NORTHERN ARIZONA UNIVERSITY

Sustainable Energy Solutions

Arizona Wind Energy Assesment

Executive Summary

Developable Windy Land
and Economic Benefits

Full reports provided on enclosed CD

Prepared for
Arizona Wind Working Group

Prepared by
Dr. Susan K. Williams
Dr. Tom Acker
Grant Brummels
Stuart Wells

April 2007

Arizona Wind Energy Assesment

Apache County

Executive Summary

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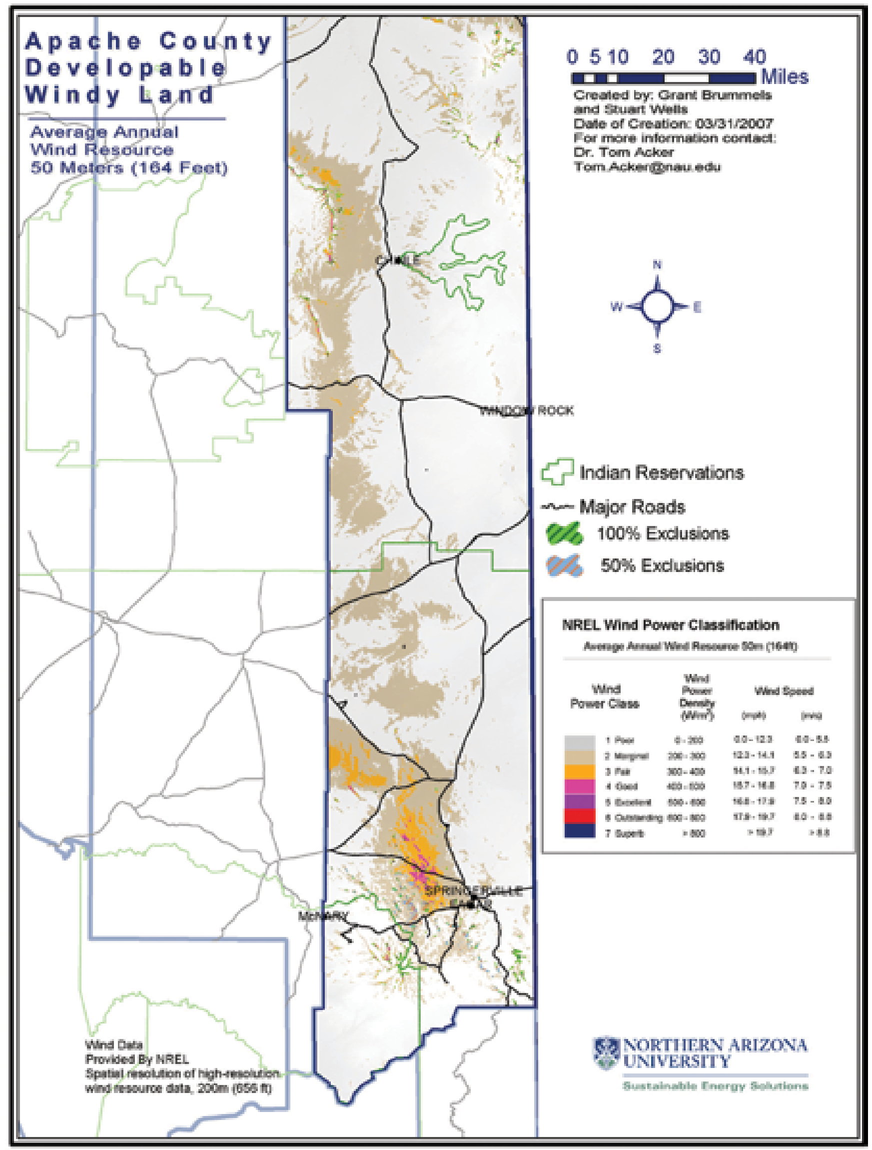
This report contains two wind energy analyses for northern-Arizona's Apache County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class in each county was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Apache County was estimated to be 3100 MW. The majority of developable windy land, 89%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Apache County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 60 MW wind energy project

- *Jobs during construction*: median was 6 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 9 jobs
- *Earnings during construction*: the median was $0.16 million
- *Earnings during O&M phase*: median was $0.33 million annually
- *Output (economic activity) during construction*: median was $0.69 million
- *Output during O&M phase*: median was $0.18 million annually



Arizona Wind Energy Assesment

Cochise County

Executive Summary

Developable Windy Land

and Economic Benefits

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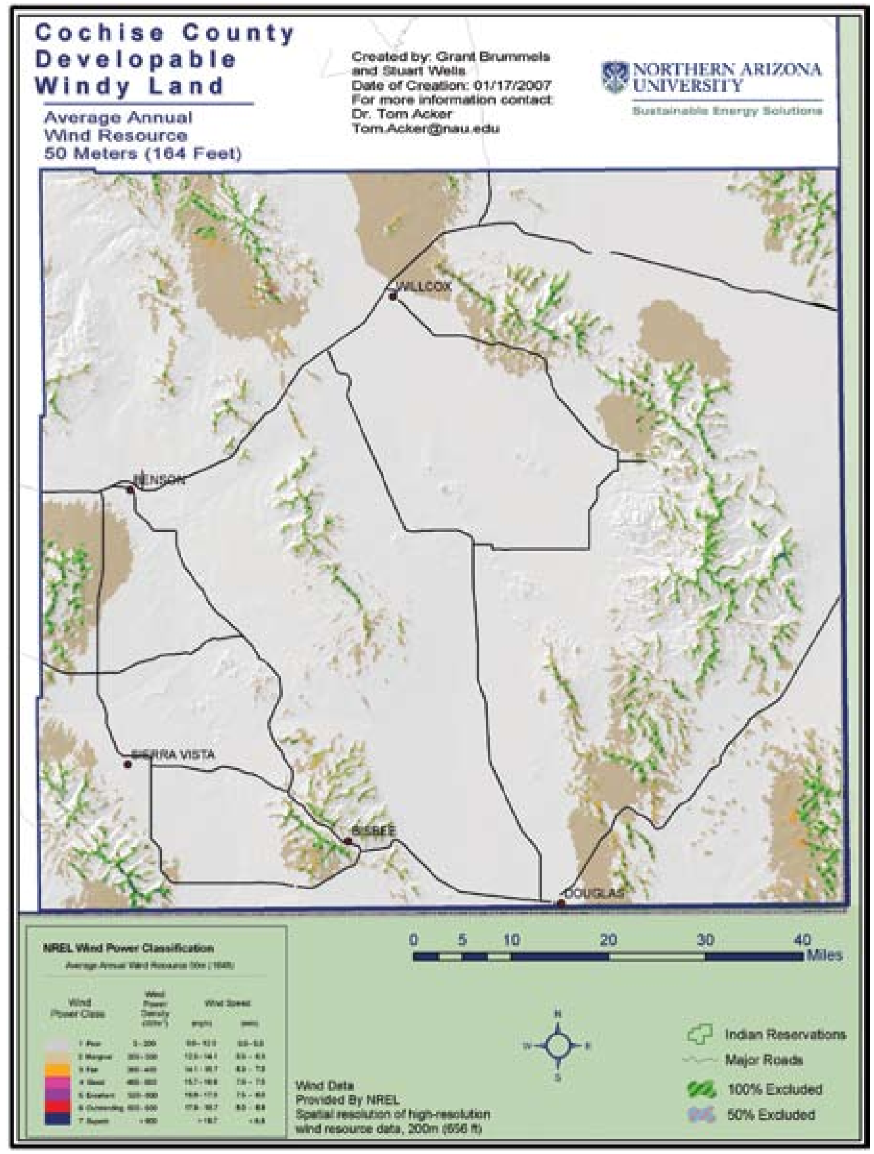
This report contains two wind energy analyses for southern-Arizona's Cochise County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class in each county was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Cochise County was estimated to be 275 MW. The majority of developable windy land, 80%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Cochise County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 60 MW wind energy project

- *Jobs during construction*: median was 27 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 11 jobs
- *Earnings during construction*: the median was $0.76 million
- *Earnings during O&M phase*: median was $0.43 million annually
- *Output (economic activity) during construction*: median was $3.21 million
- *Output during O&M phase*: median was $0.98 million annually



Arizona Wind Energy Assesment

Coconino County

Executive Summary

Developable Windy Land

and Economic Benefits

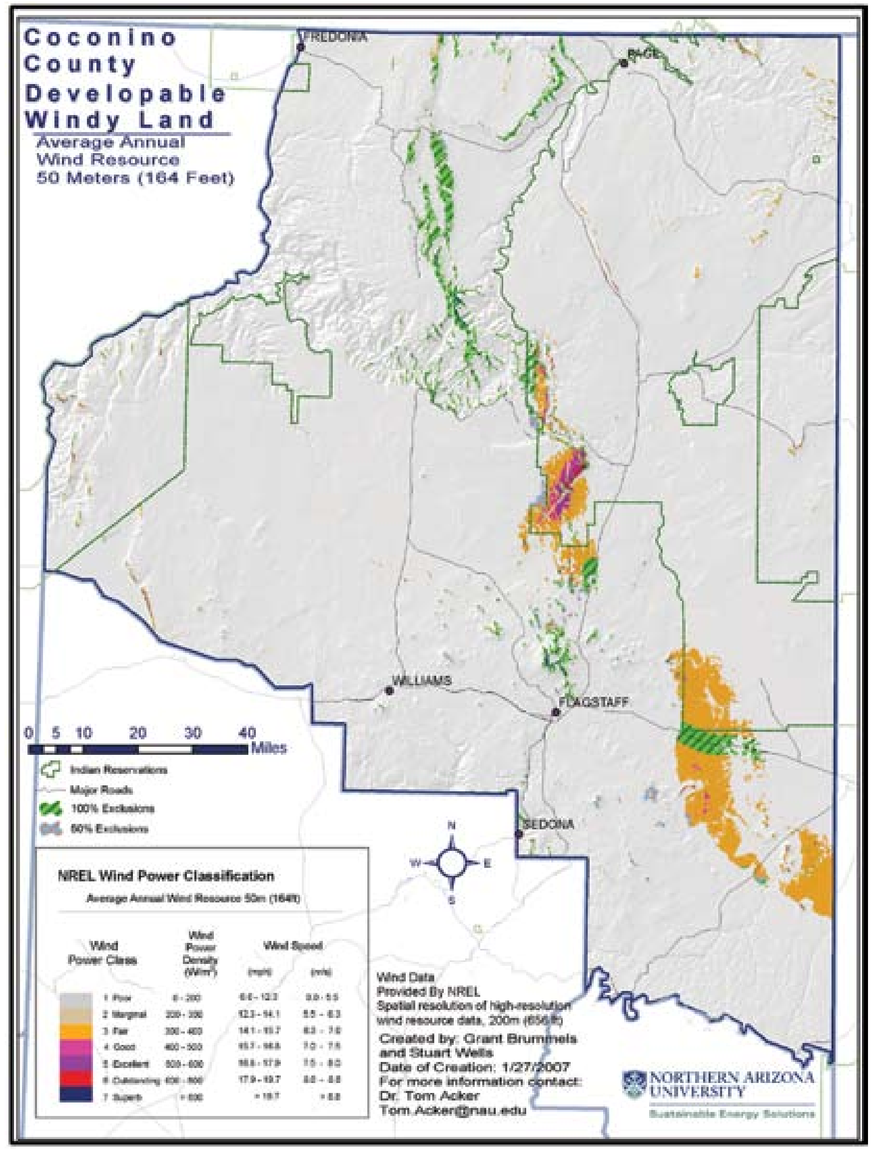
Full report provided on enclosed CD

This report contains two wind energy analyses for northern Arizona's Coconino County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Coconino County was estimated to be 7200 MW. The majority of developable windy land, 92%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Coconino County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 60 MW wind energy project

- *Jobs during construction*: median was 56 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 16 jobs
- *Earnings during construction*: the median was $1.58 million
- *Earnings during O&M phase*: median was $0.61 million annually
- *Output (economic activity) during construction*: median was $6.38 million
- *Output during O&M phase*: median was $1.24 million annually



Arizona Wind Energy Assesment

Graham County

Executive Summary

Developable Windy Land
and Economic Benefits

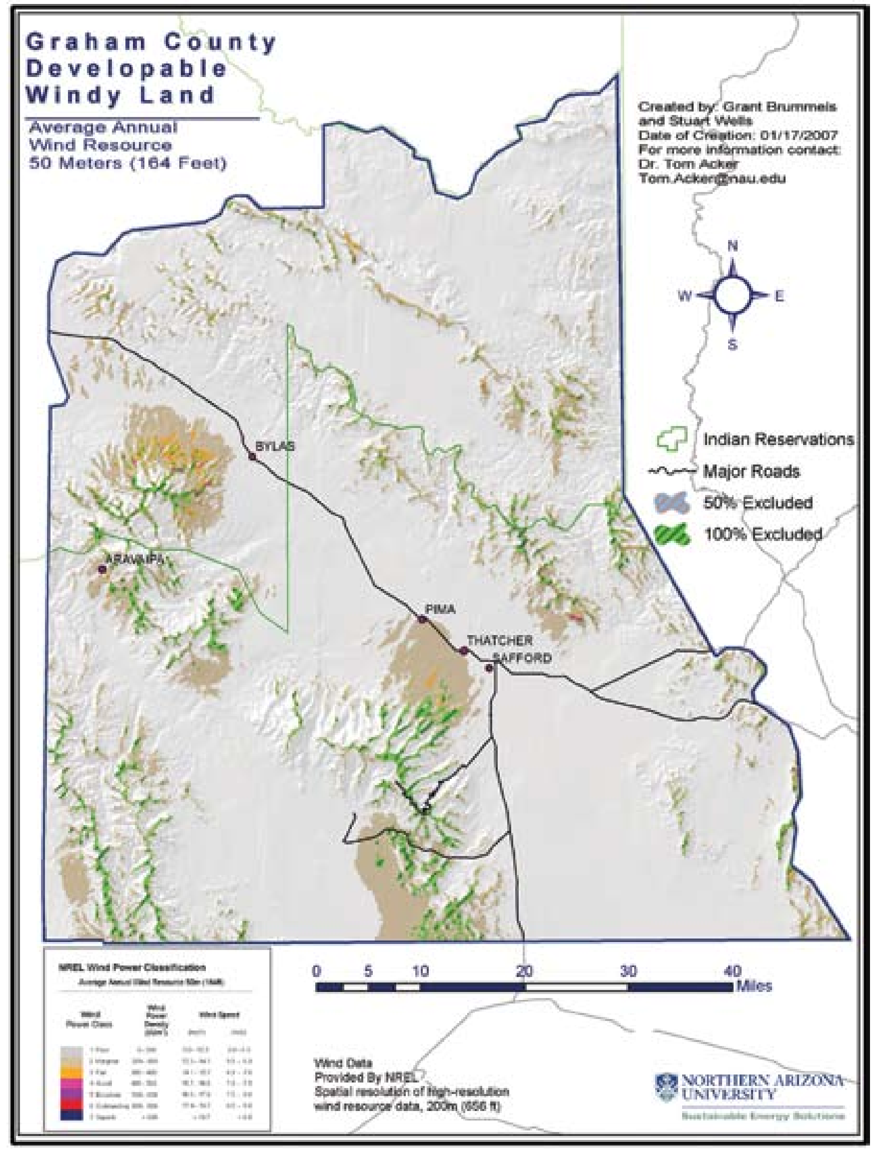
Full report provided on enclosed CD

This report contains two wind energy analyses for southeastern-Arizona's Graham County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class in each county was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Graham County was estimated to be 340 MW. The majority of developable windy land, 82%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Graham County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 60 MW wind energy project

- *Jobs during construction*: median was 9 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 17 jobs
- *Earnings during construction*: the median was $0.16 million
- *Earnings during O&M phase*: median was $0.51 million annually
- *Output (economic activity) during construction*: median was $0.88 million
- *Output during O&M phase*: median was $1.20 million annually



Arizona Wind Energy Assesment

Mohave County

Executive Summary

Developable Windy Land

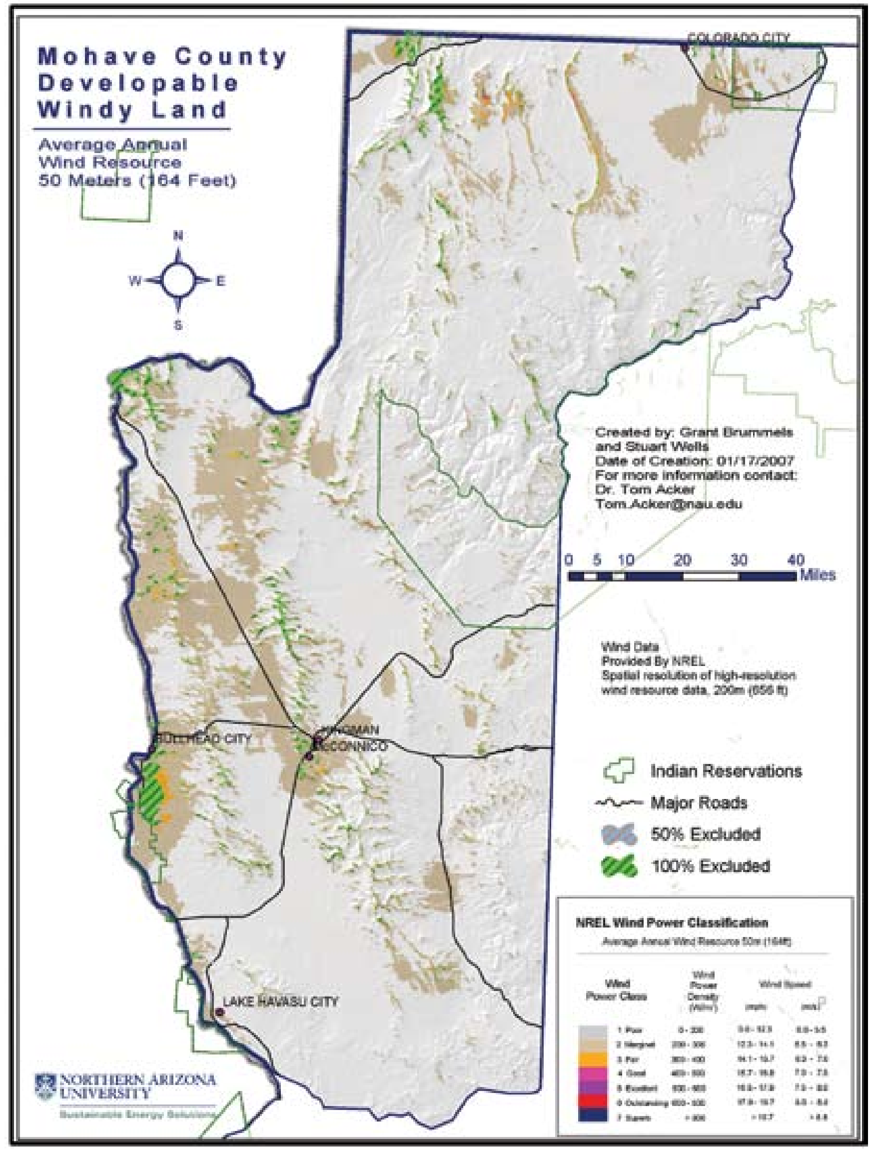
and Economic Benefits *Full report provided on enclosed CD*

This report contains two wind energy analyses for northwestern-Arizona's Mohave County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class in each county was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Mohave County was estimated to be 1100 MW. The majority of developable windy land, 88%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Mohave County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 60 MW wind energy project

- *Jobs during construction*: median was 68 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 24 jobs
- *Earnings during construction*: the median was $2.07 million
- *Earnings during O&M phase*: median was $0.77 million annually
- *Output (economic activity) during construction*: median was $7.25 million
- *Output during O&M phase*: median was $1.82 million annually



Arizona Wind Energy Assesment

Navajo County

Executive Summary

Developable Windy Land
and Economic Benefits

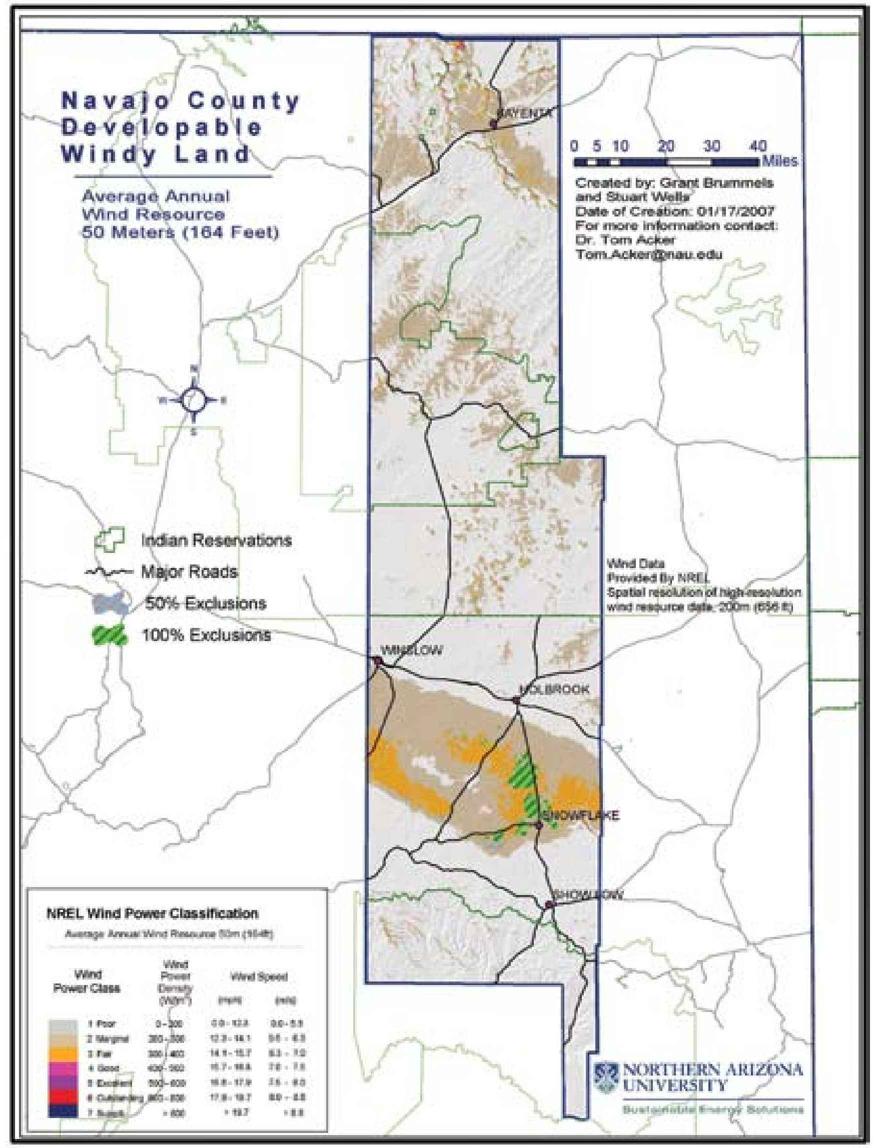
Full report provided on enclosed CD

This report contains two wind energy analyses for the northern Arizona county, Navajo County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Navajo County it was estimated to be 4800 MW. The majority of developable windy land, 97%, respectively was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Navajo County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 60 MW wind energy project

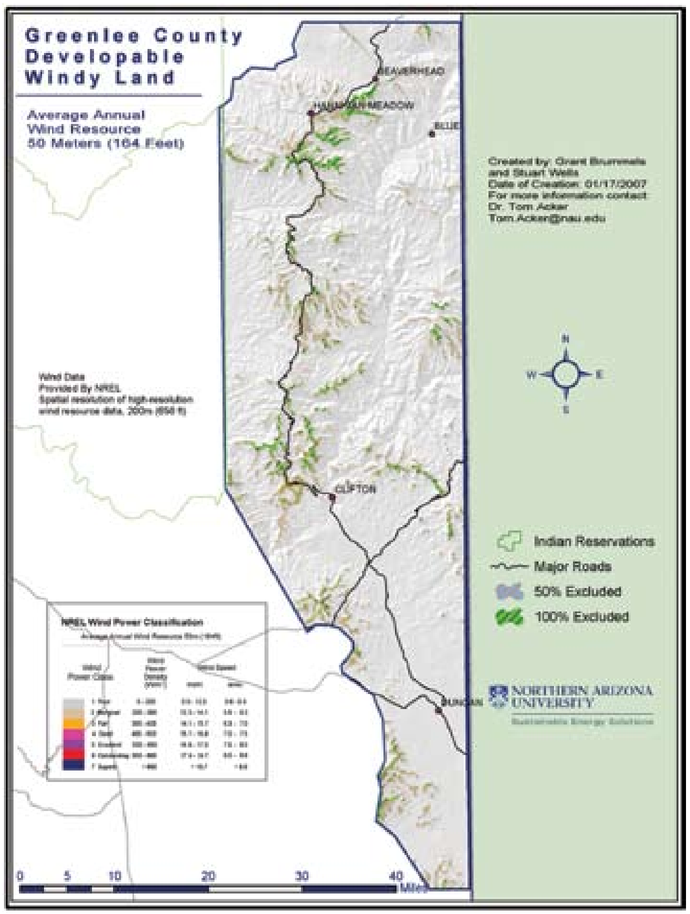
- *Jobs during construction*: median was 32 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 14 jobs
- *Earnings during construction*: the median was $0.86 million
- *Earnings during O&M phase*: median was $0.51 million annually
- *Output (economic activity) during construction*: median was $3.54 million
- *Output during O&M phase*: median was $1.15 million annually



Arizona Wind Energy Assesment
Greenlee County
Executive Summary
Developable Windy Land
and Economic Benefits

Full report provided on enclosed CD

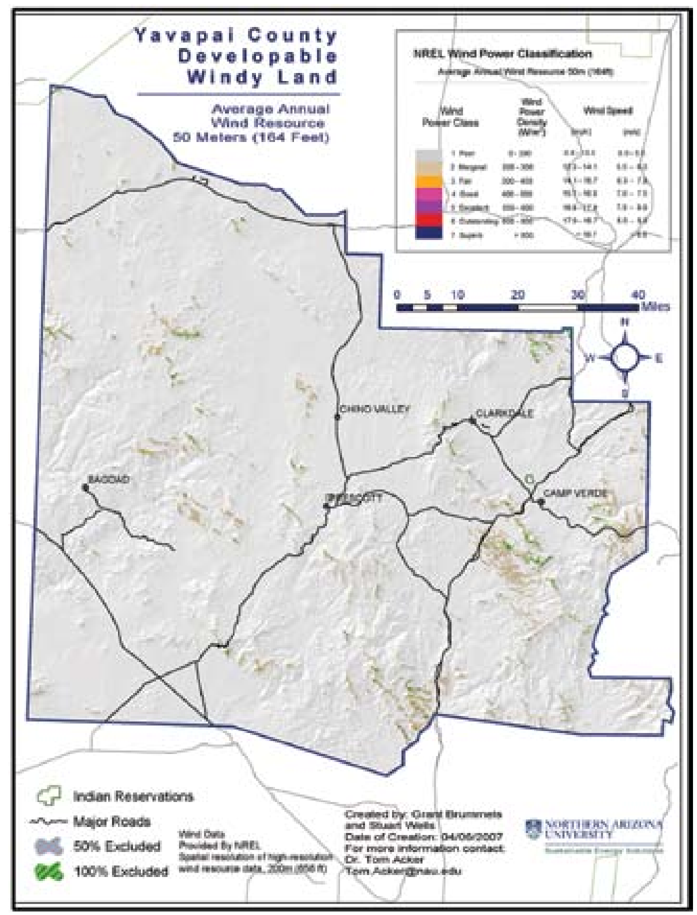
This report contains a wind energy analysis for southeastern Arizona's Greenlee County. The developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Greenlee County was estimated to be 53 MW. The majority of developable windy land, 78%, was Class 3.



