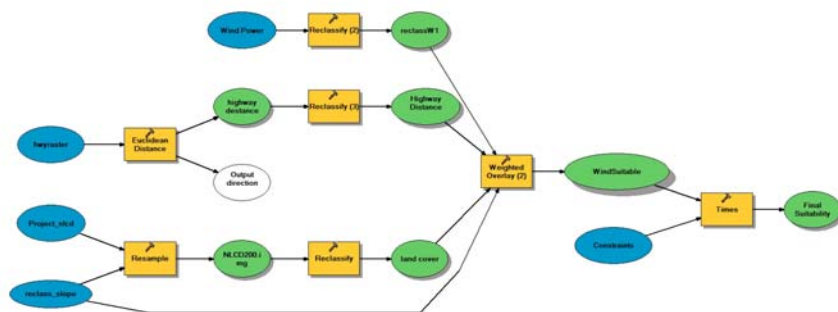
Wind Power data:
two sources,
three options

Analytical Hierarchy Process

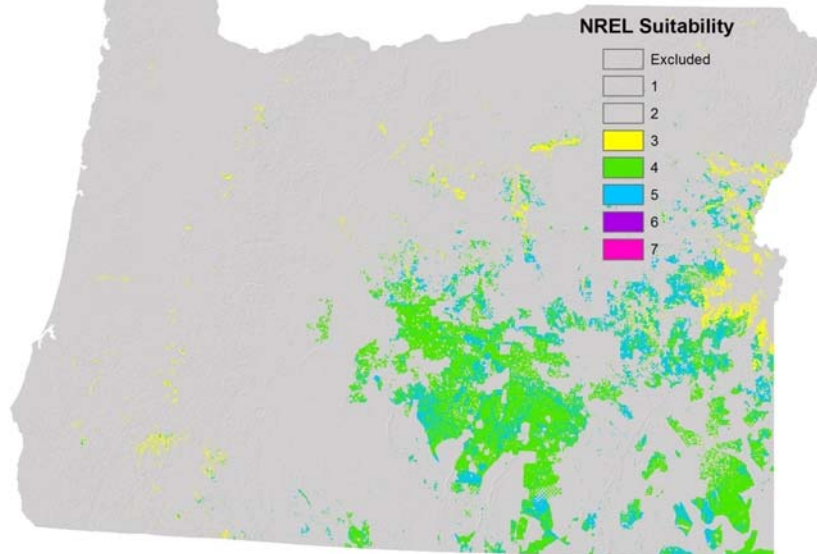
	Slope	Land Cover	Wind Power	Distance to Highway	Geometric Mean	Weight	for Weighted Overlay
Wind Power	1	3	3	9	$81^{1/3} = 3.0000$	.5238	52%
Land Cover	1/3	1	3	7	$7^{1/3} = 1.6265$	.2840	28%
Slope	1/3	1/3	1	5	$1^{1/3} = 0.8630$	.1506	15%
Distance to Highway	1/9	1/7	1/5	1	$1/315^{1/3} = 0.2370$	.0414	5%

Importance of A relative to B
 Equal: 1
 Moderately more: 3
 Strongly more: 5
 Very strongly more: 7
 Overwhelmingly more: 9