Arizona Wind Energy Assesment
Yavapai County
Executive Summary
Developable Windy Land
and Economic Benefits

Full report provided on enclosed CD

This report contains a wind energy analysis for central Arizona's Yavapai County. The developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Yavapai County was estimated to be 55 MW. The majority of developable windy land, 89%, was Class 3.



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Arizona Wind Energy Assesment

Apache County

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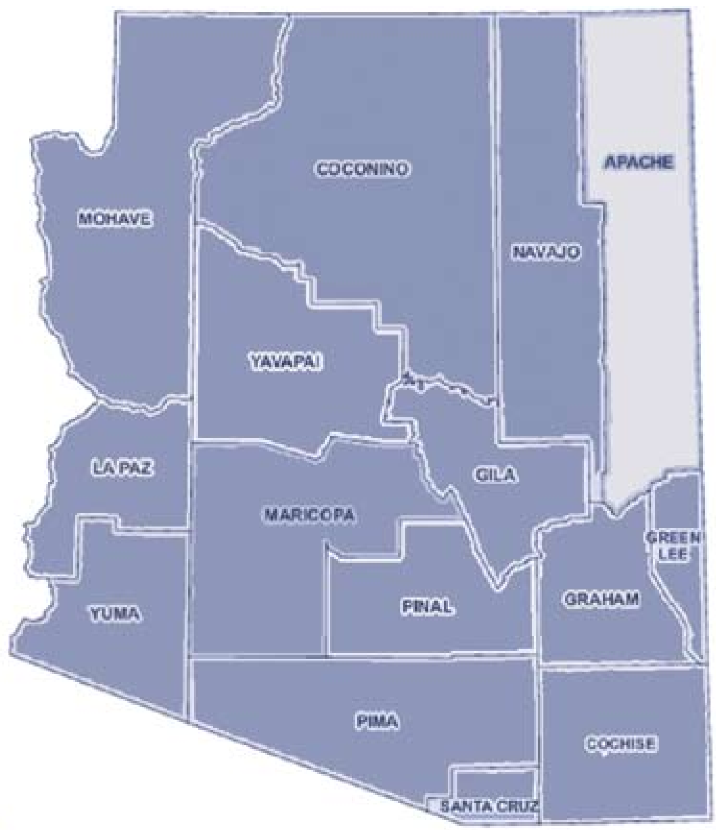

Prepared for
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April 2007

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Abstract

This report contains two wind energy analyses for the northern-Arizona's Apache County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Apache County was estimated to be 3100 MW. The majority of developable windy land, 89%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Apache County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 10.5 MW wind energy project

- *Jobs during construction*: median was 1 job
- *Jobs during operations and maintenance phase (O&M phase)*: median was 2 jobs
- *Earnings during construction*: the median was $0.03 million
- *Earnings during O&M phase*: median was $0.06 million annually
- *Output (economic activity)during construction*: median was $0.12 million
- *Output during O&M phase*: median was $0.13 million annually

For a 60 MW wind energy project

- *Jobs during construction*: median was 6 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 9 jobs
- *Earnings during construction*: the median was $0.16 million
- *Earnings during O&M phase*: median was $0.33 million annually
- *Output (economic activity) during construction*: median was $0.69 million
- *Output during O&M phase*: median was $0.18 million annually

For a 180 MW wind energy project

- *Jobs during construction*: median was 18 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 27 jobs
- *Earnings during construction*: the median was $0.47 million
- *Earnings during O&M phase*: median was $0.98 million annually
- *Output (economic activity) during construction*: median was $2.06 million
- *Output during O&M phase*: median was $2.17 million annually

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Introduction

The wind energy development potential and economic benefits were determined for a northern Arizona county, Apache (see Figure 1). Using Geographic Information System (GIS) techniques on wind map data an estimate was made of the amount of developable windy land and potential installed capacity. Secondly, an analysis was made of the economic impacts of constructing and operating wind energy projects in this county utilizing the Job and Economic Development Impact * (JEDI) model developed for National Renewable Energy Laboratory (NREL). Wind energy projects of three representative sizes were considered: 10.5 MW, 60 MW, and 180 MW. The JEDI model was used in conjunction with Monte Carlo simulation to estimate economic impacts at the county level. Direct, indirect and induced economic effects were estimated and categorized by jobs, earnings, and output (economic activity).

The wind maps and information in this report are *not* appropriate for siting wind energy projects. It is useful for discussing policy and locations that might be appropriate for further study. In order to site a wind energy project, an anemometer should be installed on the property and two years of data collected. More Arizona wind maps are available at www.ses.nau.edu.

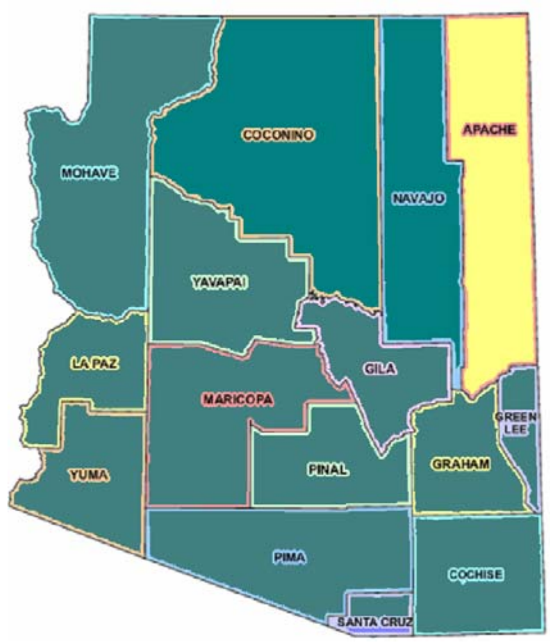


Figure 1 Apache County in northern Arizona

* The JEDI model was designed by Marshall Goldberg, of MRG & Associates, under contract with NREL.The model is posted on the Wind Powering America website: http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=707 in June 2005.

State of Arizona

According to the US Census Bureau Quick Facts[1] the population in the state of Arizona increased 40% from 1990 to 2000. During this period US population increased 13.1%. Due to this rapid population and economic growth, electricity demand increased at the rate of 2.6% per year[2].

In 2001, the average electricity retail price for Arizona residents and businesses was 7.2 cents/kwh. This is the 16th highest average electricity price in the nation behind the six New England states, New York, New Jersey, Pennsylvania, California, Alaska, Hawaii, Texas, Florida, and Nevada. In addition to Arizona's increasing population, the hot climate and resulting need for air conditioning in the summer affect the increasing demand and price of electricity. Arizona has a larger than average residential demand largely due to the demand for air conditioning. The residential sector purchases 41% of the electricity as compared to 36% nationally[2].

Arizona primarily relies on coal and nuclear fuels for electrical generation. In 2000, approximately 45% of electricity was coal-generated and 35% was nuclear with only 10% generated from natural gas and another 10% by hydroelectric. However, the balance will be shifting to natural gas in the future as there are 16,000 MW of planned generation units by 2007, of which 15,000 MW are planned to be natural gas[2].

Apache County

Apache County, located in the northeast corner of Arizona, contains 11,218 square miles that are sparsely populated with a 2003 population of 70,625. Part of the Navajo Nation is in the high, dry, plateau region of the northern part of the county. The White Mountains, with year-round recreational opportunities such as hunting, fishing, and skiing are in the southern part of the county. St. Johns is the county seat with a population of 3,575. The largest community with a population of 5,459 in 2003[3] is Chinle, Navajo Nation. Demographic information is given in Table 1[4] and industry sector information is given in Table 2[5].

The largest land ownership category in Apache County, approximately 66% is Indian Reservation[3]. These lands are home to Apache and Navajo. In 1990, 14.2% of reservation households had no access to electricity as compared to 1.2% of all households nationally. On the Navajo Reservation households with no access to electricity is as large as 38%.[6]

Table 1 Apache County Demographics

Demographic	Apache
Population, 2005 estimate	69,343
Population, percent change, April 1, 2000 to July 1, 2005	-0.1%
Population, percent change, 1990 to 2000	12.7%
High school graduates, percent of persons age 25+, 2000	63.6%
Bachelor's degree or higher, pct of persons age 25+, 2000	11.3%
Per capita money income, 1999	$8,986
Median household income, 2003	$25,489
Persons below poverty, percent, 2003	27.5%
Private nonfarm establishments, 2003	525
Private nonfarm employment, 2003	5,863
Private nonfarm employment, percent change 2000-2003	-10.0%
Retail sales, 2002 ($1000)	194,854
Retail sales per capita, 2002	$2,886
Land area, 2000 (square miles)	11,205
Persons per square mile, 2000	6.2
Metropolitan or Micropolitan Statistical Area	None

Table 2 Apache County Industry Sectors

Industry Sectors in Apache County	Percent	Employed
Agriculture, forestry, fishing and hunting, and mining	3.1	508
Construction	10.9	1,791
Manufacturing	2.6	429
Wholesale trade	1	169
Retail trade	8.1	1,329
Transportation and warehousing, and utilities	7.2	1,184
Information	1.5	239
Finance, insurance, real estate, and rental and leasing	2.8	466
Professional, scientific, management, administrative, and waste management services	2.8	464
Educational, health and social services	35.6	5,859
Arts, entertainment, recreation, accommodation and food services	8.5	1,402
Other services (except public administration)	3.3	547
Public administration	12.6	2,082

Windy Land Analysis using GIS

Methodology

For the purpose of this analysis, *windy land* is defined as land with a wind resource greater than or equal to class three as predicted by the Arizona Wind Map (the wind map will be discussed in the section on Input Data). That is, predicted average annual wind speeds are large enough that wind energy may be produced economically. However, not all windy land may be developed for wind power. There are many *development exclusions* that must be considered. For instance, land that is owned by the National Park Service must be excluded 100% from consideration for development. *Developable windy land*, therefore, is the windy land that remains after all development exclusions have been applied. Finally, *excluded windy land* is windy land (class 3 and above) that falls within a development exclusion.

Consistent with the methodology applied by NREL, there are three general *exclusion* categories of land unsuitable for development[7]:

- environmental exclusions
- land use exclusions
- additional windy land factors

These development exclusions are summarized in Table 3. Any windy land with one or more exclusion is excluded windy land and is not appropriate to be used for wind energy projects. After removing excluded windy land, the remaining land is developable and an estimate of the potential installed capacity was made by assuming a conservative 5 MW of installed capacity per square kilometer.

Input Data for Windy Land Analysis

TrueWind Solutions, in collaboration with NREL, developed a high-resolution wind map and GIS data for the state of Arizona in 2003. The data for this wind map was created using a numerical weather model coupled with climactic data and a wind flow model. The wind map provides 200-meter resolution data sufficient for identifying the most promising areas for wind development in the state. The data from this map was used to analyze the wind resource of Apache County.

A *data layer* is a geographic data set that can be represented visually using GIS software. Several data layers were required for the exclusion analysis. The data layers, their exclusion category (environmental, land use, other factors), source and brief description are listed in Table 3.

Table 3 Wind Development Exclusions

Broad Exclusion Category	Exclusion	Exclusion[†] Percentage	Exclusion Description	GIS Layer Source
Environmental Exclusions	**National Park Service**	100%	United States National Park Service Land	ALRIS [‡]
	Fish and Wildlife Service	100%	United States Fish and Wildlife service	ALRIS
	Congressionally Specially Designated Areas	100%	Special Areas, like wilderness or wild, and scenic rivers, congressionally designated as such	USFS
	Inventoried Roadless Areas	100%	These are roadless areas of the country on federal land that have been congressionally designated as such	USFS
	State and Other Environmental Land (State GAP Data)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP
	Other: Wildlife, Wilderness and Recreation Areas on Federal land of any designation (predominately USFS and BLM lands)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP[§]
	Remaining USFS & DOD Land	50%	United States Forest Service and Department of Defense lands that remain after all other windy land exclusions are removed	ALRIS
Land Use Exclusions	**Urban/Developed Areas**	100%	Urban or Developed land as described by USGS ReGAP data	USGS AZ ReGAP
	Airports	100%	Airports	National Atlas of the United States, USGS, ESRI
	Wetlands	100%	Wetland ecosystems as described by USGS ReGAP data	USGS AZ ReGAP
	Water bodies (includes seasonal and dry lakes)	100%	Areas covered by water all year or part of the year. Does not include Rivers and Streams	USGS AZ ReGAP
	Non-ridge Crest Forests	50%	Areas of forest cover that are not considered ridge crests by TPI analysis	ReGAP + TPI [**]
Additional Windy Land Factors	**Slopes > 20%**	100%	These are landscapes with slopes greater than 20%	Grant Brummels

† Windy land exclusions were excluded 100%, with the exception of "non-ridge crest forests" and "remaining USFS and DOD Land," which were excluded 50%. Additionally, all 100% exclusions were buffered 3km, except for wetlands (100m), open water (no buffer), and slopes > 20% (no buffer).[†] Non-ridge crest forests have had all 100% exclusions removed. Remaining USFS and DOD land has had all non-ridge crest forests and 100% exclusions removed.

‡ ALRIS—Arizona Land Resource Information System

§ ReGAP—Regional Gap Analysis Program, 30m satellite data

** Jenness, J. 2005. Topographic Position Index (tip_jen.avx) extension for ArcView 3.x. Jenness Enterprises. Available at: http://www.jennessent.com/arview/tpi.htm. TPI was applied to a 90m Digital Elevation Model.

Results of Windy Land Analysis

Using the wind map of Arizona, the windy land in Apache County was mapped using a GIS (Figure 2). Major roads, communities, and Native American reservation boundaries are also shown on the map. Using GIS, the square kilometers of land was then totaled by wind class. Approximately 3.3% of the land is considered windy land. Of the windy land, the majority, approximately 90%, is class 3.

The development exclusions for Apache County are mapped in Figure 3. As displayed, the land areas highlighted in blue show the areas that cannot be developed for wind energy regardless of how windy since this land was classified as a development exclusions. In Apache County, a relatively low 0.6% of the total county land area is classified as development exclusions (windy and non-windy).

The exclusions remove 20.7% of windy land from consideration for development. See Figure 4 to compare the amount if windy land by wind class with the developable windy land by wind class. When exclusions are considered, much of the excluded windy land is higher than class 3. As a result, the proportional amounts of class 4 and above decrease with a corresponding increase in the proportional amount of class 3.

Some land is excluded under multiple categories. For instance, land may have a slope greater than 20% and also be Environmental Land. The largest exclusion affecting windy land is Slopes>20% and excludes 12.5% of windy land. The 2nd largest exclusion affecting windy land is Environmental Land and excludes 3.0% of windy land. Some land is excluded by multiple categories.

Table 4 provides a summary of the results of the windy land analysis for Apache County. Organized by wind class, the total area of windy land, area of developable windy land, and potential developable capacity are shown. These tables also show that the total developable capacity in Apache County, including class 3 or better windy lands, is 3,126 MW. When restricting this estimate to windy lands of class 4 or better, the developable capacity for this county is 331 MW. Finally, the developable windy land mapped by wind class is shown in Figure 5.

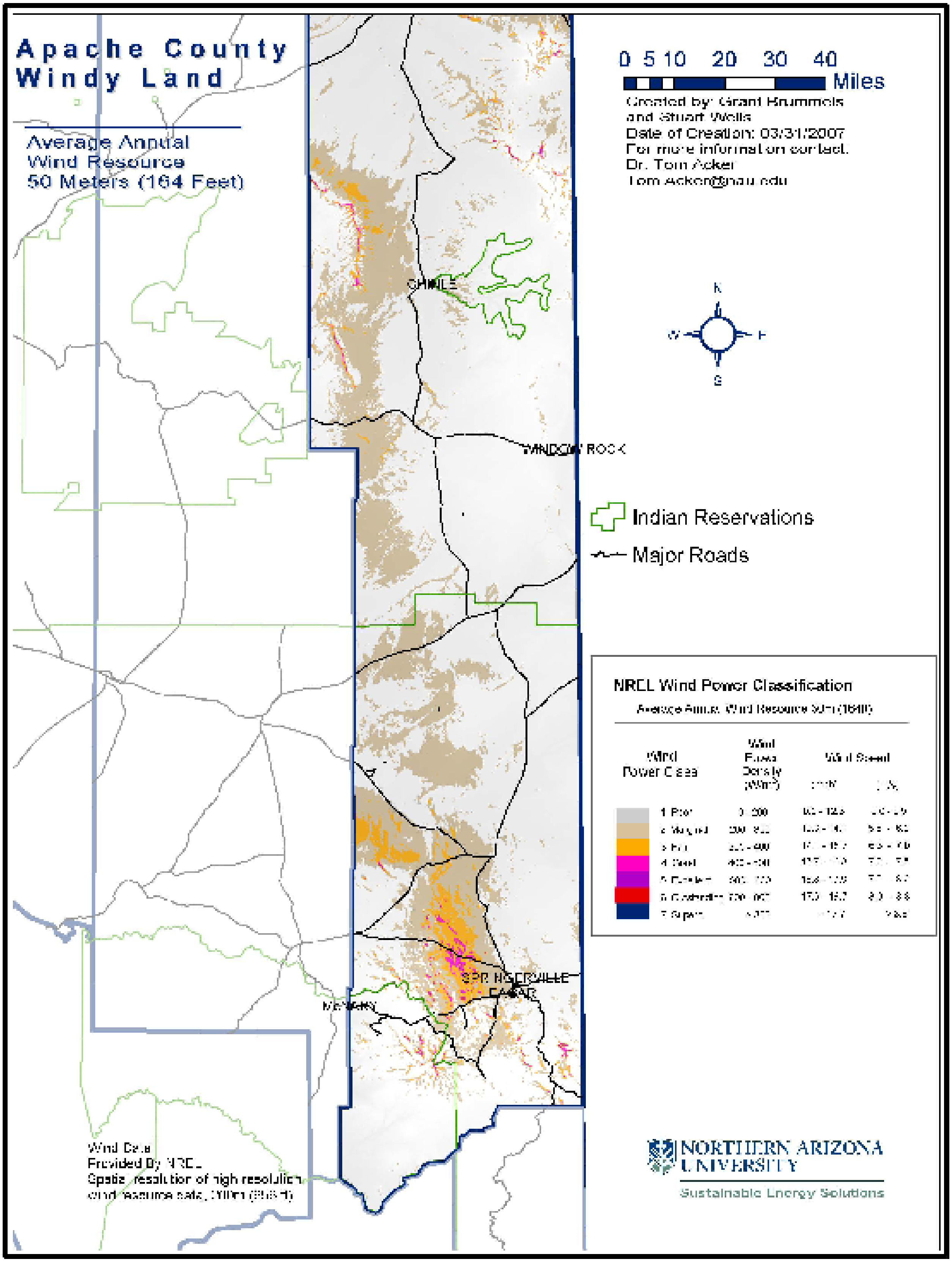


Figure 2 Map of Windy Land for Apache County, AZ

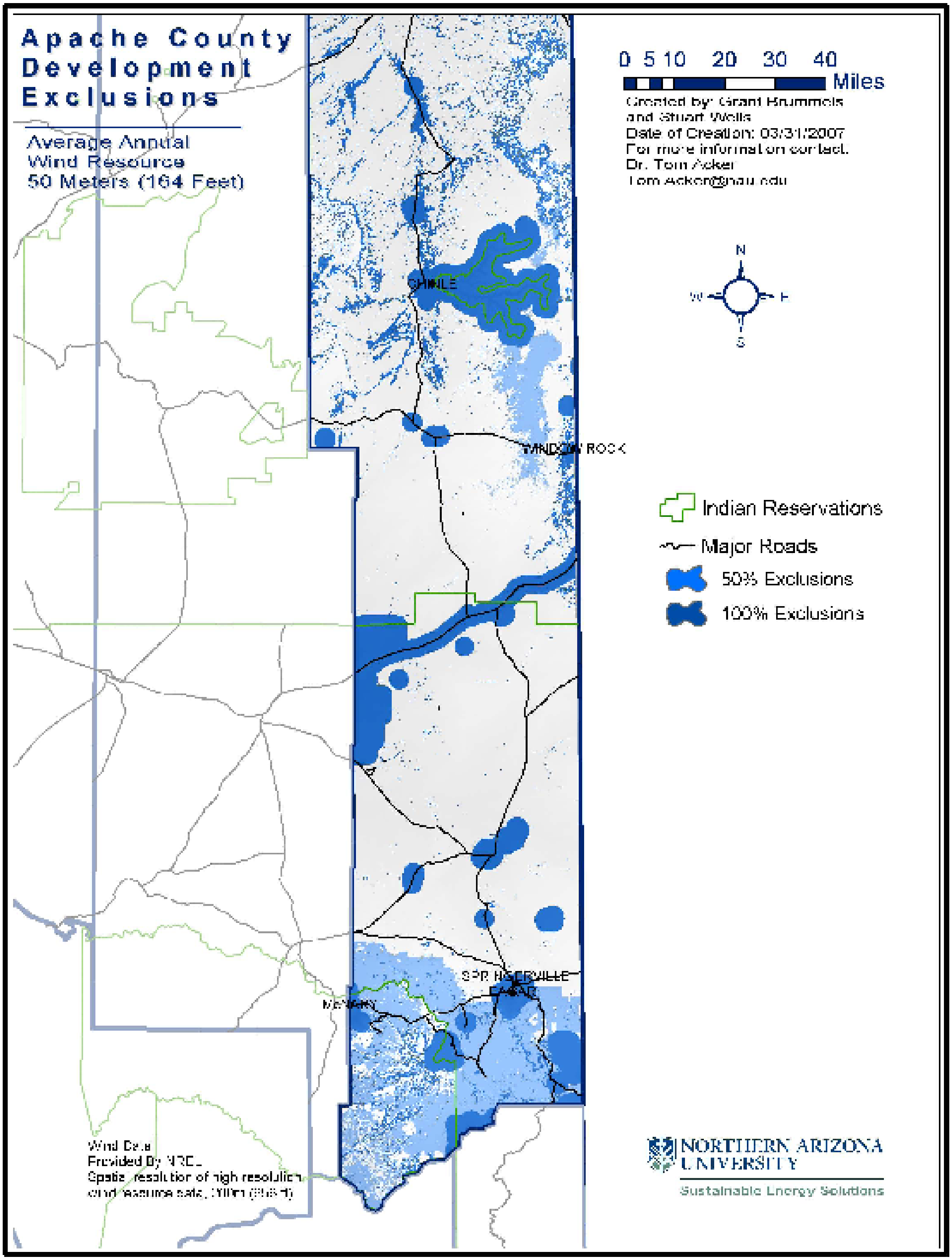
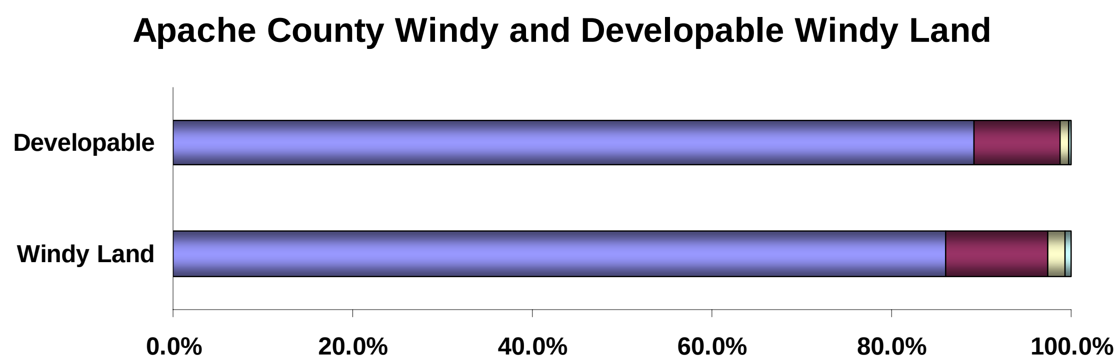