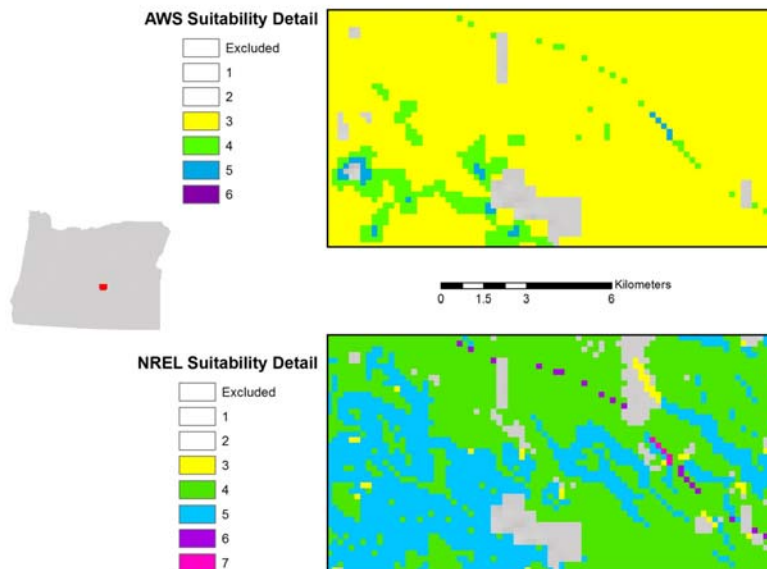
Final Suitability Model



Suitability, using NREL Wind Data

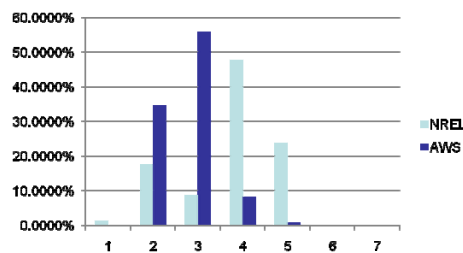


Suitability Details Compared



Comparison of Suitability Results from two wind power sources

Suitability	NREL				AWS			
	Kilometers²	200m² units	% of total	% of assigned	Kilometers²	200m² units	% of total	% of assigned
0	214,170	5,354,252	85.6247%		215,480	5,386,993	85.6496%	
1	546	13,653	0.2183%	1.5188%	57	1,436	0.0228%	0.1591%
2	6,381	159,519	2.5510%	17.7459%	12,511	312,778	4.9730%	34.6539%
3	3212	80,297	1.2841%	8.9327%	20,179	504,464	8.0206%	55.8915%
4	17,209	430,228	6.8802%	47.8612%	2,997	74,927	1.1913%	8.3015%
5	8,598	214,960	3.4376%	23.9135%	330	8,254	0.1312%	0.9145%
6	8	200	0.0032%	0.0222%	29	718	0.0114%	0.0795%
7	2	51	0.0008%	0.0057%	0	0	0.0000%	0.0000%



Conclusions

Running both the public NREL wind data and the private AWS wind data through the model showed that the AWS wind data provided more selective suitability results. The NREL data resulted in 24% of considered land in the top 3 suitability classes, while AWS data led to only 1% of potential land being placed in the top 3 classes.

Considering that this data would be used to scout suitable locations for wind farm development, more selective results would be desirable in narrowing the range of locations to those which would be most promising and worthy of more research.

References

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- Brower, Michael, Wind Resource Maps of Northern New England, June 2003
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- Bureau of Land Management: [Oregon Highways](#), [OR/WA Recreation Sites](#), [Oregon Surface Management Ownership](#), [Northern Spotted Owl Critical Habitat](#), [Wilderness Study Areas](#), [Areas of Critical Environmental Concern \(ACEC\)](#), [Visual Resource Management \(VRM\)](#), 200m Oregon DEM
- Energy Trust of Oregon, www.oregon.gov/ENERGY/RENEW/programs.shtml
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- www.ni-photos.jmcwd.com/wind-turbines.html
- Rodman, L.C., Meentemeyer, R.K. (2006). A geographic analysis of wind turbine placement in Northern California. *Energy Policy*, 34, 2137-2149
- U.S. Geological Survey/U.S. Environmental Protection Agency, NLCD Land Cover, 30 meter

Extra slides

Current Oregon Projects

Project Name	Megawatts	Developer	Partner
Operating			
Biglow Canyon	126	PGE, Orion	
Condon	49.8	SeaWest	Bonneville Power Administration
Elkhorn Wind Power Project	101	Horizon	Idaho Power
Klondike Phase I	24	Northwestern Wind	BPA/PPM Energy
Klondike Phase II	75	PPM	Portland General Electric
Klondike Phase III	221	PPM	PSE, EWEB, others
Leaning Juniper	100.5	PPM	PacifiCorp
Stateline, OR side	123	FPL	PPM Energy
Vansycle Windplant	24.5	FPL	Portland General Electric
total	844.8		
In Development			
Biglow Canyon (phases II & III)	324	Portland General Electric	
Eurus Combine Hills Phase II	59	Eurus	
Leaning Juniper II South	186	PPM Energy	
Mar-Lu	5	Columbia Energy	
Pebble Springs Wind	104	PPM Energy	
Rattlesnake Road Wind Phase I	104	Horizon Wind	Columbia Energy, Confed Tribes of Umatilla
Stateline Expansion (1 of 2)	184	FPL	
Stateline Expansion (2 of 2)	19	FPL	
Willow Creek	72	Invenergy	
Cascade Wind	60	UPC	
Total	1117		

<http://www.rnp.org/Projects/projectlist.php>

Recreation Sites, .5 kilometer buffer

0-Recreation Area
 Outside Rec Area



Spotted Owl Habitat Constraint

0-Spotted Owl Area
1



Wilderness Study Area Constraint

0-Wilderness Study Area
Wilderness Study Area



Areas of Critical Environmental Concern Constraint

- 0-Areas of Critical Environmental Concern
- Non-Areas of Critical Environmental Concern



Visual Resource Management Classes I, II, III

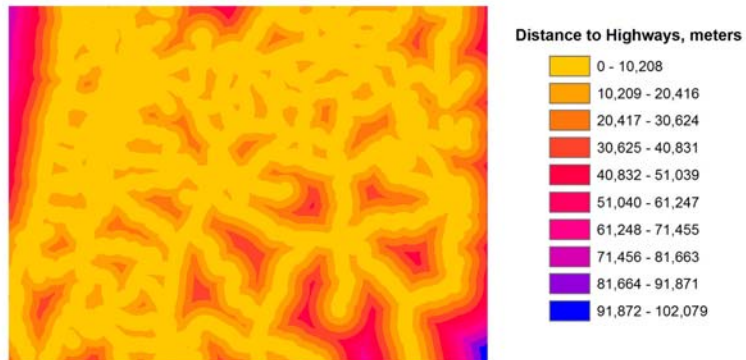
- 0-Visual Resource Mgmt Class I, II, or III
- Visual Resource Mgmt Class IV



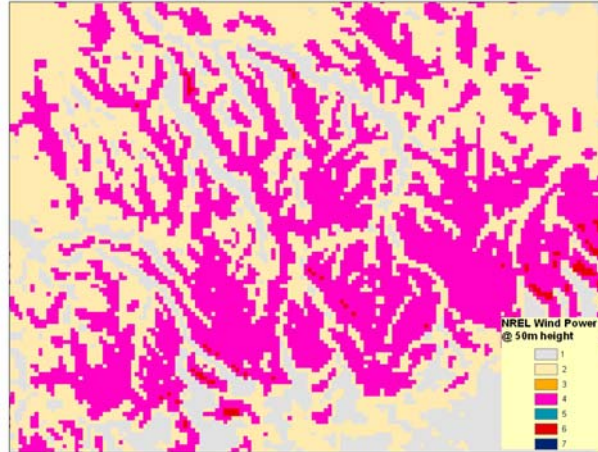
Slope



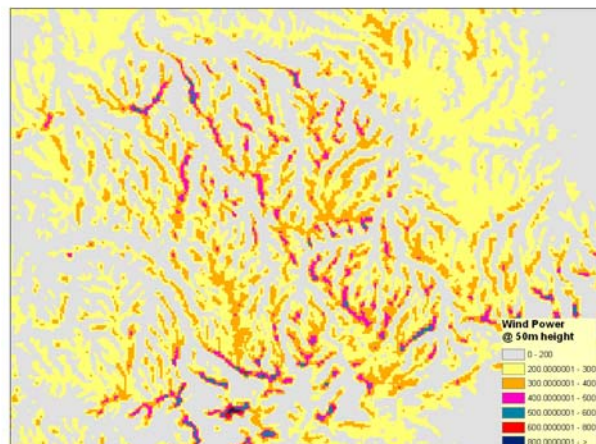
Distance to Highways



NREL Power at 50 meter height



Calculated Wind Power at 50 meter height



Calculated Wind Power at 70 meter height