Figure 3 Map of Development Exclusions in Coconino County



	Windy Land	Developable
Class 7	0.0%	0.00%
Class 6	0.6%	0.23%
Class 5	2.0%	1.03%
Class 4	11.3%	9.59%
Class 3	86.1%	89.15%

Figure 4 Windy Land and Developable Windy Land by Wind Class for Apache County

Table 4 Windy Land and Developable Windy Land in Apache County

Apache County Wind Class Area Analysis						
Wind Class	Power (w/m^2)	Total Area (km^2)	Windy Land as Percent of Total Land Area	Developable Windy Land (km^2)#	Developable Windy Land as Percent of Total Land Area	Developable Installed Capacity (MW)*
3	300-400	721	2.82%	559	2.18%	2,795
4	400-500	95	0.37%	59	0.23%	293
5	500-600	16	0.06%	6	0.02%	31
6	600-800	5	0.02%	1	0.01%	7
7	>800	0	0.00%	0	0.00%	0
		28,704	**Apache County Total**			3,126

*Assuming 5 MW per sq. km.

#Exclusions determined using GIS analysis

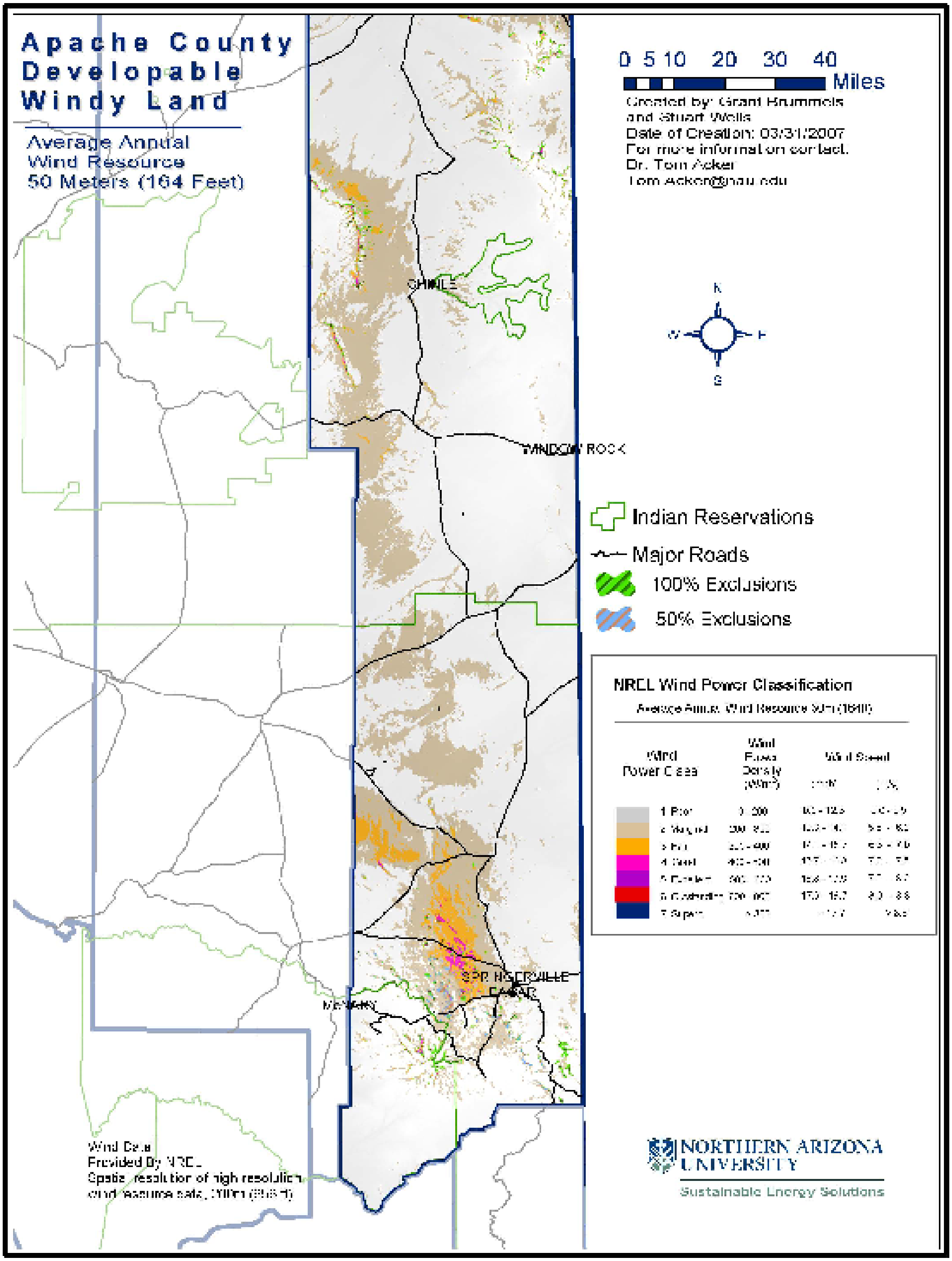


Figure 5 Map of Developable Windy Land for Apache County

Economic Impact Analysis

In this study, economic input/output (I/O) analysis in conjunction with Monte Carlo simulation was used to estimate the economic impact for wind energy projects. The JEDI model performs I/O analysis with an Excel add-in, *@Risk*[8], used to perform the Monte Carlo simulation.

In I/O analysis, a project expenditure may have up to three impacts on the local economy:

- **Direct effects** – on-site effect created by expenditure (i.e., on-site jobs of contractors and crews, jobs at the turbine).
- **Indirect effects** – increase in economic activity that occurs when a contractor, vendor or manufacturer receives payment for goods or services and in turn is able to pay others who support their business.
- **Induced effects** – change in wealth and income that is induced by the spending of those persons directly and indirectly employed by the project (i.e., spending on food, clothes, utilities, transportation, insurance, medical, etc.).

The results of I/O analysis estimate these effects (direct, indirect, and induced) on the jobs, earnings, and economic output.

Methodology

JEDI Model

JEDI is a spreadsheet economic input/output model that accepts wind project data and estimates the direct, indirect, and induced effects of the expenditure to build and operate a wind energy project. The model separates a wind energy project into two distinct phases: construction phase and operations and maintenance (O&M) phase. The construction phase is approximately a year while the O&M phase is from the time the project is brought on-line until it is decommissioned. JEDI estimates the jobs, earnings, and economic activity for the one-time impact of the construction phase and the annual impact of the O&M phase.

JEDI was designed for users that have a variety of experience-levels in I/O analysis or with wind energy projects. To obtain results from JEDI, a user can input as little as the year of installation, the size of the project, and the state for which the economic impacts will be estimated. The remaining input has default values designed for a state-level analysis. As the user gains additional experience or information about the project, additional details can be entered into the model[9].

Why Monte Carlo simulation?

Monte Carlo simulation is a statistical simulation technique which allows input parameters that are uncertain to be randomly varied over a specified range of values. Multiple trials of the Monte Carlo model allow the user to observe and average the results of the output.[10] @Risk by Palisade Corporation[8], an add-in to Microsoft Office Excel, was utilized for Monte Carlo simulation.[11] Using Monte Carlo simulation in conjunction with the I/O analysis provided two advantages over an analysis with JEDI only:

1) Increased input flexibility – cost estimates may be entered as a range of values instead of a single estimate.
2) Increased output information –a range of output values was obtained instead of a single value.

The data required by the JEDI model to estimate the economic impact of constructing and operating a wind energy project can be difficult to accurately estimate. Some input parameters are specific to the site and design. However, estimates for economic impacts are often desired before a site and design have been selected. In addition some of this data is proprietary and industry norms must be relied on to estimate the parameters.

The approach in other work[12,13] has been to use a single estimate representing the most likely value or industry average. For each of the outputs, the JEDI model then produced a single value. By using Monte Carlo simulation any input parameters can be approximated by a range of input values. For each of these input parameters, three estimates were determined: (1) the most likely estimate, (2) the minimum estimate, and (3) the maximum estimate.

Running a simulation with these input parameters as random variables provides an expected value and a variance of the output variables. Therefore, the output is a range of values instead of a single number. This provides a measure of certainty or risk: the smaller the range, the more certainty in the results. When using the JEDI model, the economic impact is estimated using six measures: jobs during construction phase, jobs during O&M phase, earnings during construction phase, earnings during O&M phase, output during construction phase, and output during O&M phase.

Finally, the input parameter(s) which have the most influence on the output can be determined using Monte Carlo simulation. Effort can then be focused on accurately estimating those input parameters that have the most significant effect on the outputs.

Input Data for Economic Impact Analysis

Sources of information are documented. However, many modeling decisions are also based on information gained from discussion with wind energy professionals and experts. These discussions have occurred over time in many venues including the Arizona Wind Working Group and the AWEA Windpower meetings.

County Multipliers

In order to utilize JEDI for county-level analysis, appropriate multipliers for Apache County were obtained from Marshal Goldberg via NREL. Specifically, the direct, indirect and induced multipliers for employment, earnings and output (per million dollars change in final demand) and personal consumption expenditures (i.e., average consumer expenditures on goods for the counties) were obtained[14]. Using the state-level multipliers that are provided with JEDI would overstate the economic benefits so it was important to obtain county-level multipliers for this analysis.

Wind Energy Project Size

Three wind energy project sizes were selected for the economic impact analysis. The sizes that were selected are based on discussions with wind energy experts and professionals, examination of the results of the windy land analysis and surveying the projects that came on-line in 2003-2004 in the southwest. For all analysis, 1.5 MW wind turbines were assumed.

The smallest project size considered was 10.5 MW and the largest was 180 MW. The mid-sized project was assumed to be 60 MW, which is the size of the wind project planned for another northern-Arizona county, Coconino County (Sunshine Wind Park near Winslow, Arizona) and the size of two wind energy projects built in the southwest in 2003-2004, Caprock Wind Ranch in New Mexico and the Oasis Wind Power Project in southern California. In the southwest during 2003-04, three wind energy projects were built that were in the size range of 160-200 MW (New Mexico Wind Energy Center, Colorado Green Lamar, Brazos Wind Ranch in Texas) [15]. To date, no utility-scale wind energy projects have been built in Arizona.

Construction Cost and Operations & Maintenance Cost

Construction cost and O&M cost depend on site and design specific data. Since the site and design were not known, these costs were estimated by a range of values. The estimates used for construction cost and operations and maintenance (O&M) cost are given in Table 5. Estimates for these costs are based on several sources including conversation with a wind developer[12,13,16,17].

Table 5 Input Parameter Estimates

Input Parameter	Minimum	Most Likely	Maximum
Construction Cost ($/kw)	$1,000	$1,200	$1,500
Annual Operating Cost ($/kw)	$9.50	$12.50	$25.00
Property Tax Rate	2.2%	5.2%	13.9%

Both construction cost and O&M cost were uncertain input parameters and were therefore simulated. The triangular distribution was used to generate these costs. The triangular distribution is often used in practice because it is uni-modal and may be non-symmetrical. In addition, there are fixed endpoints for the range of values. Finally, the triangular distribution is a good distribution to use in the absence of data. In the absence of data, experts can be surveyed and industry data consulted for averages. Experts can be asked for their subjective estimates of the minimum, most likely, and maximum values.[18]

Property tax calculation

To calculate the property tax in Arizona the construction cost which includes the cost of the equipment (wind turbines), building and installation costs, must first be determined. Typically, the *full-cost value* is 80% of the construction cost. Property taxes are based on the *assessed value* which is 25% of the full-cost value. The *property tax* is the tax rate multiplied by the assessed value, see Table 6

Table 6 Arizona Property Tax Calculation

Full Cost Value = 80% * Construction Cost
Assessed Value = 25% of Full Cost Value
Tax = Tax Rate * Assessed value

The tax rate varies significantly depending on the location within the state. Tax rates vary from a minimum of 2.2% to a maximum 13.9%. Tax rates were estimated from information obtained in conversations with the Apache County Tax Assessor's office[3,19]. The property tax rate was simulated using a triangular distribution.

Local Share

Local share is the percentage of expenditures spent in the state or local region where the wind energy project is constructed. For this work, it represents the percentage of expenditures spent in the county. Currently, the JEDI model provides default values for local share percentages that are estimated at the state-level (See Table 7). The JEDI model default values are not appropriate for a county-level analysis as the results will be considerably overstated.

We developed local share percentages that apply to Apache County by consulting with a wind developer and an economist. Constanti (2004) also provides guidance for setting the local share percentages for rural counties in Montana. Finally, we examined Apache County demographics (Table 1, Table 2) focusing particularly on population and employment. Minimum and maximum local share percentages were established and are also shown in Table 7[12]. The local share percentages were simulated using a uniform distribution which implies that all values between the minimum and maximum (default) are equally likely.

Simulation Parameters

For each county and wind project size, a simulation was run. For each simulation, the number of trials was determined by observing the convergence of the distribution statistics for the output variables (construction phase: jobs, earnings, output; O&M phase: jobs, earnings, output). When the measured statistics changed no more than 1%, the output distribution was considered 'stable' and the simulation was considered to have converged. The number of trials in each simulation varied between 900 and 1100. The output distribution statistics that were measured are the average percent change of the percentiles, the mean, and the standard deviation.

Table 7 Local Shares Values[††]

Project Cost Data	JEDI default State-level Local Share	Apache County Minimum Local Share	 Maximum Local Share
Construction Costs			
Materials			
Construction (concrete, rebar, equip, roads and site prep)	90%	0%	10%
Transformer	0%	0%	0%
Electrical (drop cable, wire,)	100%	0%	10%
HV line extension	100%	0%	10%
Labor			
Foundation	100%	15%	25%
Erection	75%	0%	10%
Electrical	75%	0%	10%
Management/supervision	0%	0%	0%
Equipment Costs			
Turbines (excluding blades and towers)	0%	0%	0%
Blades	0%	0%	0%
Towers	0%	0%	0%
Other Costs			
HV Sub/Interconnection	100%	0%	10%
Engineering	0%	0%	0%
Legal Services	100%	0%	10%
Land Easements	100%	100%	100%
Site Certificate/Permitting	100%	75%	100%
Wind Plant Annual Operating and Maintenance Costs			
Personnel			
Field Salaries	100%	40%	60%
Administrative	100%	40%	60%
Management	100%	40%	60%
Materials and Services			
Vehicles	100%	0%	10%
Misc. Services	80%	0%	10%
Fees, Permits, Licenses	100%	100%	100%
Utilities	100%	100%	100%
Insurance	0%	0%	0%
Fuel (motor vehicle gasoline)	100%	100%	100%
Tools and Misc. Supplies	100%	40%	60%
Spare Parts Inventory	2%	0%	2%

[††] JEDI default values should not be used for a county-level analysis. The JEDI default values are appropriate only for a state-level analysis. If used for a county-level analysis, benefits will be greatly overstated.

Results of Economic Impact Analysis

All economic outputs from JEDI are divided into benefits that occur during the construction phase (usually less than a year) and annual benefits that occur during the operational life of the wind project. For each phase, the model estimates:

- Jobs – the number of full-time equivalent employment for a year.
- Earnings - wage and salary compensation paid to workers.
- Output - economic activity or the value of production in the county economy.

For all three estimates, the simulation in conjunction with the JEDI model produces a frequency distribution. We report the percentiles for these distributions. The 50th percentile is the median. That is there is 50% chance that the number of jobs will be above the median and a 50% chance that the number of jobs will be below the median. We report the minimum, 5th percentile, 50th percentile, 95th percentile and maximum. There is a 95% likelihood that the number of jobs will be less than the 95th percentile.

Jobs

Results pertaining to job creation for each wind energy project size and project phase are given in Figure 6 and Figure 7. A summary table is given in Appendix A-1. Based on simulation, there is a 90% likelihood that the number of jobs created during the construction phase in Apache County will be between 3 and 9 for a 60 MW wind energy project. During the O&M phase, there is a 90% likelihood that the number of jobs created in Apache County will be between 8 and 10.

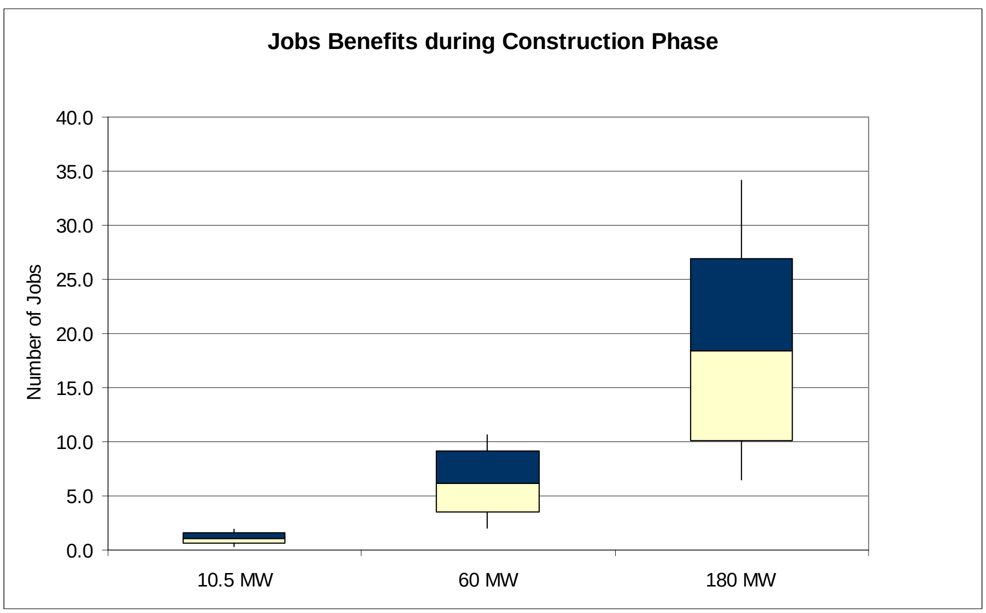


Figure 6 Wind Energy Project Impact on JOBS during Construction Phase

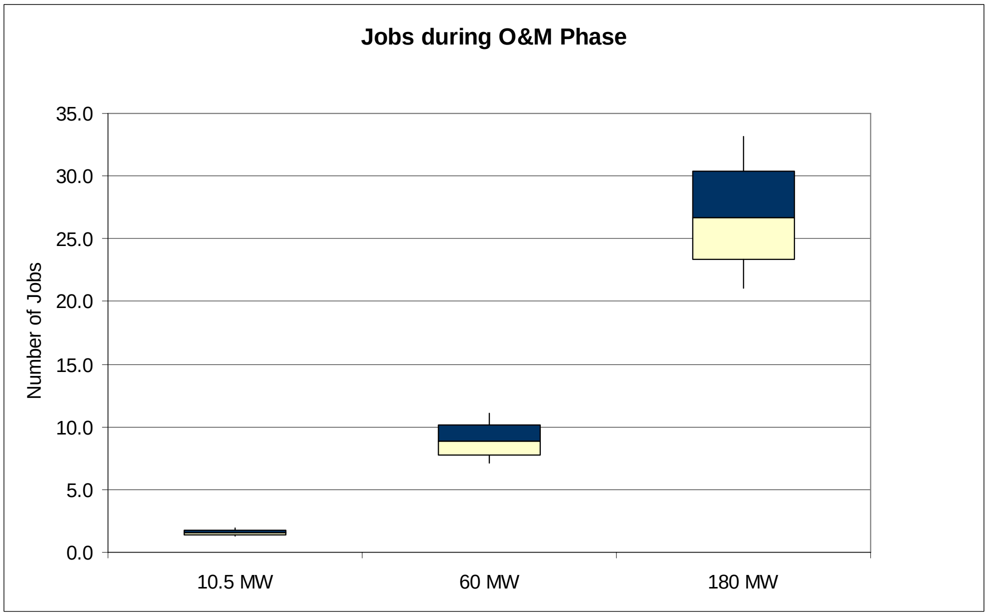


Figure 7 Wind Energy Project Impact on JOBS during O&M Phase

Earnings

Earnings refer to millions of dollars in wages and salary paid to workers. Results for earning for all wind energy project sizes, phases, and counties are given in Figure 8 and Figure 9. A summary table is given in Appendix A-2. Based on simulation, there is a 90% likelihood that the earnings paid during the construction phase in Apache County will be between $0.09 and $0.23 million annually for a 60 MW wind energy project (in 2005 dollars). During the O&M phase, there is a 90% likelihood that the annual earnings in Apache County will be between $0.25 and $0.44 million.

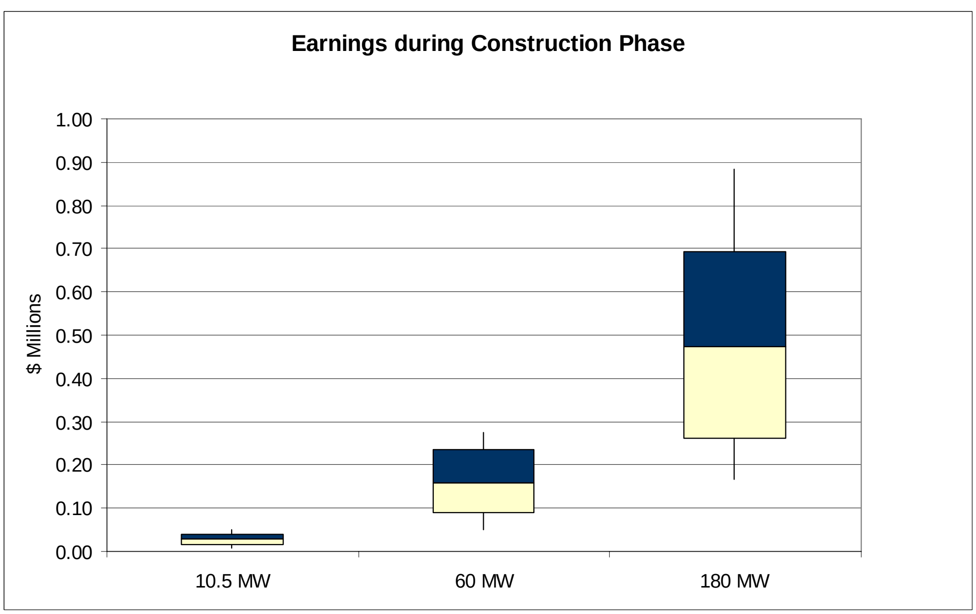


Figure 8 Wind Energy Project Impact on EARNINGS during Construction

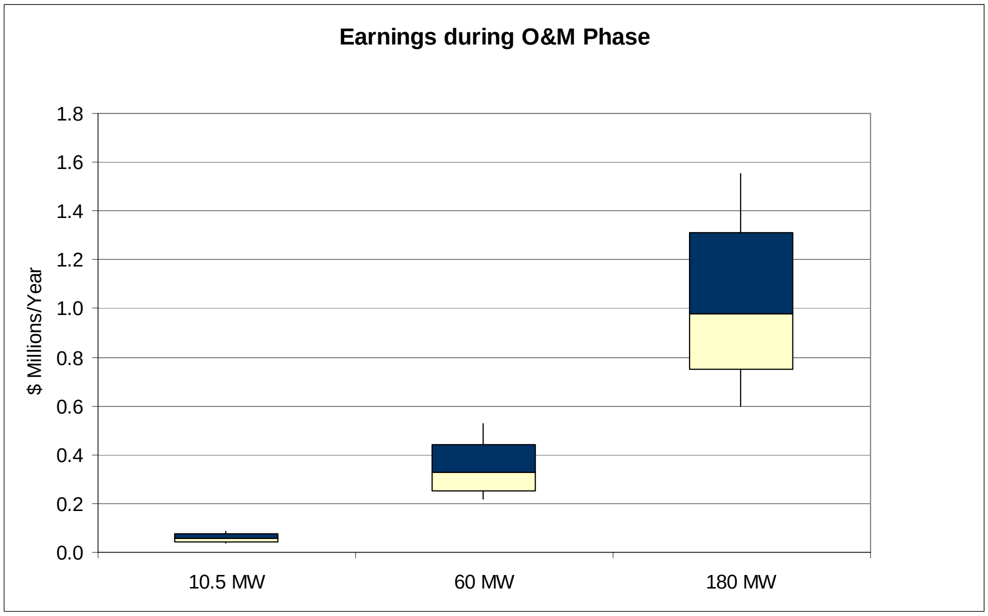


Figure 9 Wind Energy Project Impact on EARNINGS during O&M Phase

Output

Figure 10 and Figure 11 show a summary of output results for all wind energy project sizes and phases. A summary table is given in Appendix A-3. Output refers to economic activity or the value of production in the county and is also in millions of 2007 dollars. Based on the simulation results there is a 90% likelihood that the output will be between $0.38 and $1.01 million annually for Apache County. During the O&M phase, there is a 90% likelihood that the annual output in Apache County will be between $0.57 and $0.92 million.

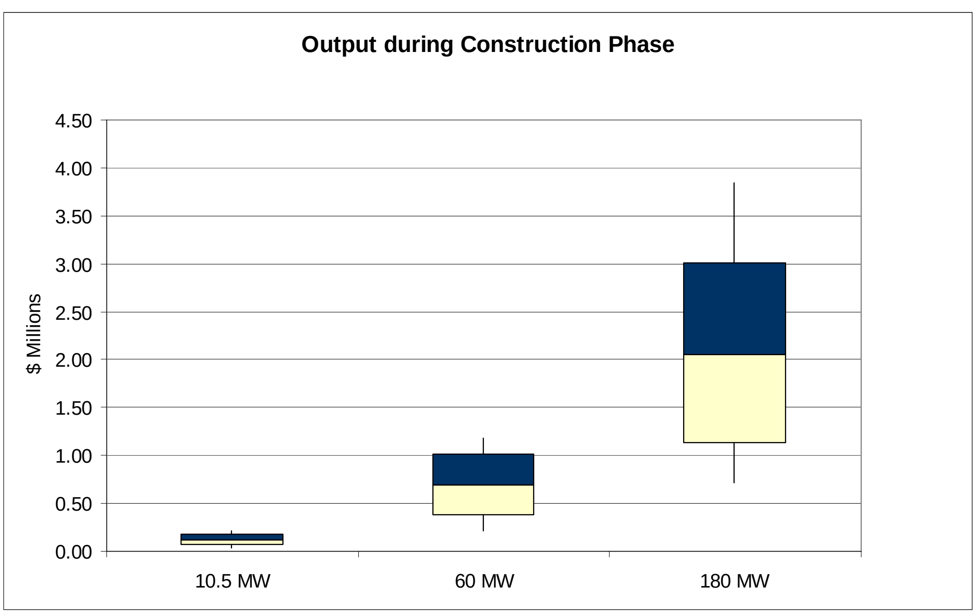


Figure 10 Wind Energy Project Impact on OUTPUT during Construction Phase

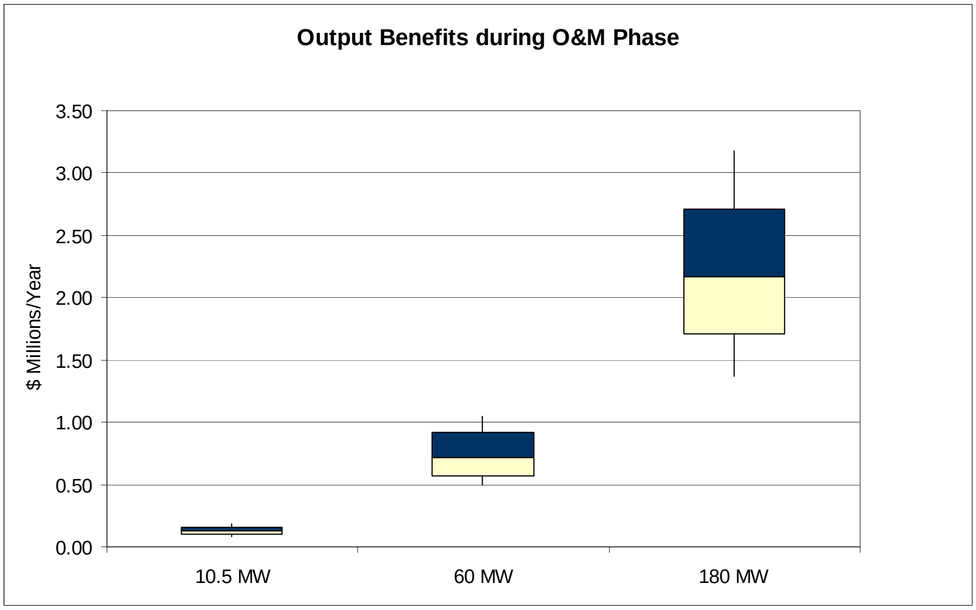


Figure 11 Wind Energy Project Impact on OUTPUT during O&M Phase

Conclusions

The first objective of this project was to estimate the wind energy development potential for Apache County. Based on high-resolution wind map data analyzed in a GIS while considering development exclusions, it was estimated that the developable windy land and potential installed capacity for Apache is approximately 3100 MW. The majority of this capacity is from Class 3 wind. When this estimate is restricted to windy lands of class 4 or better, the developable capacity is 300 MW.

The second objective of this work was to estimate the economic impact of constructing and operating wind energy projects of various sizes in Apache County. Monte Carlo simulation was conducted in conjunction with the JEDI model and provided a range of outputs corresponding to a range of estimated input parameters. For a 60 MW wind energy project, there is 90% likelihood that:

- number of jobs created during the construction phase is between 3 and 9 with a median of 6 jobs.
- number of jobs created during the O&M phase is between 8 and 10 with a median of 9 jobs.
- earnings during the construction phase is between $0.09 and $0.23 million with a median of $0.16 million.
- earnings during the O&M phase is between $0.25 and $0.44 million annually with a median of $0.61 million.
- output during the construction phase is between $0.38 and $1.01 million with a median of $0.69 million.
- output during the O&M phase is between $0.57 and $0.92 million annually with a median of $0.72 million.

Appendix A Tables of JEDI/Monte Carlo Simulation Results

Appendix A- 1 Wind Energy Project Impact on JOBS

	Jobs for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0	1
5th	1	1
50th	1	2
95th	2	2
100th	2	2
	Jobs for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	2	7
5th	3	8
50th	6	9
95th	9	10
100th	11	11
	Jobs for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	6	21
5th	10	23
50th	18	27
95th	27	30
100th	34	33

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Construction Jobs for 60 MW Wind Farm). The 95^{th} percentile tells us that 95% of those 1000 simulations had 9 or fewer Construction Jobs for a 60 MW Wind Farm. We interpret this as a 95% probably that the number of Construction Jobs for a 60 MW Wind Farm will be 9 or less. The 50^{th} percentile represents the median.

Appendix A- 2 Wind Energy Project Impact on EARNINGS

($ millions)

	Earnings for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.01	0.04
5th	0.02	0.04
50th	0.03	0.06
95th	0.04	0.08
100th	0.05	0.09
	Earnings for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	0.05	0.22
5th	0.09	0.25
50th	0.16	0.33
95th	0.23	0.44
100th	0.27	0.22
	Earnings for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	0.17	0.60
5th	0.55	0.75
50th	0.47	0.98
95th	0.69	1.31
100th	0.88	1.55

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Earnings for 60 MW Wind Farm). The 95^{th} percentile tells us that 95% of those 1000 simulations had $0.23 million or less Earnings from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Earnings from a 60 MW Wind Farm will be $0.23 million or less. The 50^{th} percentile represents the median.

Appendix A- 3 Wind Energy Project Impact on OUTPUT

($ millions)

	Output for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.04	0.09
5th	0.07	0.10
50th	0.12	0.13
95th	0.18	0.16
100th	0.21	0.18
	Output for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	0.21	0.49
5th	0.38	0.57
50th	0.69	0.72
95th	1.01	0.92
100th	1.19	1.04
	Output for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	0.72	1.37
5th	1.13	1.71
50th	2.06	2.17
95th	3.01	2.71
100th	3.84	3.18

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Output from a 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $1.01 million or less Output from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Output from a 60 MW Wind Farm will be $1.01 million or less. The 50th percentile represents the median.

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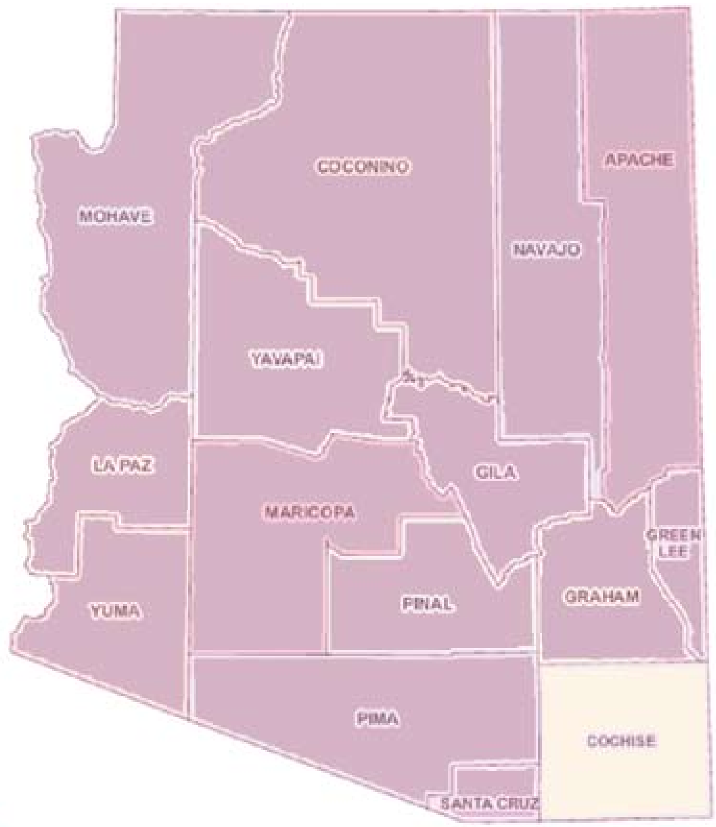
NORTHERN ARIZONA UNIVERSITY

Sustainable Energy Solutions

Arizona Wind Energy Assesment

Cochise County

Developable Windy Land and Economic Benefits



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April 2007

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Abstract

This report contains two wind energy analyses for the southern-Arizona's Cochise County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class in each county was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Cochise County was estimated to be 275 MW. The majority of developable windy land, 80%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Coconino County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 10.5 MW wind energy project

- *Jobs during construction*: median was 5 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 2 jobs
- *Earnings during construction*: the median was $0.13 million
- *Earnings during O&M phase*: median was $0.08 million annually
- *Output (economic activity) during construction*: median was $0.56 million
- *Output during O&M phase*: median was $0.17 million annually

For a 60 MW wind energy project

- *Jobs during construction*: median was 27 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 11 jobs
- *Earnings during construction*: the median was $0.76 million
- *Earnings during O&M phase*: median was $0.43 million annually
- *Output (economic activity) during construction*: median was $3.21 million
- *Output during O&M phase*: median was $0.98 million annually

For a 180 MW wind energy project

- *Jobs during construction*: median was 80 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 33 jobs
- *Earnings during construction*: the median was $2.27 million
- *Earnings during O&M phase*: median was $1.29 million annually
- *Output (economic activity) during construction*: median was $9.59 million
- *Output during O&M phase*: median was $2.92 million annually

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Introduction

The wind energy development potential and economic benefits were determined for a southern Arizona county, Cochise (see Figure 1). Using Geographic Information System (GIS) techniques on wind map data an estimate was made of the amount of developable windy land and potential installed capacity. Secondly, an analysis was made of the economic impacts of constructing and operating wind energy projects utilizing the Job and Economic Development Impact [*] (JEDI) model developed for National Renewable Energy Laboratory (NREL). Wind energy projects of three representative sizes were considered: 10.5 MW, 60 MW, and 180 MW. The JEDI model was used in conjunction with Monte Carlo simulation to estimate economic impacts at the county level. Direct, indirect and induced economic effects were estimated and categorized by jobs, earnings, and output (economic activity).

The wind maps and information in this report are *not* appropriate for siting wind energy projects. It is useful for discussing policy and locations that might be appropriate for further study. In order to site a wind energy project, an anemometer should be installed on the property and two years of data collected. More Arizona wind maps are available at www.ses.nau.edu.

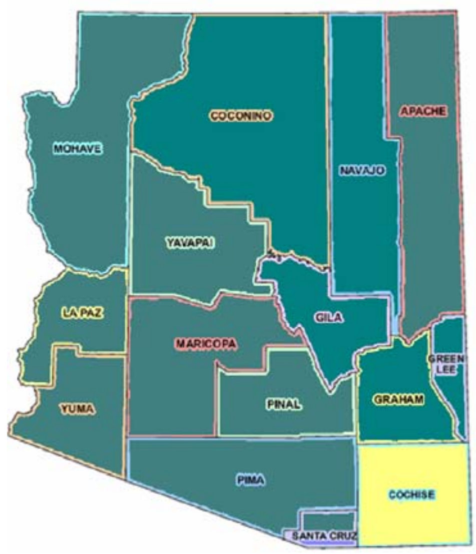

Figure 1 Cochise County in northern Arizona

[*] The JEDI model was designed by Marshall Goldberg, of MRG & Associates, under contract with NREL.The model is posted on the Wind Powering America website: http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=707 in June 2005.

State of Arizona

According to the US Census Bureau Quick Facts[1] the population in the state of Arizona increased 40% from 1990 to 2000. During this period US population increased 13.1%. Due to this rapid population and economic growth, electricity demand increased at the rate of 2.6% per year[2].

In 2001, the average electricity retail price for Arizona residents and businesses was 7.2 cents/kwh. This is the 16th highest average electricity price in the nation behind the six New England states, New York, New Jersey, Pennsylvania, California, Alaska, Hawaii, Texas, Florida, and Nevada. In addition to Arizona's increasing population, the hot climate and resulting need for air conditioning in the summer affect the increasing demand and price of electricity. Arizona has a larger than average residential demand largely due to the demand for air conditioning. The residential sector purchases 41% of the electricity as compared to 36% nationally[2].

Arizona primarily relies on coal and nuclear fuels for electrical generation. In 2000, approximately 45% of electricity was coal-generated and 35% was nuclear with only 10% generated from natural gas and another 10% by hydroelectric. However, the balance will be shifting to natural gas in the future as there are 16,000 MW of planned generation units by 2007, of which 15,000 MW are planned to be natural gas[2].

Cochise County

Cochise County, in southeastern Arizona, is 6,219 square miles with a 2001 population of 121,040. The area is known for mining and agriculture. Historic Tombstone may be its most widely recognized town though Bisbee is the county seat and Sierra Vista is the largest community with a population of 40,415 in 2003[3]. Demographic information is given in Table 1[4] and industry sector information is given in Table 2[5]. The largest land ownership category in Cochise County, approximately 40% is individual and corporate ownership (see Table 3)[3].

Table 1 Cochise County Demographics

Demographic	Cochise
Population, 2005 estimate	126,106
Population, percent change, April 1, 2000 to July 1, 2005	7.1%
Population, percent change, 1990 to 2000	20.6%
High school graduates, percent of persons age 25+, 2000	79.5%
Bachelor's degree or higher, pct of persons age 25+, 2000	18.8%
Per capita money income, 1999	$15,988
Median household income, 2003	$34,755
Persons below poverty, percent, 2003	16.3%
Private nonfarm establishments, 2003	2,256
Private nonfarm employment, 2003	25,122
Private nonfarm employment, percent change 2000-2003	10.8%
Retail sales, 2002 ($1000)	917,299
Retail sales per capita, 2002	$7,641
Land area, 2000 (square miles)	6,169
Persons per square mile, 2000	19.1
Metropolitan or Micropolitan Statistical Area	Sierra Vista-Douglas

Table 2 Cochise County Industry Sectors

Industry Sectors in Cochise County	Percent	Employed
Agriculture, forestry, fishing and hunting, and mining	3.3	1418
Construction	7.4	3,164
Manufacturing	3.9	1649
Wholesale trade	1.4	615
Retail trade	14.7	6,264
Transportation and warehousing, and utilities	4.9	2,108
Information	2.4	1024
Finance, insurance, real estate, and rental and leasing	4	1695
Professional, scientific, management, administrative, and waste management services	7.9	3359
Educational, health and social services	20.3	8,640
Arts, entertainment, recreation, accommodation and food services	9.9	4,226
Other services (except public administration)	5.6	2389
Public administration	14.3	6,075

Table 3 Land Ownership in Cochise County

Land owner	Cochise
Private	40%
State of AZ	35%
US Forest Service & BLM	22%
Other public lands	3%
	100%

Windy Land Analysis using GIS

Methodology

For the purpose of this analysis, *windy land* is defined as land with a wind resource greater than or equal to class three as predicted by the Arizona Wind Map (the wind map will be discussed in the section on Input Data). That is, predicted average annual wind speeds are large enough that wind energy may be produced economically. However, not all windy land may be developed for wind power. There are many *development exclusions* that must be considered. For instance, land that is owned by the National Park Service must be excluded 100% from consideration for development. *Developable windy land*, therefore, is the windy land that remains after all development exclusions have been applied. Finally, *excluded windy land* is windy land (class 3 and above) that falls within a development exclusion.

Consistent with the methodology applied by NREL, there are three general *exclusion* categories of land unsuitable for development[6]:

- environmental exclusions
- land use exclusions
- additional windy land factors

These development exclusions are summarized in Table 4. Any windy land with 1 or more exclusion is excluded windy land and is not appropriate to be used for wind energy projects. After removing excluded windy land, the remaining land is developable and an estimate of the potential installed capacity by wind class for each county was made by assuming a conservative 5 MW of installed capacity per square kilometer.

Input Data for Windy Land Analysis

TrueWind Solutions, in collaboration with NREL, developed a high-resolution wind map and GIS data for the state of Arizona in 2003. The data for this wind map was created using a numerical weather model coupled with climactic data and a wind flow model. The wind map provides 200-meter resolution data sufficient for identifying the most promising areas for wind development in the state. The data from this map was used to analyze the wind resource of Cochise County.

A *data layer* is a geographic data set that can be represented visually using GIS software. Several data layers were required for the exclusion analysis. The data layers, their exclusion category (environmental, land use, other factors), source and brief description are listed in Table 4.

Table 4 Wind Development Exclusions

Broad Exclusion Category	Exclusion	Exclusion[†] Percentage	Exclusion Description	GIS Layer Source
Environmental Exclusions	**National Park Service**	100%	United States National Park Service Land	ALRIS [‡]
	Fish and Wildlife Service	100%	United States Fish and Wildlife service	ALRIS
	Congressionally Specially Designated Areas	100%	Special Areas, like wilderness or wild, and scenic rivers, congressionally designated as such	USFS
	Inventoried Roadless Areas	100%	These are roadless areas of the country on federal land that have been congressionally designated as such	USFS
	State and Other Environmental Land (State GAP Data)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP
	Other: Wildlife, Wilderness and Recreation Areas on Federal land of any designation (predominately USFS and BLM lands)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP[§]
	Remaining USFS & DOD Land	50%	United States Forest Service and Department of Defense lands that remain after all other windy land exclusions are removed	ALRIS
Land Use Exclusions	**Urban/Developed Areas**	100%	Urban or Developed land as described by USGS ReGAP data	USGS AZ ReGAP
	Airports	100%	Airports	National Atlas of the United States, USGS, ESRI
	Wetlands	100%	Wetland ecosystems as described by USGS ReGAP data	USGS AZ ReGAP
	Water bodies (includes seasonal and dry lakes)	100%	Areas covered by water all year or part of the year. Does not include Rivers and Streams	USGS AZ ReGAP
	Non-ridge Crest Forests	50%	Areas of forest cover that are not considered ridge crests by TPI analysis	ReGAP + TPI [**]
Additional Windy Land Factors	**Slopes > 20%**	100%	These are landscapes with slopes greater than 20%	Grant Brummels

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[†] Windy land exclusions were excluded 100%, with the exception of "non-ridge crest forests" and "remaining USFS and DOD Land," which were excluded 50%. Additionally, all 100% exclusions were buffered 3km, except for wetlands (100m), open water (no buffer), and slopes > 20% (no buffer).[†] Non-ridge crest forests have had all 100% exclusions removed. Remaining USFS and DOD land has had all non-ridge crest forests and 100% exclusions removed.

[‡] ALRIS—Arizona Land Resource Information System

[§] ReGAP—Regional Gap Analysis Program, 30m satellite data

[**] Jenness, J. 2005. Topographic Position Index (tip_jen.avx) extension for ArcView 3.x. Jenness Enterprises. Available at: http://www.jennessent.com/arview/tpi.htm. TPI was applied to a 90m Digital Elevation Model.

Results of Windy Land Analysis

The windy land in Cochise County is shown in Figure 2. Using GIS, the square kilometers of land was then totaled by wind class. Approximately 2.2% of the land is considered windy land. Of the windy land, the majority is class 3.

The development exclusions for Cochise County are mapped in Figure 3. As displayed, the land areas highlighted in blue show the areas that cannot be developed for wind energy regardless of how windy since this land was classified as a development exclusions. In Cochise County, 3.0% of the total county land area is classified as development exclusions.

Exclusions are significant in Cochise County – 90% of windy land is excluded from consideration for development. See Figure 4 to compare the wind class breakdown of the amount of windy land with the wind class breakdown of the amount of developable windy land. When exclusions are considered, much of the excluded windy land is higher than class 3. As a result, the proportional amounts of class 4 and above decrease with a corresponding increase in the proportional amount of class 3.

Some land is excluded under multiple categories. For instance, land may have a slope greater than 20% and also be an Inventoried Roadless Area. The largest exclusion affecting windy land is Slopes>20% and excludes 67% of windy land. Other exclusion categories that remove windy land are given in Table 5. The percentages will not add to 100% because trivial categories have not been included and because some land is excluded by multiple categories.

Table 6 provides a summary of the results of the windy land analysis for Cochise County. Organized by wind class, the total area of windy land, area of developable windy land, and potential developable capacity are shown. These tables also show that the total developable capacity in Cochise County, including class 3 or better windy lands, is 276 MW. When restricting this estimate to windy lands of class 4 or better, the developable capacity for these counties is 56 MW. Finally, the developable windy land is shown in Figure 5.

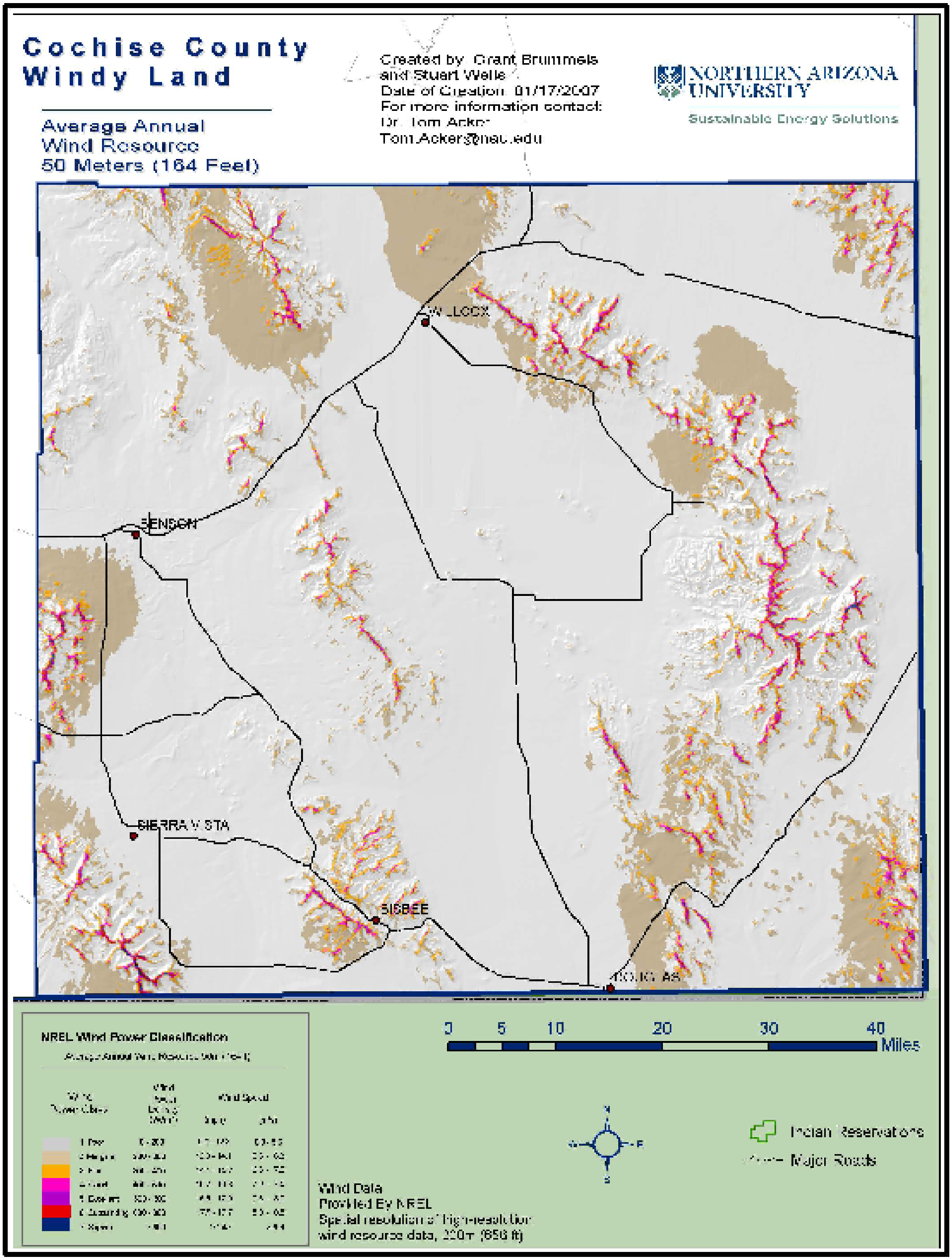


Figure 2 Map of Windy Land for Cochise County, AZ

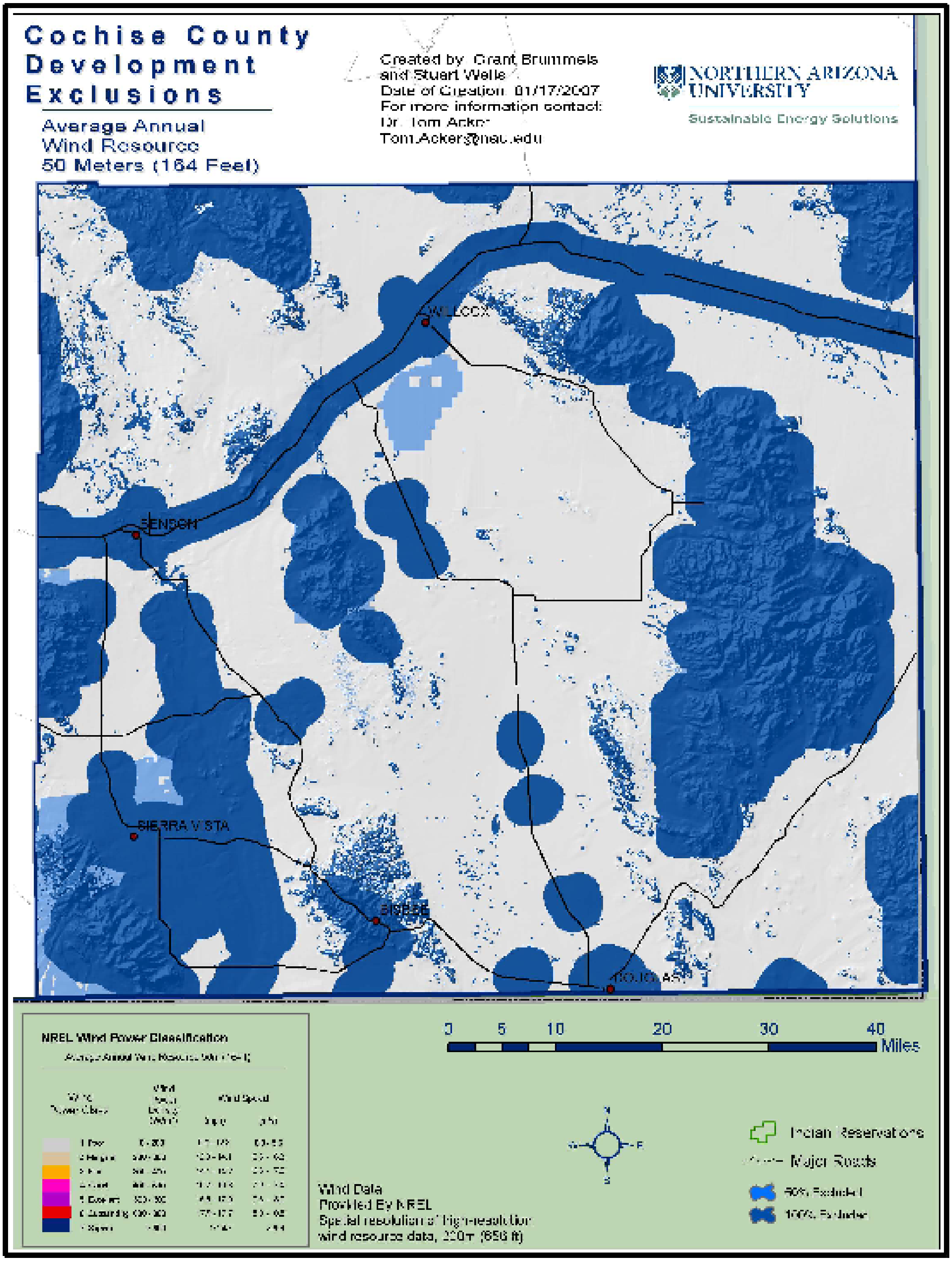
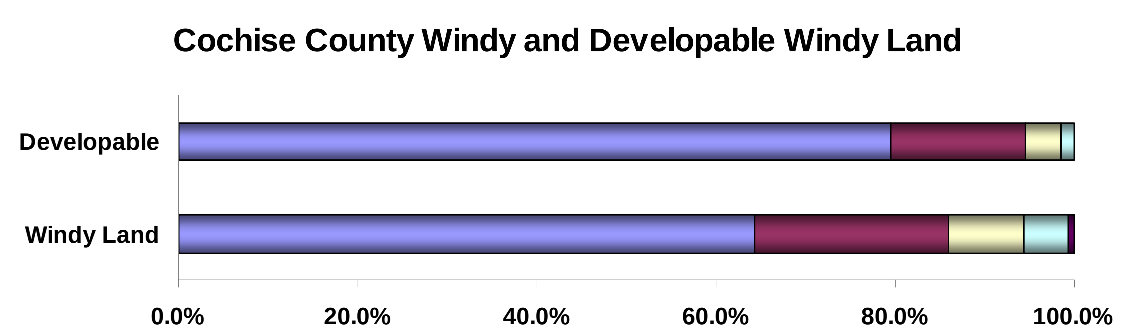


Figure 3 Map of Development Exclusions in Cochise County



	Windy Land	Developable
Class 7	0.7%	0.0%
Class 6	4.9%	1.5%
Class 5	8.4%	4.0%
Class 4	21.7%	14.9%
Class 3	64.3%	79.6%

Figure 4 Windy Land by Wind Class for Cochise County

Table 5 Cochise County Exclusion Categories that Remove Windy Land

Exclusion Category	Windy Land Excluded
Slopes > 20%	67.1%
Inventoried Roadless Areas	45.2%
Environmental Lands	32.9%
Specially Designated Areas	18.5%

Table 6 Windy Land and Developable Windy Land in Cochise County

Cochise County Wind Class Area Analysis						
Wind Class	Power (w/m^2)	Total Area (km^2)	Windy Land as Percent of Total Land Area	Developable Windy Land (km^2)#	Developable Windy Land as Percent of Total Land Area	Developable Installed Capacity (MW)*
3	300-400	354	1.38%	44	0.17%	220
4	400-500	119	0.47%	8	0.03%	41
5	500-600	46	0.18%	2	0.01%	11
6	600-800	27	0.10%	1	0.00%	4
7	>800	4	0.02%	0	0.00%	0
		16,212	**Cochise County Total**			276

*Assuming 5 MW per sq. km.

#Exclusions determined using GIS analysis

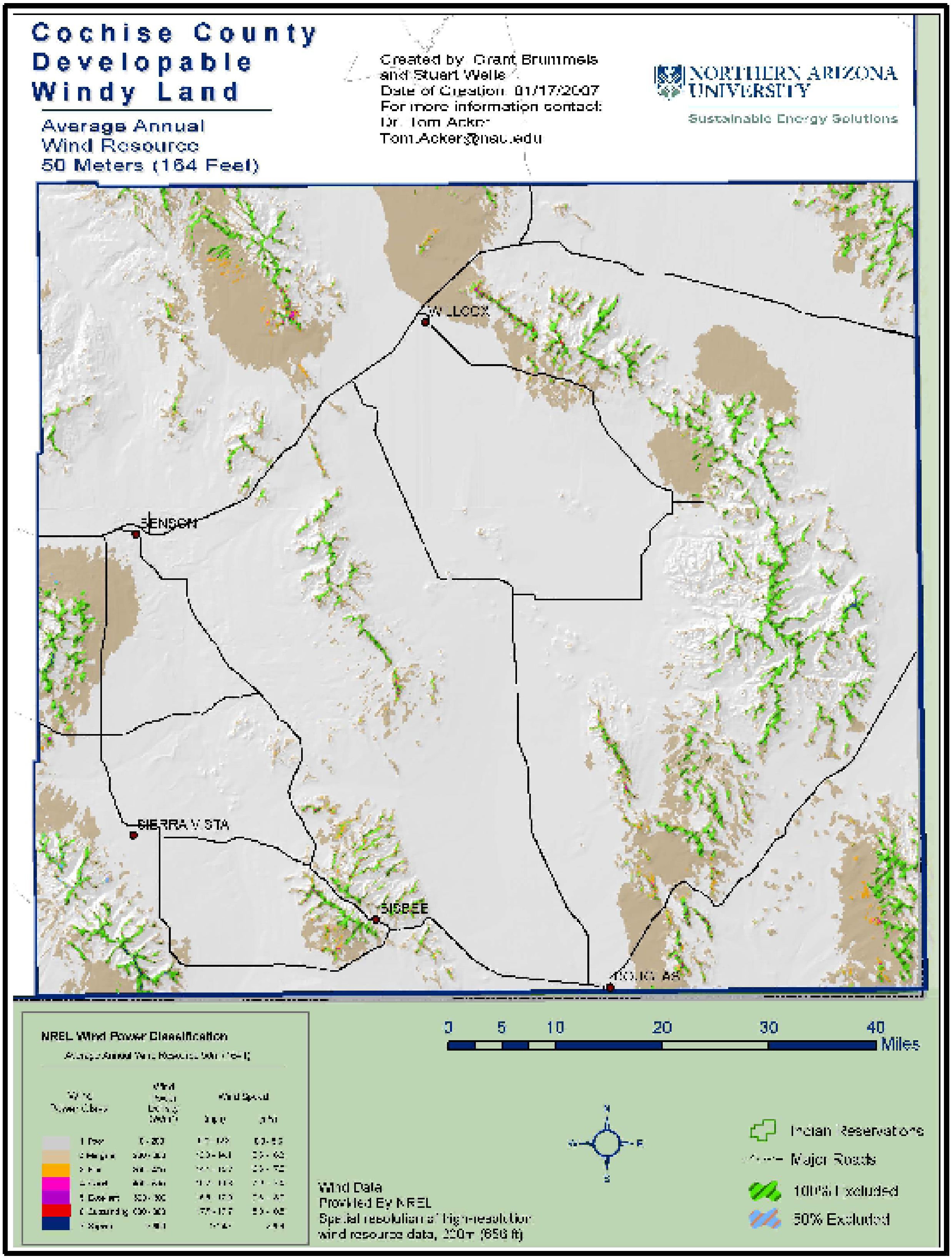


Figure 5 Map of Developable Windy Land for Cochise County

Economic Impact Analysis

In this study, economic input/output (I/O) analysis in conjunction with Monte Carlo simulation was used to estimate the economic impact for wind energy projects. The JEDI model performs I/O analysis with an Excel add-in, *@Risk*[7], used to perform the Monte Carlo simulation.

In I/O analysis, a project expenditure may have up to three impacts on the local economy:

- **Direct effects** – on-site effect created by expenditure (i.e., on-site jobs of contractors and crews, jobs at the turbine).
- **Indirect effects** – increase in economic activity that occurs when a contractor, vendor or manufacturer receives payment for goods or services and in turn is able to pay others who support their business.
- **Induced effects** – change in wealth and income that is induced by the spending of those persons directly and indirectly employed by the project (i.e., spending on food, clothes, utilities, transportation, insurance, medical, etc.).

The results of I/O analysis estimate these effects (direct, indirect, and induced) on the jobs, earnings, and economic output.

Methodology

JEDI Model

JEDI is a spreadsheet economic input/output model that accepts wind project data and estimates the direct, indirect, and induced effects of the expenditure to build and operate a wind energy project. The model separates a wind energy project into two distinct phases: construction phase and operations and maintenance (O&M) phase. The construction phase is approximately a year while the O&M phase is from the time the project is brought on-line until it is decommissioned. JEDI estimates the jobs, earnings, and economic activity for the one-time impact of the construction phase and the annual impact of the O&M phase.

JEDI was designed for users that have a variety of experience-levels in I/O analysis or with wind energy projects. To obtain results from JEDI, a user can input as little as the year of installation, the size of the project, and the state for which the economic impacts will be estimated. The remaining input has default values designed for a state-level analysis. As the user gains additional experience or information about the project, additional details can be entered into the model[8].

Why Monte Carlo simulation?

Monte Carlo simulation is a statistical simulation technique which allows input parameters that are uncertain to be randomly varied over a specified range of values. Multiple trials of the Monte Carlo model allow the user to observe and average the results of the output.[9] @Risk by Palisade Corporation[8], an add-in to Microsoft Office Excel, was utilized for Monte Carlo simulation.[10] Using Monte Carlo simulation in conjunction with the I/O analysis provided two advantages over an analysis with JEDI only:

1) Increased input flexibility – cost estimates may be entered as a range of values instead of a single estimate.
2) Increased output information –a range of output values was obtained instead of a single value.

The data required by the JEDI model to estimate the economic impact of constructing and operating a wind energy project can be difficult to accurately estimate. Some input parameters are specific to the site and design. However, estimates for economic impacts are often desired before a site and design have been selected. In addition some of this data is proprietary and industry norms must be relied on to estimate the parameters.

The approach in other work[11,12] has been to use a single estimate representing the most likely value or industry average. For each of the outputs, the JEDI model then produced a single value. By using Monte Carlo simulation any input parameters can be approximated by a range of input values. For each of these input parameters, three estimates were determined: (1) the most likely estimate, (2) the minimum estimate, and (3) the maximum estimate.

Running a simulation with these input parameters as random variables provides an expected value and a variance of the output variables. Therefore, the output is a range of values instead of a single number. This provides a measure of certainty or risk: the smaller the range, the more certainty in the results. When using the JEDI model, the economic impact is estimated using six measures: jobs during construction phase, jobs during O&M phase, earnings during construction phase, earnings during O&M phase, output during construction phase, and output during O&M phase.

Finally, the input parameter(s) which have the most influence on the output can be determined using Monte Carlo simulation. Effort can then be focused on accurately estimating those input parameters that have the most significant effect on the outputs.

Input Data for Economic Impact Analysis

Sources of information are documented. However, many modeling decisions are also based on information gained from discussion with wind energy professionals and experts. These discussions have occurred over time in many venues including the Arizona Wind Working Group and the AWEA Windpower meetings.

County Multipliers

In order to utilize JEDI for county-level analysis, appropriate multipliers for Coconino County were obtained from Marshal Goldberg via NREL. Specifically, the direct, indirect and induced multipliers for employment, earnings and output (per million dollars change in final demand) and personal consumption expenditures (i.e., average consumer expenditures on goods for the counties) were obtained[13]. Using the state-level multipliers that are provided with JEDI would overstate the economic benefits so it was important to obtain county-level multipliers for this analysis.

Wind Energy Project Size

Three wind energy project sizes were selected for the economic impact analysis. The sizes that were selected are based on discussions with wind energy experts and professionals, examination of the results of the windy land analysis and surveying the projects that came on-line in 2003-2004 in the southwest. For all analysis, 1.5 MW wind turbines were assumed.

The smallest project size considered was 10.5 MW and the largest was 180 MW. The mid-sized project was assumed to be 60 MW, which is the size of the wind project planned for another Arizona county, Coconino County (Sunshine Wind Park near Winslow, Arizona) and the size of two wind energy projects built in the southwest in 2003-2004, Caprock Wind Ranch in New Mexico and the Oasis Wind Power Project in southern California. In the southwest during 2003-04, three wind energy projects were built that were in the size range of 160-200 MW (New Mexico Wind Energy Center, Colorado Green Lamar, Brazos Wind Ranch in Texas) [14]. To date, no utility-scale wind energy projects have been built in Arizona.

Construction Cost and Operations & Maintenance Cost

Construction cost and O&M cost depend on site and design specific data. Since the site and design were not known, these costs were estimated by a range of values. The estimates used for construction cost and operations and maintenance (O&M) cost are given in Table 7. Estimates for these costs are based on several sources including conversation with a wind developer[11,12,15,16].

Table 7 Input Parameter Estimates

Input Parameter	Minimum	Most Likely	Maximum
Construction Cost ($/kw)	$1,000	$1,200	$1,500
Annual Operating Cost ($/kw)	$9.50	$12.50	$25.00
Property Tax Rate	9.6%	11.6%	15.0%

Both construction cost and O&M cost were uncertain input parameters and were therefore simulated. The triangular distribution was used to generate these costs. The triangular distribution is often used in practice because it is uni-modal and may be non-symmetrical. In addition, there are fixed endpoints for the range of values. Finally, the triangular distribution is a good distribution to use in the absence of data. In the absence of data, experts can be surveyed and industry data consulted for averages. Experts can be asked for their subjective estimates of the minimum, most likely, and maximum values.[17]

Property tax calculation

To calculate the property tax in Arizona the construction cost which includes the cost of the equipment (wind turbines), building and installation costs, must first be determined. Typically, the *full-cost value* is 80% of the construction cost. Property taxes are based on the *assessed value* which is 25% of the full-cost value. The *property tax* is the tax rate multiplied by the assessed value, see Table 8

Table 8 Arizona Property Tax Calculation

Full Cost Value = 80% * Construction Cost
Assessed Value = 25% of Full Cost Value
Tax = Tax Rate * Assessed value

The tax rate varies significantly depending on the location within the state. Examining the tax tables, it was determined that the range of tax rates vary from a minimum of 9.6% to a maximum 15%. Tax rates were estimated from information obtained in conversations with the Cochise County Tax Assessor's office[3,18]. The property tax rate was simulated using a triangular distribution.

Local Share

Local share is the percentage of expenditures spent in the state or local region where the wind energy project is constructed. For this work, it represents the percentage of expenditures spent in the county. Currently, the JEDI model provides default values for local share percentages that are estimated at the state-level (See Table 9). The JEDI model default values are not appropriate for a county-level analysis as the results will be considerably overstated.

We developed local share percentages that apply to Cochise County by consulting with a wind developer and an economist. Constanti (2004) also provides guidance for setting the local share percentages for rural counties in Montana. Finally, we examined Cochise County demographics (Table 1, Table 2) focusing particularly on population and employment. Minimum and maximum local share percentages were established and are also shown in Table 9[11]. The local share percentages were simulated using a uniform distribution which implies that all values between the minimum and maximum (default) are equally likely.

Simulation Parameters

For each county and wind project size, a simulation was run. For each simulation, the number of trials was determined by observing the convergence of the distribution statistics for the output variables (construction phase: jobs, earnings, output; O&M phase: jobs, earnings, output). When the measured statistics changed no more than 1%, the output distribution was considered 'stable' and the simulation was considered to have converged. The number of trials in each simulation varied between 900 and 1100. The output distribution statistics that were measured are the average percent change of the percentiles, the mean, and the standard deviation.

Table 9 Local Shares Values[††]

Project Cost Data	JEDI default State-level Local Share	Cochise County Minimum Local Share	Cochise County Maximum Local Share
Construction Costs			
Materials			
Construction (concrete, rebar, equip, roads and site prep)	90%	25%	50%
Transformer	0%	0%	0%
Electrical (drop cable, wire,)	100%	10%	25%
HV line extension	100%	0%	10%
Labor			
Foundation	100%	40%	60%
Erection	75%	10%	15%
Electrical	75%	25%	50%
Management/supervision	0%	0%	0%
Equipment Costs			
Turbines (excluding blades and towers)	0%	0%	0%
Blades	0%	0%	0%
Towers	0%	0%	0%
Other Costs			
HV Sub/Interconnection	100%	10%	25%
Engineering	0%	0%	5%
Legal Services	100%	25%	50%
Land Easements	100%	100%	100%
Site Certificate/Permitting	100%	100%	100%
Wind Plant Annual Operating and Maintenance Costs			
Personnel			
Field Salaries	100%	60%	75%
Administrative	100%	60%	75%
Management	100%	60%	75%
Materials and Services			
Vehicles	100%	50%	75%
Misc. Services	80%	25%	50%
Fees, Permits, Licenses	100%	100%	100%
Utilities	100%	100%	100%
Insurance	0%	0%	0%
Fuel (motor vehicle gasoline)	100%	100%	100%
Tools and Misc. Supplies	100%	60%	75%
Spare Parts Inventory	2%	2%	2%

[††] JEDI default values should not be used for a county-level analysis. The JEDI default values are appropriate only for a state-level analysis. If used for a county-level analysis, benefits will be greatly overstated.

Results of Economic Impact Analysis

All economic outputs from JEDI are divided into benefits that occur during the construction phase (usually less than a year) and annual benefits that occur during the operational life of the wind project. For each phase, the model estimates:

- Jobs – the number of full-time equivalent employment for a year.
- Earnings - wage and salary compensation paid to workers.
- Output - economic activity or the value of production in the county economy.

For all three estimates, the simulation in conjunction with the JEDI model produces a frequency distribution. We report the percentiles for these distributions. The 50th percentile is the median. That is there is 50% chance that the number of jobs will be above the median and a 50% chance that the number of jobs will be below the median. We report the minimum, 5th percentile, 50th percentile, 95th percentile and maximum. There is a 95% likelihood that the number of jobs will be less than the 95th percentile.

Jobs

Results pertaining to job creation for each wind energy project size and project phase are given in Figure 6 and Figure 7. A summary table is given in Appendix A-1. Based on simulation, there is a 90% likelihood that the number of jobs created during the construction phase in Cochise County will be between 21 and 33 for a 60 MW wind energy project. During the O&M phase, there is a 90% likelihood that the number of jobs created in Cochise County will be between 10 and 12.

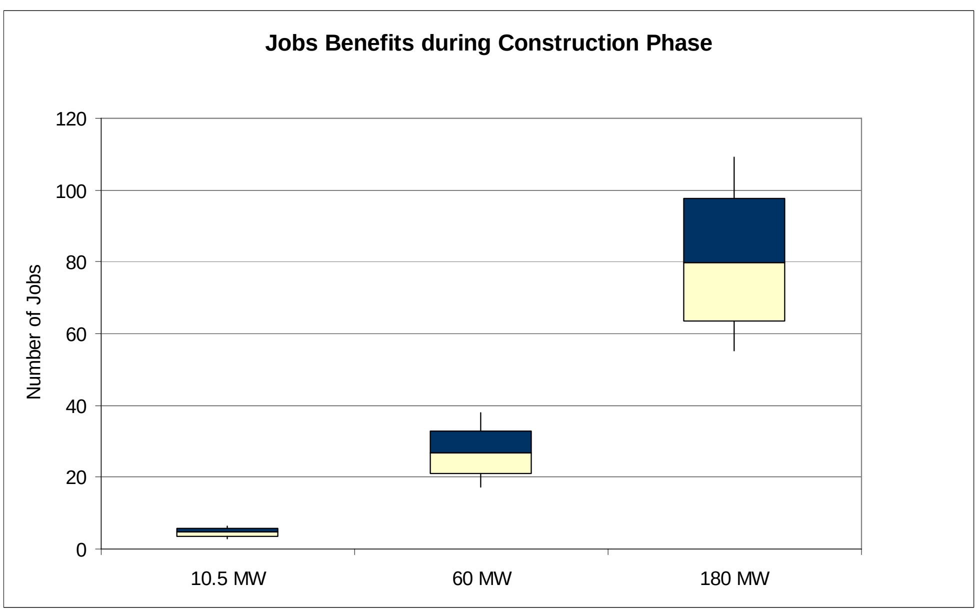


Figure 6 Wind Energy Project Impact on JOBS during Construction Phase

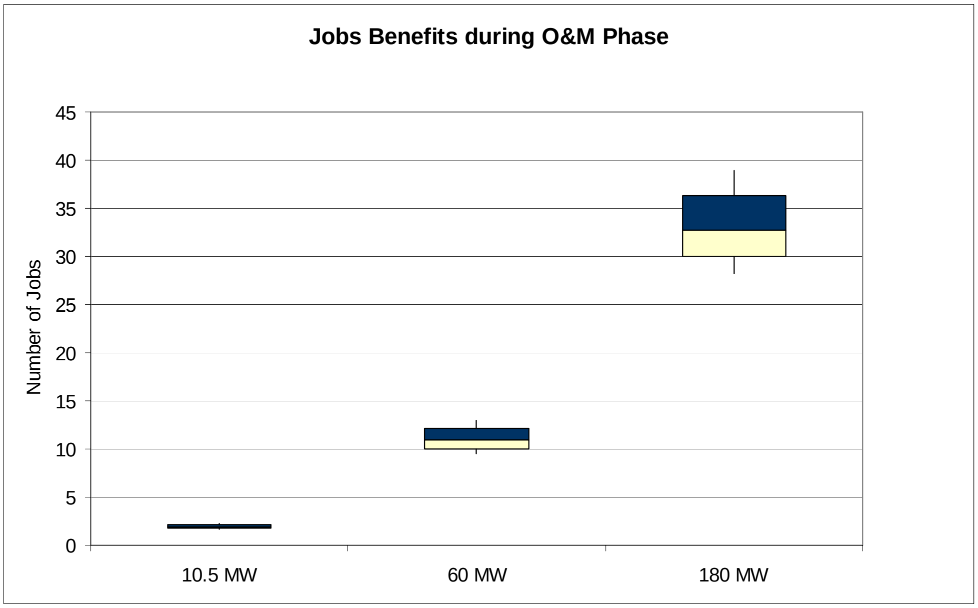


Figure 7 Wind Energy Project Impact on JOBS during O&M Phase

Earnings

Earnings refer to millions of dollars in wages and salary paid to workers. Results for earnings for all wind energy project sizes and phases are given in Figure 8 and Figure 9. A summary table is given in Appendix A-2. Based on simulation, there is a 90% likelihood that the earnings paid during the construction phase in Cochise County will be between $0.60 and $0.93 million annually for a 60 MW wind energy project (in 2007 dollars). During the O&M phase, there is a 90% likelihood that the annual earnings in Cochise County will be between $0.33 and $0.58 million.

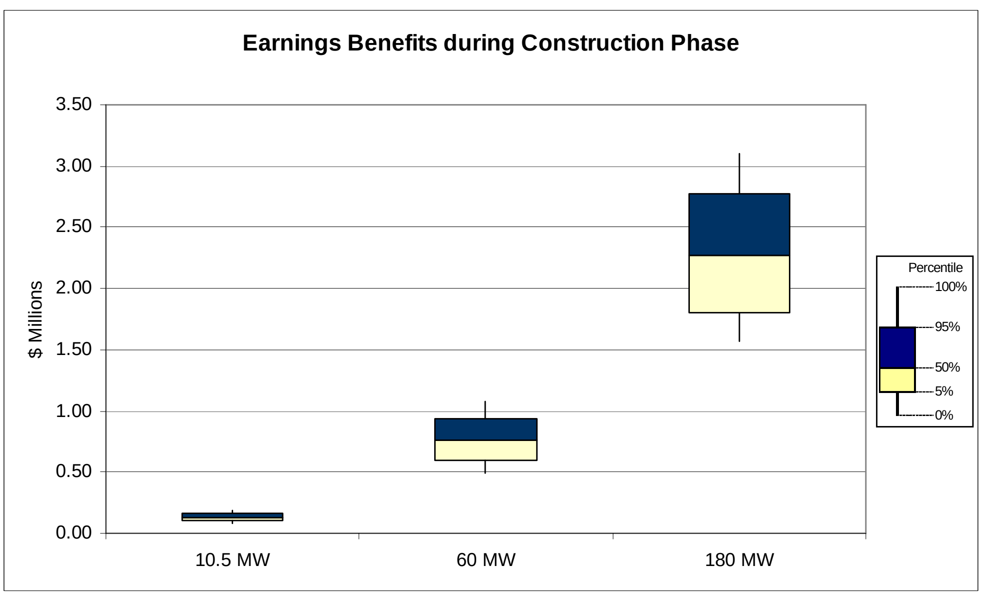


Figure 8 Wind Energy Project Impact on EARNINGS during Construction

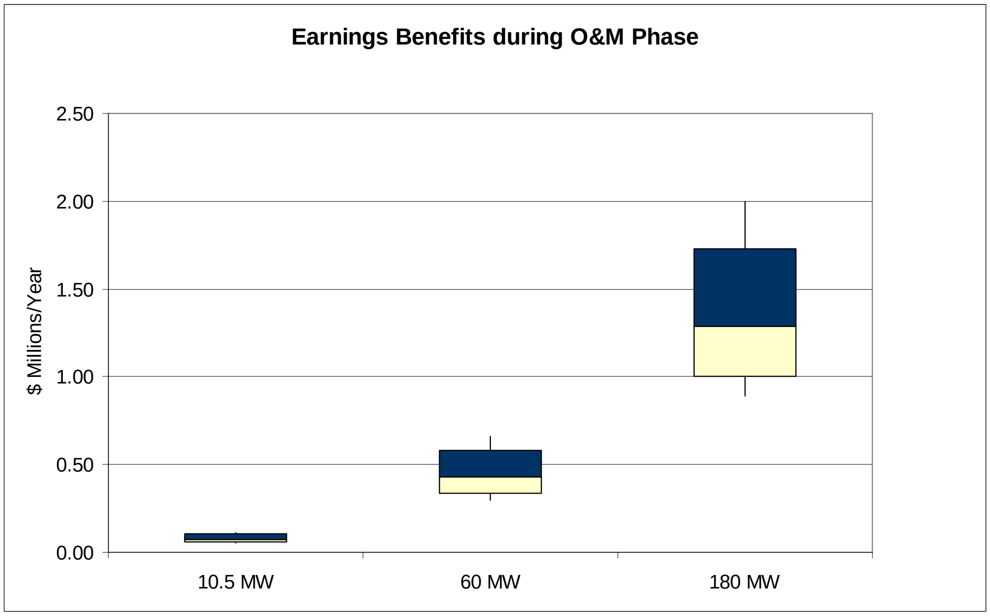


Figure 9 Wind Energy Project Impact on EARNINGS during O&M Phase

Output

Figure 10 and Figure 11 show a summary of output results for all wind energy project sizes and phases. A summary table is given in Appendix A-3. Output refers to economic activity or the value of production in the county and is also in millions of 2007 dollars. Based on the simulation results there is a 90% likelihood that the output will be between $2.52 and $3.95 million annually for Cochise County. During the O&M phase, there is a 90% likelihood that the annual output in Cochise County will be between $0.83 and $1.21 million.

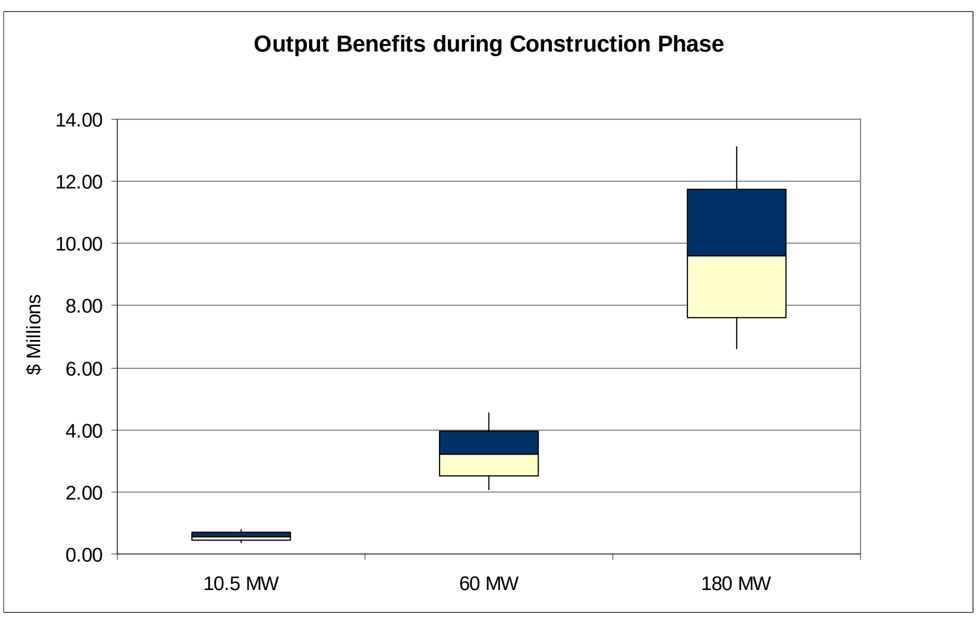


Figure 10 Wind Energy Project Impact on OUTPUT during Construction Phase

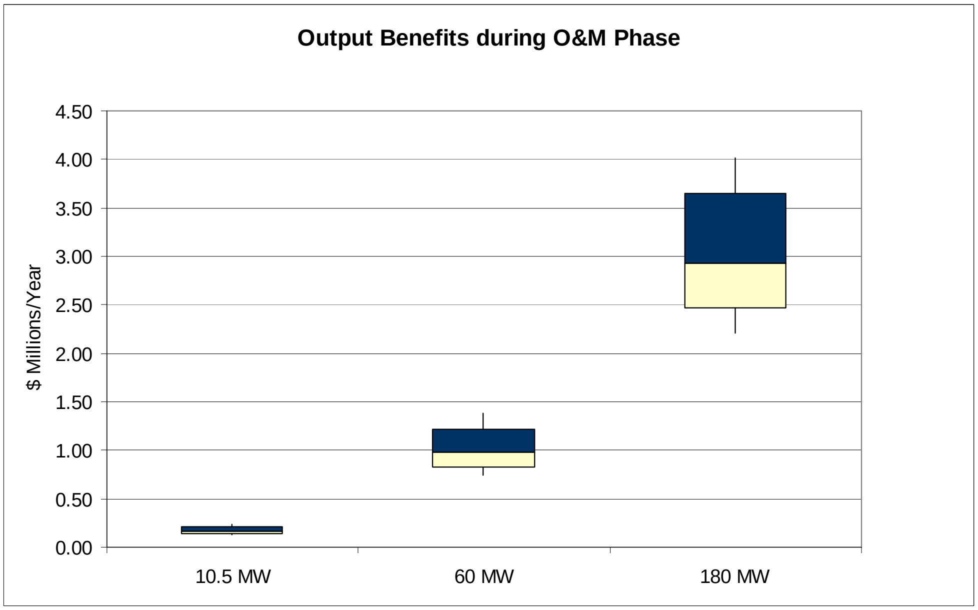


Figure 11 Wind Energy Project Impact on OUTPUT during O&M Phase

Conclusions

The first objective of this project was to estimate the wind energy development potential for Cochise County. Based on high-resolution wind map data analyzed in a GIS while considering development exclusions, it was estimated that the developable windy land and potential installed capacity for Cochise is approximately 275 MW. The majority of this capacity is from Class 3 wind. When this estimate is restricted to windy lands of class 4 or better, the developable capacity is 50 MW.

The second objective of this work was to estimate the economic impact of constructing and operating wind energy projects of various sizes in Cochise County. Monte Carlo simulation was conducted in conjunction with the JEDI model and provided a range of outputs corresponding to a range of estimated input parameters. For a 60 MW wind energy project, there is 90% likelihood that:

- number of jobs created during the construction phase is between 21 and 33 with a median of 27 jobs.
- number of jobs created during the O&M phase is between 10 and 12 with a median of 11.
- earnings during the construction phase is between $0.60 and $0.93 million with a median of $0.76 million in Cochise.
- earnings during the O&M phase is between $0.33 and $.58 million annually with a median of $0.43 million.
- output during the construction phase is between $2.52 and $3.95 million with a median of $3.21 million.
- output during the O&M phase is between $1.02 and $1.55 million annually with a median of $1.24 million.

Appendix A Tables of JEDI/Monte Carlo Simulation Results

Appendix A- 1 Wind Energy Project Impact on JOBS

	Jobs for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	3	2
5th	4	2
50th	5	2
95th	6	2
100th	6	2
	Jobs for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	17	10
5th	21	10
50th	27	11
95th	33	12
100th	38	13
	Jobs for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	55	28
5th	63	30
50th	80	33
95th	98	36
100th	109	39

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Construction Jobs for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had 33 or fewer Construction Jobs for a 60 MW Wind Farm. We interpret this as a 95% probably that the number of Construction Jobs for a 60 MW Wind Farm will be 33 or less. The 50th percentile represents the median.

Appendix A- 2 Wind Energy Project Impact on EARNINGS

($ millions)

	Earnings for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.09	0.05
5th	0.10	0.06
50th	0.13	0.08
95th	0.16	0.10
100th	0.18	0.11
	Earnings for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	0.49	0.30
5th	0.60	0.33
50th	0.76	0.43
95th	0.93	0.58
100th	1.07	0.66
	Earnings for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	1.56	0.89
5th	1.80	1.00
50th	2.27	1.29
95th	2.77	1.73
100th	3.10	2.00

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Earnings for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $0.93 million or less Earnings from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Earnings from a 60 MW Wind Farm will be $0.93 million or less. The 50th percentile represents the median.

Appendix A- 3 Wind Energy Project Impact on OUTPUT

($ millions)

	Output for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.36	0.13
5th	0.44	0.14
50th	0.56	0.17
95th	0.69	0.21
100th	0.78	0.23
	Output for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	2.06	0.75
5th	2.52	0.83
50th	3.21	0.98
95th	3.95	1.21
100th	4.55	1.38
	Output for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	6.63	2.21
5th	7.62	2.47
50th	9.59	2.92
95th	11.73	3.65
100th	13.10	4.02

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Output from a 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $3.95 million or less Output from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Output from a 60 MW Wind Farm will be $3.95 million or less. The 50th percentile represents the median.

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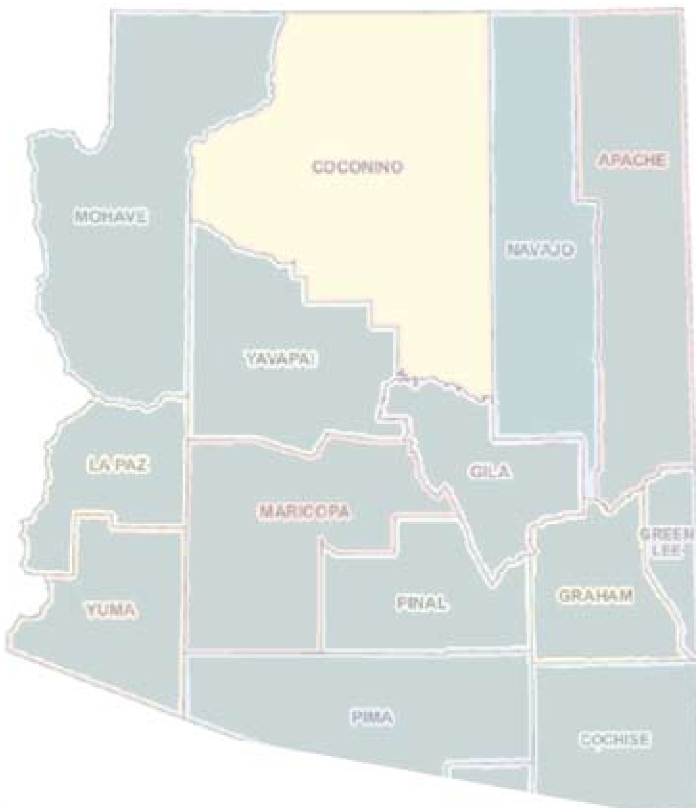
NORTHERN ARIZONA UNIVERSITY

Sustainable Energy Solutions

Arizona Wind Energy Assesment

Coconino County

Developable Windy Land
and Economic Benefits



Prepared for
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April 2007

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Abstract

This report contains two wind energy analyses for northern Arizona's Coconino County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Coconino County was estimated to be 7200 MW. The majority of developable windy land, 92%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Coconino County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 10.5 MW wind energy project

- *Jobs during construction*: median was 10 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 3 jobs
- *Earnings during construction*: the median was $0.27 million
- *Earnings during O&M phase*: median was $0.11 million annually
- *Output (economic activity) during construction*: median was $1.11 million
- *Output during O&M phase*: median was $0.22 million annually

For a 60 MW wind energy project

- *Jobs during construction*: median was 56 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 16 jobs
- *Earnings during construction*: the median was $1.58 million
- *Earnings during O&M phase*: median was $0.61 million annually
- *Output (economic activity) during construction*: median was $6.38 million
- *Output during O&M phase*: median was $1.24 million annually

For a 180 MW wind energy project

- *Jobs during construction*: median was 167 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 49 jobs
- *Earnings during construction*: the median was $4.72 million
- *Earnings during O&M phase*: median was $1.80 million annually
- *Output (economic activity) during construction*: median was $19.02 million
- *Output during O&M phase*: median was $3.74 million annually

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Introduction

The wind energy development potential and economic benefits were determined for a northern Arizona county, Coconino (see Figure 1). Using Geographic Information System (GIS) techniques on wind map data an estimate was made of the amount of developable windy land and potential installed. Secondly, an analysis was made of the economic impacts of constructing and operating wind energy projects in this county utilizing the Job and Economic Development Impact * (JEDI) model developed for National Renewable Energy Laboratory (NREL). Wind energy projects of three representative sizes were considered: 10.5 MW, 60 MW, and 180 MW. The JEDI model was used in conjunction with Monte Carlo simulation to estimate economic impacts at the county level. Direct, indirect and induced economic effects were estimated and categorized by jobs, earnings, and output (economic activity).

The wind maps and information in this report are *not* appropriate for siting wind energy projects. It is useful for discussing policy and locations that might be appropriate for further study. In order to site a wind energy project, an anemometer should be installed on the property and two years of data collected. More Arizona wind maps are available at www.ses.nau.edu.

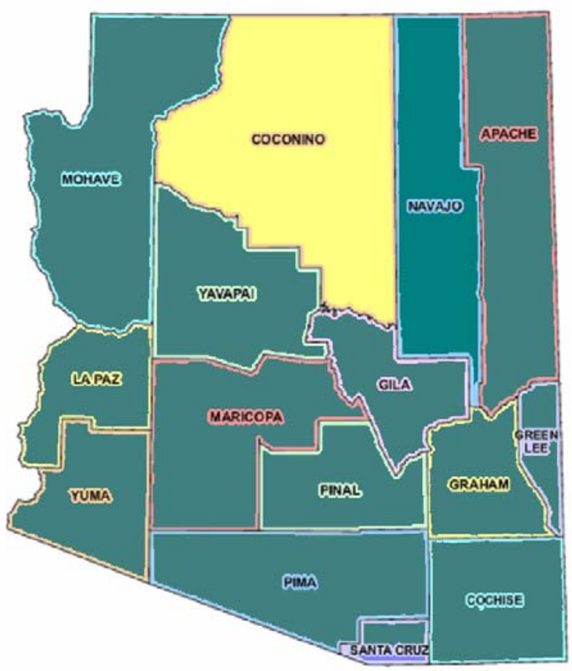

Figure 1 Coconino County in northern Arizona

* The JEDI model was designed by Marshall Goldberg, of MRG & Associates, under contract with NREL.The model is posted on the Wind Powering America website: http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=707 in June 2005.

State of Arizona

According to the US Census Bureau Quick Facts[1] the population in the state of Arizona increased 40% from 1990 to 2000. During this period US population increased 13.1%. Due to this rapid population and economic growth, electricity demand increased at the rate of 2.6% per year[2].

In 2001, the average electricity retail price for Arizona residents and businesses was 7.2 cents/kwh. This is the 16th highest average electricity price in the nation behind the six New England states, New York, New Jersey, Pennsylvania, California, Alaska, Hawaii, Texas, Florida, and Nevada. In addition to Arizona's increasing population, the hot climate and resulting need for air conditioning in the summer affect the increasing demand and price of electricity. Arizona has a larger than average residential demand largely due to the demand for air conditioning. The residential sector purchases 41% of the electricity as compared to 36% nationally[2].

Arizona primarily relies on coal and nuclear fuels for electrical generation. In 2000, approximately 45% of electricity was coal-generated and 35% was nuclear with only 10% generated from natural gas and another 10% by hydroelectric. However, the balance will be shifting to natural gas in the future as there are 16,000 MW of planned generation units by 2007, of which 15,000 MW are planned to be natural gas[2].

Coconino County

Coconino County is the largest county in Arizona and second largest county in the US. In central-northern Arizona, the 18,617 square miles are sparsely populated with a 2005 estimated population of 121,301. The area is known for many scenic sites, such as the Grand Canyon, Oak Creek Canyon, the San Francisco Peaks (highest point in AZ at 12,633 feet), and Lake Powell. Flagstaff is the county seat and largest community with a population of 59,160 in 2003[3]. Demographic information is given in Table 1[4] and industry sector information is given in Table 2[5].

The largest land ownership category in Coconino County, approximately 46%, is Indian Reservation (see Table 3)[3]. These lands are home to Navajo, Hopi, Paiute, Havasupai, and Hualapai tribes. In 1990, 14.2% of reservation households had no access to electricity as compared to 1.2% of all households nationally. On the Navajo Reservation, the number of households with no access to electricity is as large as 38%.[6]

Table 1 Coconino County Demographics

Demographic	Coconino
Population, 2005 estimate	121,301
Population, percent change, April 1, 2000 to July 1, 2005	4.3%
Population, percent change, 1990 to 2000	20.4%
High school graduates, percent of persons age 25+, 2000	83.8%
Bachelor's degree or higher, pct of persons age 25+, 2000	29.9%
Per capita money income, 1999	$17,139
Median household income, 2003	$38,980
Persons below poverty, percent, 2003	18.2%
Private nonfarm establishments, 2003	3,461
Private nonfarm employment, 2003	38,466
Private nonfarm employment, percent change 2000-2003	-1.2%
Retail sales, 2002 ($1000)	1,081,174
Retail sales per capita, 2002	$9,507
Land area, 2000 (square miles)	18,617
Persons per square mile, 2000	6.2
Metropolitan or Micropolitan Statistical Area	Flagstaff

Table 2 Coconino County Industry Sectors

Industry Sectors in Coconino County	Percent	Employed
Agriculture, forestry, fishing and hunting, and mining	1.7	957
Construction	7.7	4,265
Manufacturing	5.2	2,881
Wholesale trade	1.6	910
Retail trade	13.2	7,308
Transportation and warehousing, and utilities	5.4	2,991
Information	1.5	851
Finance, insurance, real estate, and rental and leasing	3.9	2,167
Professional, scientific, management, administrative, and waste management services	5.9	3,290
Educational, health and social services	26.9	14,918
Arts, entertainment, recreation, accommodation and food services	16.3	9,035
Other services (except public administration)	3.9	2,183
Public administration	6.8	3,754

Table 3 Land Ownership in Coconino County

Land owner	Coconino
Indian reservation	46%
US Forest Service & BLM	32%
State of AZ	10%
Other public lands	6%
Private	6%
	100%

Windy Land Analysis using GIS

Methodology

For the purpose of this analysis, *windy land* is defined as land with a wind resource greater than or equal to class three as predicted by the Arizona Wind Map (the wind map will be discussed in the section on Input Data). That is, predicted average annual wind speeds are large enough that wind energy may be produced economically. However, not all windy land may be developed for wind power. There are many *development exclusions* that must be considered. For instance, land that is owned by the National Park Service must be excluded 100% from consideration for development. *Developable windy land*, therefore, is the windy land that remains after all development exclusions have been applied. Finally, *excluded windy land* is windy land (class 3 and above) that falls within a development exclusion.

Consistent with the methodology applied by NREL, there are three general *exclusion* categories of land unsuitable for development[7]:

- environmental exclusions
- land use exclusions
- additional windy land factors

These development exclusions are summarized in Table 4. Any windy land with 1 or more exclusion is excluded windy land and is not appropriate to be used for wind energy projects. After removing excluded windy land, the remaining land is developable and an estimate of the potential installed capacity by wind class for each county was made by assuming a conservative 5 MW of installed capacity per square kilometer.

Input Data for Windy Land Analysis

TrueWind Solutions, in collaboration with NREL, developed a high-resolution wind map and GIS data for the state of Arizona in 2003. The data for this wind map was created using a numerical weather model coupled with climactic data and a wind flow model. The wind map provides 200-meter resolution data sufficient for identifying the most promising areas for wind development in the state. The data from this map was used to analyze the wind resource of Coconino County.

A *data layer* is a geographic data set that can be represented visually using GIS software. Several data layers were required for the windy land and exclusion analysis. For the exclusions analysis, the data layers, their exclusion category (environmental, land use, other factors), source and brief description are listed in Table 4.

Table 4 Wind Development Exclusions

Broad Exclusion Category	Exclusion	Exclusion[†] Percentage	Exclusion Description	GIS Layer Source
Environmental Exclusions	**National Park Service**	100%	United States National Park Service Land	ALRIS [‡]
	Fish and Wildlife Service	100%	United States Fish and Wildlife service	ALRIS
	Congressionally Specially Designated Areas	100%	Special Areas, like wilderness or wild, and scenic rivers, congressionally designated as such	USFS
	Inventoried Roadless Areas	100%	These are roadless areas of the country on federal land that have been congressionally designated as such	USFS
	State and Other Environmental Land (State GAP Data)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP
	Other: Wildlife, Wilderness and Recreation Areas on Federal land of any designation (predominately USFS and BLM lands)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP[§]
	Remaining USFS & DOD Land	50%	United States Forest Service and Department of Defense lands that remain after all other windy land exclusions are removed	ALRIS
Land Use Exclusions	**Urban/Developed Areas**	100%	Urban or Developed land as described by USGS ReGAP data	USGS AZ ReGAP
	Airports	100%	Airports	National Atlas of the United States, USGS, ESRI
	Wetlands	100%	Wetland ecosystems as described by USGS ReGAP data	USGS AZ ReGAP
	Water bodies (includes seasonal and dry lakes)	100%	Areas covered by water all year or part of the year. Does not include Rivers and Streams	USGS AZ ReGAP
	Non-ridge Crest Forests	50%	Areas of forest cover that are not considered ridge crests by TPI analysis	ReGAP + TPI [**]
Additional Windy Land Factors	**Slopes > 20%**	100%	These are landscapes with slopes greater than 20%	Grant Brummels

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[†] Windy land exclusions were excluded 100%, with the exception of "non-ridge crest forests" and "remaining USFS and DOD Land," which were excluded 50%. Additionally, all 100% exclusions were buffered 3km, except for wetlands (100m), open water (no buffer), and slopes > 20% (no buffer).[†] Non-ridge crest forests have had all 100% exclusions removed. Remaining USFS and DOD land has had all non-ridge crest forests and 100% exclusions removed.

[‡] ALRIS—Arizona Land Resource Information System

[§] ReGAP—Regional Gap Analysis Program, 30m satellite data

[**] Jenness, J. 2005. Topographic Position Index (tip_jen.avx) extension for ArcView 3.x. Jenness Enterprises. Available at: http://www.jennessent.com/arview/tpi.htm. TPI was applied to a 90m Digital Elevation Model.

Results of Windy Land Analysis

The windy land in Coconino County is shown in Figure 2. Using GIS, for each wind class the amount of land area with the corresponding wind resources was calculated. Approximately 5% of the county land is considered windy land. Of the windy land, the majority is class 3.

The development exclusions for Coconino County are mapped in Figure 3. As displayed, the land areas highlighted cannot be developed for wind energy regardless of how windy. In Coconino County, 1.8% of the total county land area is classified as development exclusions (windy and non-windy).

The exclusions remove 37.4% of windy land from consideration for development. See Figure 4 to compare the wind class breakdown of the amount of windy land with the wind class breakdown of the amount of developable windy land. When exclusions are considered, much of the excluded windy land is class 4 or higher. As a result, the proportional amounts of class 4 and above decrease with a corresponding increase in the proportional amount of class 3.

Some land is excluded under multiple categories. For instance, land may have a slope greater than 20% and also be National Park Service land. The largest exclusion affecting windy land is Slopes>20% and excludes 13.9% of windy land. Other exclusion categories that remove windy land are given in Table 5. The percentages will not add to 100% because trivial categories have not been included and because some land is excluded by multiple categories.

Table 6 provides a summary of the results of the windy land analysis for Coconino County. Organized by wind class, the total area of windy land, area of developable windy land, and potential developable capacity are shown. These tables also show that the total developable capacity in Coconino County is 7,168 MW. When restricting this estimate to windy lands of class 4 or better, the developable capacity for this county are 586 MW. Finally, the developable windy land is shown in Figure 5.

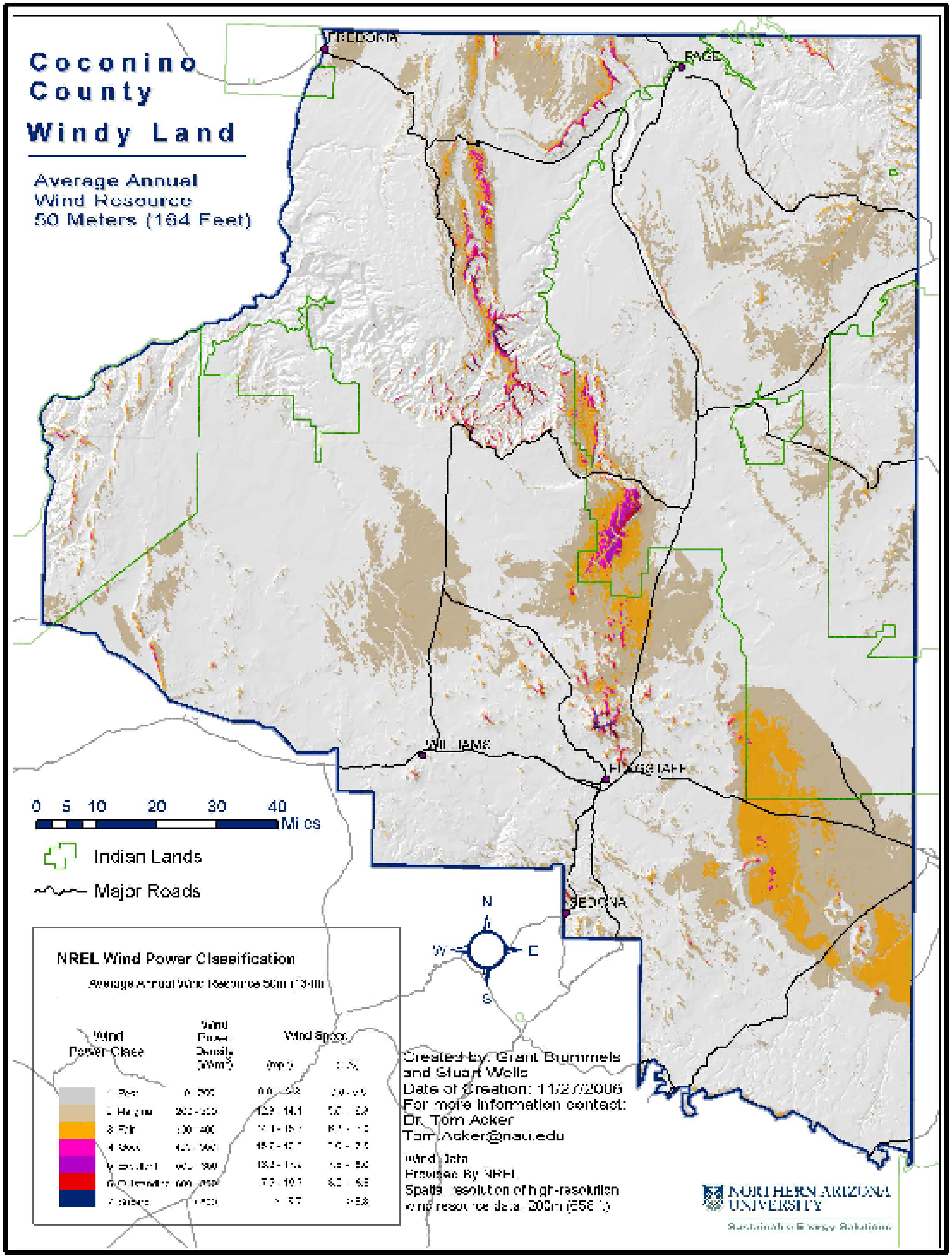


Figure 2 Map of Windy Land for Coconino County, AZ

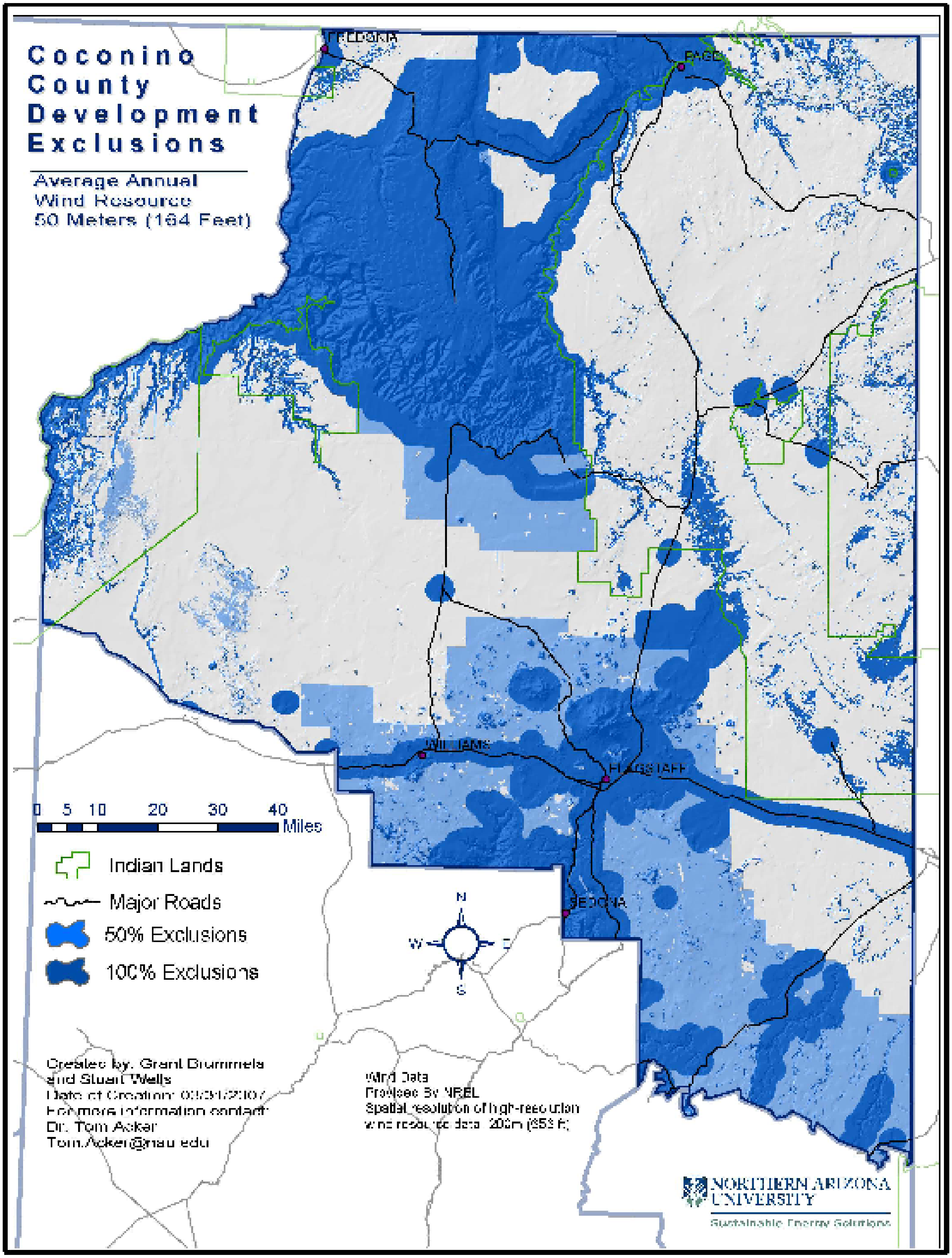
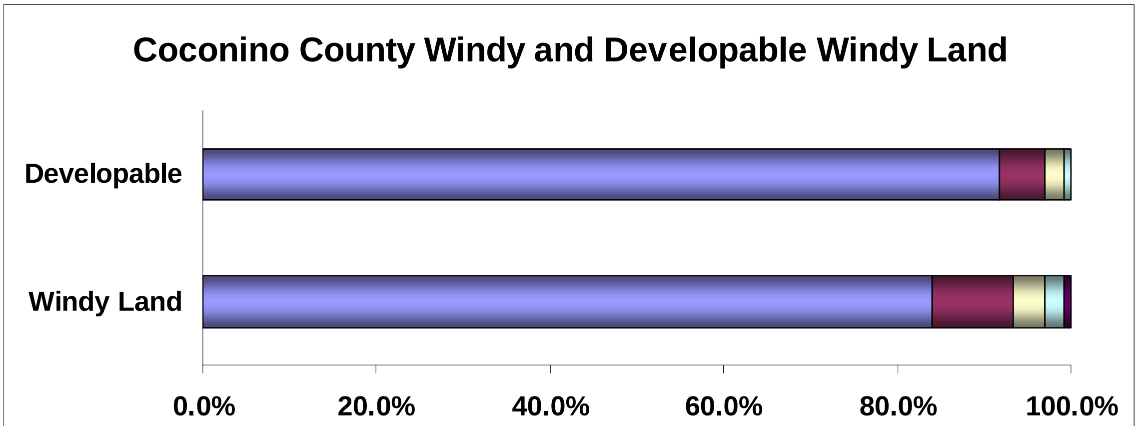


Figure 3 Map of Development Exclusions in Coconino County



	Windy Land	Developable
Class 7	0.8%	0.1%
Class 6	2.2%	0.8%
Class 5	3.7%	2.2%
Class 4	9.4%	5.3%
Class 3	83.9%	91.7%

Class 3 Class 4 Class 5 Class 6 Class 7

Figure 4 Windy Land and Developable Windy Land by Wind Class for Coconino County

Table 5 Coconino County Exclusion Categories that Remove Windy Land

Exclusion Category	**Windy Land Excluded**
Slopes > 20%	13.9%
Specially Designated Areas	11.6%
National Park Service	11.4%
Environmental Lands	10.6%
Urban/Developed Lands	6.0%

Table 6 Windy Land and Developable Windy Land in Coconino County

Coconino County Wind Class Area Analysis						
Wind Class	Power (w/m^2)	Total Area (km^2)	Windy Land as Percent of Total Land Area	Developable Windy Land (km^2)#	Developable Windy Land as Percent of Total Land Area	Developable Installed Capacity (MW)*
3	300-400	1,990	4.13%	1,316	2.735%	6,582
4	400-500	222	0.46%	74	0.154%	370
5	500-600	87	0.18%	31	0.065%	157
6	600-800	52	0.11%	11	0.022%	54
7	>800	20	0.04%	1	0.002%	5
		48,137	**Coconino County Total**			7,168

*Assuming 5 MW per sq. km.

#Exclusions determined using GIS analysis

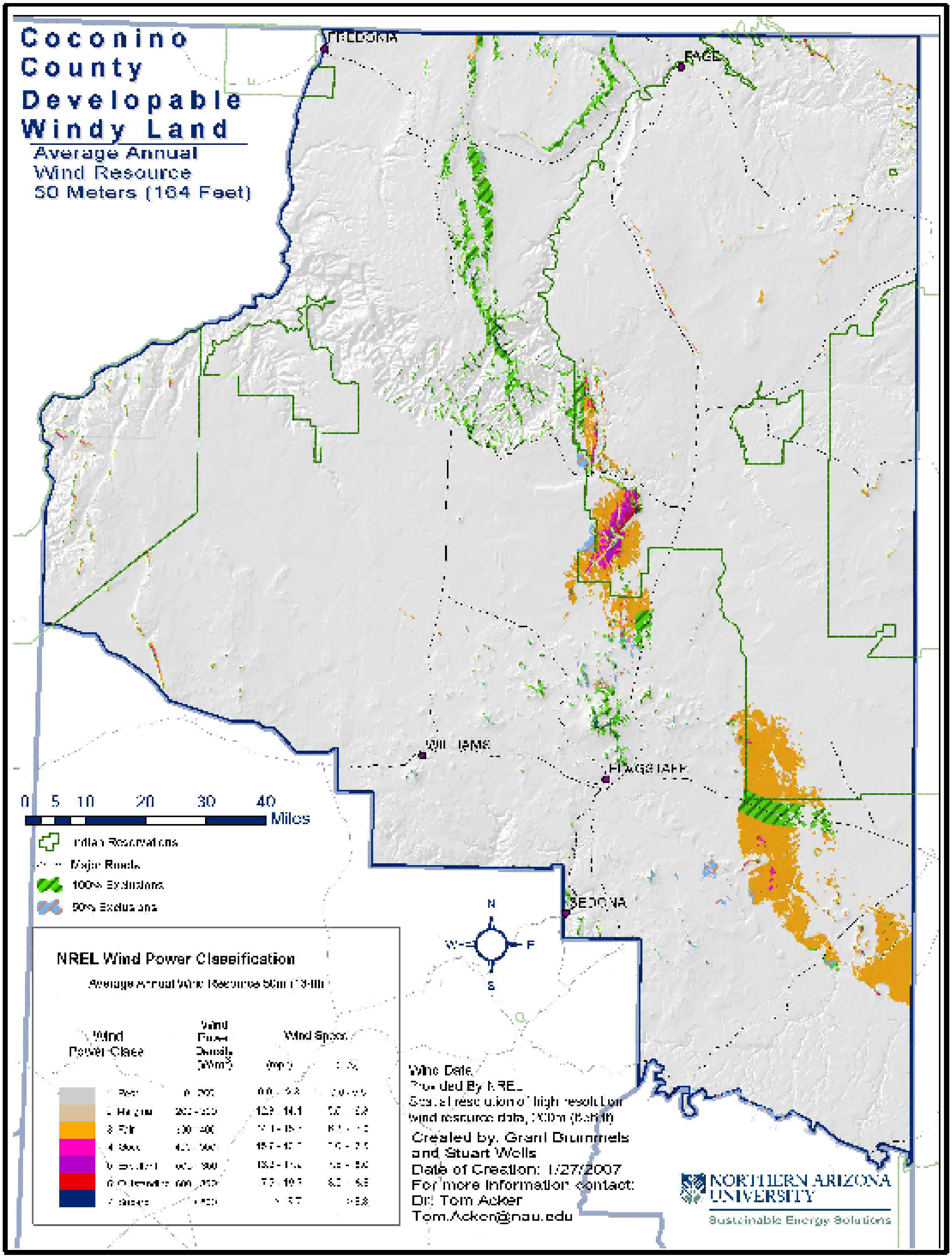


Figure 5 Map of Developable Windy Land for Coconino County

Economic Impact Analysis

In this study, economic input/output (I/O) analysis in conjunction with Monte Carlo simulation was used to estimate the economic impact for wind energy projects. The JEDI model performs I/O analysis with an Excel add-in, *@Risk*[8], used to perform the Monte Carlo simulation.

In I/O analysis, a project expenditure may have up to three impacts on the local economy:

- **Direct effects –** on-site effect created by expenditure (i.e., on-site jobs of contractors and crews, jobs at the turbine).
- **Indirect effects –** increase in economic activity that occurs when a contractor, vendor or manufacturer receives payment for goods or services and in turn is able to pay others who support their business.
- **Induced effects –** change in wealth and income that is induced by the spending of those persons directly and indirectly employed by the project (i.e., spending on food, clothes, utilities, transportation, insurance, medical, etc.).

The results of I/O analysis estimate these effects (direct, indirect, and induced) on the jobs, earnings, and economic output.

Methodology

JEDI Model

JEDI is a spreadsheet economic input/output model that accepts wind project data and estimates the direct, indirect, and induced effects of the expenditure to build and operate a wind energy project. The model separates a wind energy project into two distinct phases: construction phase and operations and maintenance (O&M) phase. The construction phase is approximately a year while the O&M phase is from the time the project is brought on-line until it is decommissioned. JEDI estimates the jobs, earnings, and economic activity for the one-time impact of the construction phase and the annual impact of the O&M phase.

JEDI was designed for users that have a variety of experience-levels in I/O analysis or with wind energy projects. To obtain results from JEDI, a user can input as little as the year of installation, the size of the project, and the state for which the economic impacts will be estimated. The remaining input has default values designed for a state-level analysis. As the user gains additional experience or information about the project, additional details can be entered into the model[9].

Why Monte Carlo simulation?

Monte Carlo simulation is a statistical simulation technique which allows input parameters that are uncertain to be randomly varied over a specified range of values. Multiple trials of the Monte Carlo model allow the user to observe and average the results of the output.[10] @Risk by Palisade Corporation[8], an add-in to Microsoft Office Excel, was utilized for Monte Carlo simulation.[11] Using Monte Carlo simulation in conjunction with the I/O analysis provided two advantages over an analysis with JEDI only:

1) Increased input flexibility – cost estimates may be entered as a range of values instead of a single estimate.

2) Increased output information –a range of output values was obtained instead of a single value.

The data required by the JEDI model to estimate the economic impact of constructing and operating a wind energy project can be difficult to accurately estimate. Some input parameters are specific to the site and design. However, estimates for economic impacts are often desired before a site and design have been selected. In addition some of this data is proprietary and industry norms must be relied on to estimate the parameters.

The approach in other work[12,13] has been to use a single estimate representing the most likely value or industry average. For each of the outputs, the JEDI model then produced a single value. By using Monte Carlo simulation any input parameters can be approximated by a range of input values. For each of these input parameters, three estimates were determined: (1) the most likely estimate, (2) the minimum estimate, and (3) the maximum estimate.

Running a simulation with these input parameters as random variables provides an expected value and a variance of the output variables. Therefore, the output is a range of values instead of a single number. This provides a measure of certainty or risk: the smaller the range, the more certainty in the results. When using the JEDI model, the economic impact is estimated using six measures: jobs during construction phase, jobs during O&M phase, earnings during construction phase, earnings during O&M phase, output during construction phase, and output during O&M phase.

Finally, the input parameter(s) which have the most influence on the output can be determined using Monte Carlo simulation. Effort can then be focused on accurately estimating those input parameters that have the most significant effect on the outputs.

Input Data for Economic Impact Analysis

Sources of information are documented. However, many modeling decisions are also based on information gained from discussion with wind energy professionals and experts. These discussions have occurred over time in many venues including the Arizona Wind Working Group and the AWEA Windpower meetings.

County Multipliers

In order to utilize JEDI for county-level analysis, appropriate multipliers for Coconino County were obtained from Marshal Goldberg via NREL. Specifically, the direct, indirect and induced multipliers for employment, earnings and output (per million dollars change in final demand) and personal consumption expenditures (i.e., average consumer expenditures on goods for the counties) were obtained[14]. Using the state-level multipliers that are provided with JEDI would overstate the economic benefits so it was important to obtain county-level multipliers for this analysis.

Wind Energy Project Size

Three wind energy project sizes were selected for the economic impact analysis. The sizes that were selected are based on discussions with wind energy experts and professionals, examination of the results of the windy land analysis and surveying the projects that came on-line in 2003-2004 in the southwest. For all analysis, 1.5 MW wind turbines were assumed.

The smallest project size considered was 10.5 MW and the largest was 180 MW. The mid-sized project was assumed to be 60 MW, which is the size of the wind project planned for Coconino County (Sunshine Wind Park near Winslow, Arizona) and the size of two wind energy projects built in the southwest in 2003-2004, Caprock Wind Ranch in New Mexico and the Oasis Wind Power Project in southern California. In the southwest during 2003-04, three wind energy projects were built that were in the size range of 160-200 MW (New Mexico Wind Energy Center, Colorado Green Lamar, Brazos Wind Ranch in Texas) [15]. To date, no utility-scale wind energy projects have been built in Arizona.

Construction Cost and Operations & Maintenance Cost

Construction cost and O&M cost depend on site and design specific data. Since the site and design were not known, these costs were estimated by a range of values. The estimates used for construction cost and operations and maintenance (O&M) cost are given in Table 7. Estimates for these costs are based on several sources including conversation with a wind developer[12,13,16,17].

Table 7 Input Parameter Estimates

Input Parameter	Minimum	Most Likely	Maximum
Construction Cost ($/kw)	$1,300	$1,500	$1,700
Annual Operating Cost ($/kw)	$9.50	$12.50	$25.00
Property Tax Rate	5.0%	7.6%	11.0%

Both construction cost and O&M cost were uncertain input parameters and were therefore simulated. The triangular distribution was used to generate these costs. The triangular distribution is often used in practice because it is uni-modal and may be non-symmetrical. In addition, there are fixed endpoints for the range of values. Finally, the triangular distribution is a good distribution to use in the absence of data. In the absence of data, experts can be surveyed and industry data consulted for averages. Experts can be asked for their subjective estimates of the minimum, most likely, and maximum values.[18]

Property tax calculation

To calculate the property tax in Arizona the construction cost which includes the cost of the equipment (wind turbines), building and installation costs, must first be determined. Typically, the *full-cost value* is 80% of the construction cost. Property taxes are based on the *assessed value* which is 25% of the full-cost value. The *property tax* is the tax rate multiplied by the assessed value, see Table 8

Table 8 Arizona Property Tax Calculation

Full Cost Value = 80% * Construction Cost
Assessed Value = 25% of Full Cost Value
Tax = Tax Rate * Assessed value

The tax rate varies significantly depending on the location within the state. The tax rate for the Sunshine Wind Park that is planned for eastern Coconino county will be 7.6%. This rate was used as the most likely estimate. Examining the tax tables, it was determined that the range of tax rates vary from a minimum of 5 to a maximum 11%. Tax rates were estimated from information obtained in conversations with the Coconino County Tax Assessor's office[3,19]. The property tax rate was simulated using a triangular distribution.

Local Share

Local share is the percentage of expenditures spent in the state or local region where the wind energy project is constructed. For this work, it represents the percentage of expenditures spent in the county. Currently, the JEDI model provides default values for local share percentages that are estimated at the state-level (See Table 9). The JEDI model default values are not appropriate for a county-level analysis as the results will be considerably overstated.

We developed local share percentages that apply to Coconino County by consulting with a wind developer and an economist. Constanti (2004) also provides guidance for setting the local share percentages for rural counties in Montana. Finally, we examined Coconino County demographics (Table 1, Table 2) focusing particularly on population and employment. Minimum and maximum local share percentages were established and are also shown in Table 9[12]. The local share percentages were simulated using a uniform distribution which implies that all values between the minimum and maximum (default) are equally likely.

Simulation Parameters

For each county and wind project size, a simulation was run. For each simulation, the number of trials was determined by observing the convergence of the distribution statistics for the output variables (construction phase: jobs, earnings, output; O&M phase: jobs, earnings, output). When the measured statistics changed no more than 1%, the output distribution was considered 'stable' and the simulation was considered to have converged. The number of trials in each simulation varied between 900 and 1100. The output distribution statistics that were measured are the average percent change of the percentiles, the mean, and the standard deviation.

Table 9 Local Shares Values[††]

Project Cost Data	JEDI default State-level Local Share	Coconino County Minimum Local Share	Coconino County Maximum Local Share
Construction Costs			
Materials			
Construction (concrete, rebar, equip, roads and site prep)	90%	50%	75%
Transformer	0%	0%	0%
Electrical (drop cable, wire,)	100%	25%	50%
HV line extension	100%	0%	10%
Labor			
Foundation	100%	75%	100%
Erection	75%	15%	25%
Electrical	75%	50%	75%
Management/supervision	0%	0%	0%
Equipment Costs			
Turbines (excluding blades and towers)	0%	0%	0%
Blades	0%	0%	0%
Towers	0%	0%	0%
Other Costs			
HV Sub/Interconnection	100%	25%	50%
Engineering	0%	0%	10%
Legal Services	100%	50%	75%
Land Easements	100%	100%	100%
Site Certificate/Permitting	100%	100%	100%
Wind Plant Annual Operating and Maintenance Costs			
Personnel			
Field Salaries	100%	75%	100%
Administrative	100%	75%	100%
Management	100%	75%	100%
Materials and Services			
Vehicles	100%	75%	100%
Misc. Services	80%	50%	75%
Fees, Permits, Licenses	100%	100%	100%
Utilities	100%	100%	100%
Insurance	0%	0%	0%
Fuel (motor vehicle gasoline)	100%	100%	100%
Tools and Misc. Supplies	100%	75%	100%
Spare Parts Inventory	2%	2%	2%

[††] JEDI default values should not be used for a county-level analysis. The JEDI default values are appropriate only for a state-level analysis. If used for a county-level analysis, benefits will be greatly overstated.

Results of Economic Impact Analysis

All economic outputs from JEDI are divided into benefits that occur during the construction phase (usually less than a year) and annual benefits that occur during the operational life of the wind project. For each phase, the model estimates:

- Jobs – the number of full-time equivalent employment for a year.
- Earnings - wage and salary compensation paid to workers.
- Output - economic activity or the value of production in the county economy.

For all three estimates, the simulation in conjunction with the JEDI model produces a frequency distribution. We report the percentiles for these distributions. The 50th percentile is the median. That is there is 50% chance that the number of jobs will be above the median and a 50% chance that the number of jobs will be below the median. We report the minimum, 5th percentile, 50th percentile, 95th percentile and maximum. There is a 95% likelihood that the number of jobs will be less than the 95th percentile.

Jobs

Results pertaining to job creation for each wind energy project size and project phase are given in Figure 6 and Figure 7. A summary table is given in Appendix A-1. Based on simulation, there is a 90% likelihood that the number of jobs created during the construction phase in Coconino County will be between 47 and 64 for a 60 MW wind energy project. During the O&M phase, there is a 90% likelihood that the number of jobs created in Coconino County will be between 15 and 18.

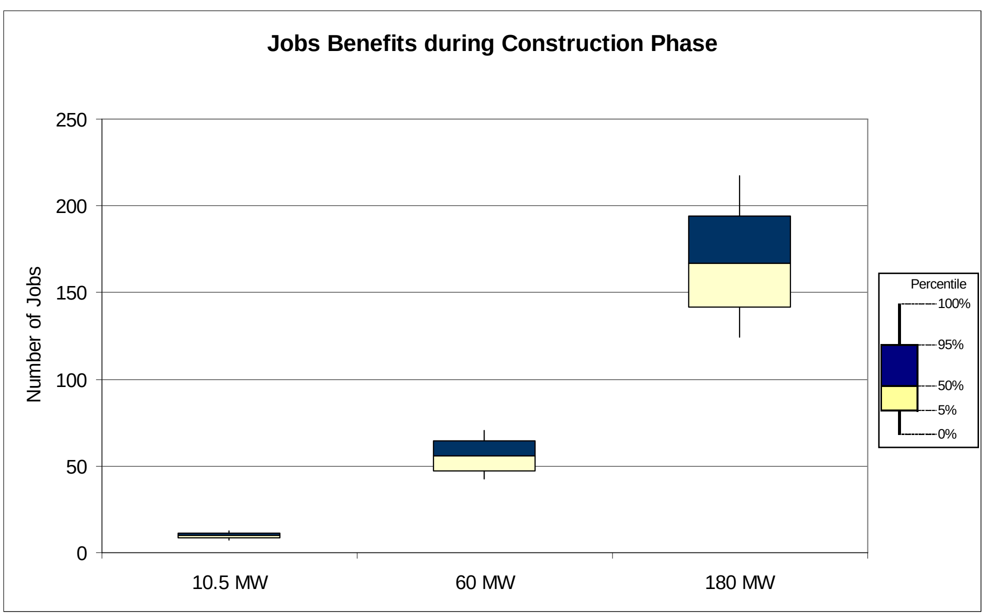


Figure 6 Wind Energy Project Impact on JOBS during Construction Phase

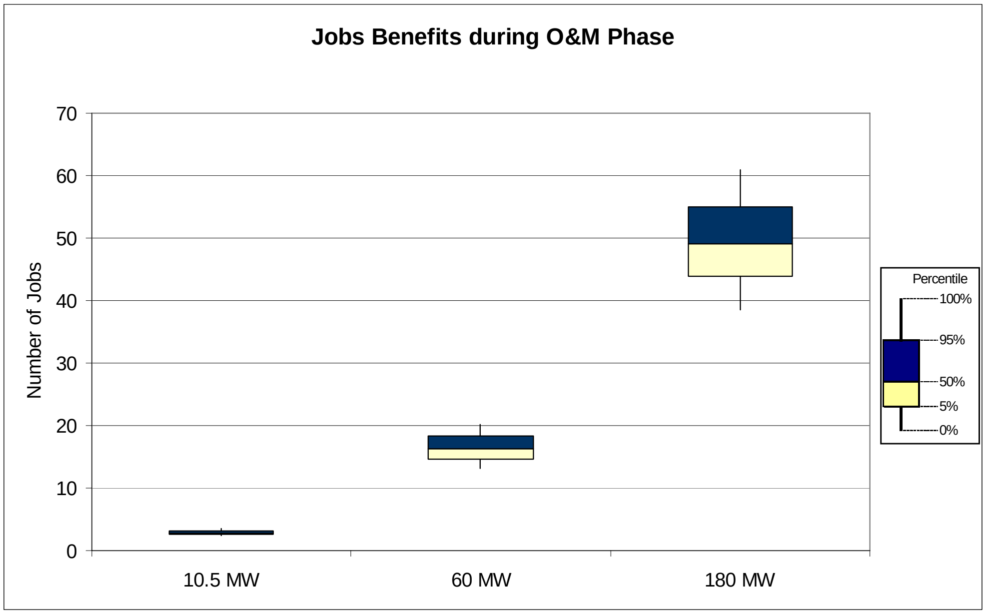


Figure 7 Wind Energy Project Impact on JOBS during O&M Phase

Earnings

Earnings refer to millions of dollars in wages and salary paid to workers. Results for earnings for all wind energy project sizes and phases are given in Figure 8 and Figure 9. A summary table is given in Appendix A-2. Based on simulation, there is a 90% likelihood that the earnings paid during the construction phase in Coconino County will be between $1.33 and $1.82 million annually for a 60 MW wind energy project (in 2007 dollars). During the O&M phase, there is a 90% likelihood that the annual earnings in Coconino County will be between $0.47 and $0.81 million.

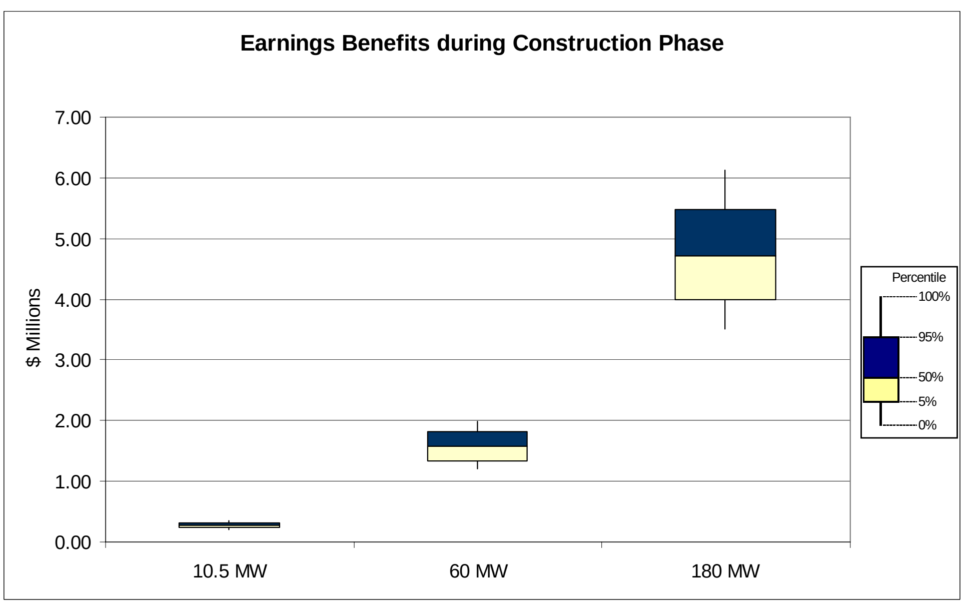


Figure 8 Wind Energy Project Impact on EARNINGS during Construction

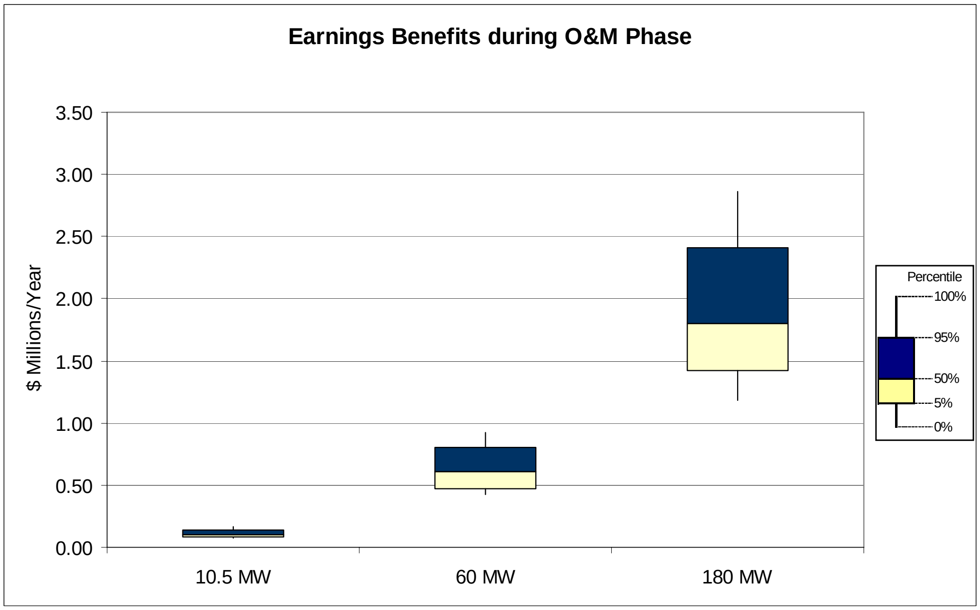


Figure 9 Wind Energy Project Impact on EARNINGS during O&M Phase

Output

Figure 10 and Figure 11 show a summary of output results for all wind energy project sizes and phases. A summary table is given in Appendix A-3. Output refers to economic activity or the value of production in the county and is also in millions of 2007 dollars. Based on the simulation results there is a 90% likelihood that the output will be between $5.37 and $7.33 million annually for Coconino County. During the O&M phase, there is a 90% likelihood that the annual output in Coconino County will be between $1.02 and $1.55 million.

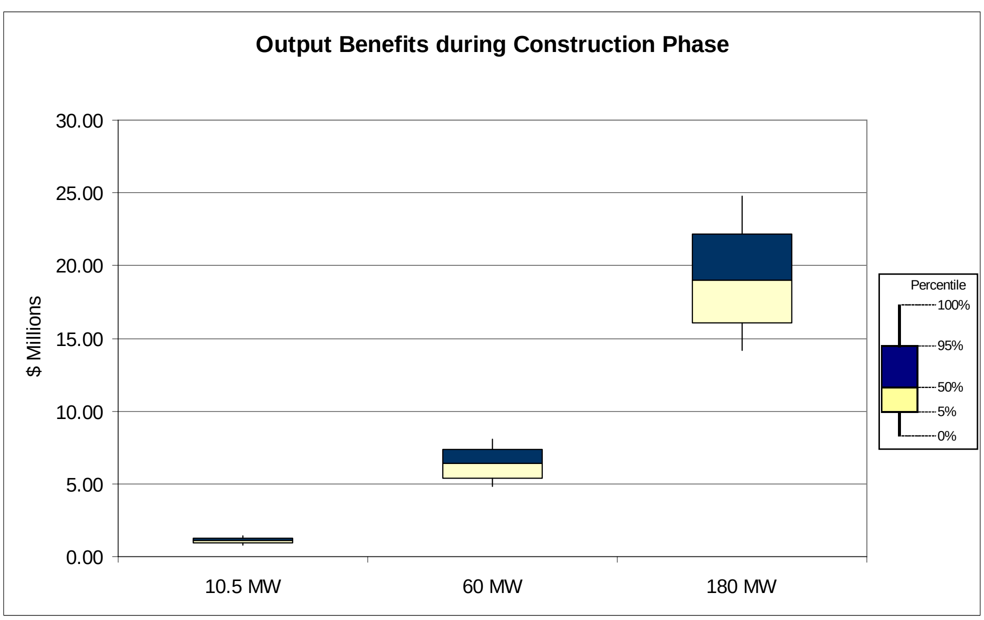


Figure 10 Wind Energy Project Impact on OUTPUT during Construction Phase

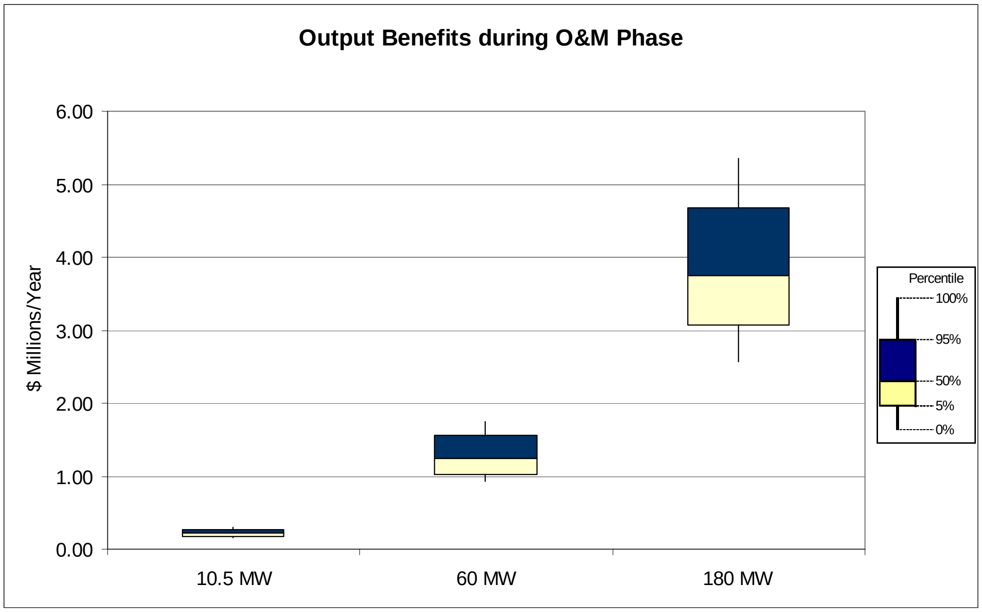


Figure 11 Wind Energy Project Impact on OUTPUT during O&M Phase

Conclusions

The first objective of this project was to estimate the wind energy development potential for Coconino County. Based on high-resolution wind map data analyzed in a GIS while considering development exclusions, it was estimated that the developable windy land and potential installed capacity for Coconino is approximately 7200 MW. The majority of this capacity is from Class 3 wind. When this estimate is restricted to windy lands of class 4 or better, the developable capacity is 590 MW.

The second objective of this work was to estimate the economic impact of constructing and operating wind energy projects of various sizes in Coconino County. Monte Carlo simulation was conducted in conjunction with the JEDI model and provided a range of outputs corresponding to a range of estimated input parameters. For a 60 MW wind energy project, there is 90% likelihood that:

- number of jobs created during the construction phase is between 47 and 64 with a median of 56 jobs.
- number of jobs created during the O&M phase is between 15 and 18 with a median of 16.
- earnings during the construction phase is between $1.33 and $1.82 million with a median of $1.58 million in Coconino.
- earnings during the O&M phase is between $0.47 and $.81 million annually with a median of $0.61 million.
- output during the construction phase is between $5.37 and $7.33 million with a median of $6.38 million.
- output during the O&M phase is between $1.02 and $1.55 million annually with a median of $1.24 million.

Appendix A Tables of JEDI/Monte Carlo Simulation Results

Appendix A- 1 Wind Energy Project Impact on JOBS

	Jobs for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	7	2
5th	8	3
50th	10	3
95th	11	3
100th	13	4
	Jobs for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	43	13
5th	47	15
50th	56	16
95th	64	18
100th	71	20
	Jobs for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	124	39
5th	142	44
50th	167	49
95th	194	55
100th	217	61

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Construction Jobs for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had 64 or fewer Construction Jobs for a 60 MW Wind Farm. We interpret this as a 95% probably that the number of Construction Jobs for a 60 MW Wind Farm will be 64 or less. The 50th percentile represents the median.

Appendix A- 2 Wind Energy Project Impact on EARNINGS

($ millions)

	Earnings for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.20	0.07
5th	0.24	0.08
50th	0.27	0.11
95th	0.32	0.14
100th	0.36	0.16
	Earnings for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	1.21	0.42
5th	1.33	0.47
50th	1.58	0.61
95th	1.82	0.81
100th	1.99	0.92
	Earnings for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	3.51	1.18
5th	4.00	1.42
50th	4.72	1.80
95th	5.48	2.41
100th	6.14	2.87

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Earnings for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $1.82 million or less Earnings from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Earnings from a 60 MW Wind Farm will be $1.82 million or less. The 50th percentile represents the median.

Appendix A- 3 Wind Energy Project Impact on OUTPUT

($ millions)

	Output for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.82	0.16
5th	0.95	0.18
50th	1.11	0.22
95th	1.30	0.27
100th	1.44	0.30
	Output for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	4.87	0.92
5th	5.37	1.02
50th	6.38	1.24
95th	7.33	1.55
100th	8.04	1.76
	Output for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	14.14	2.57
5th	16.10	3.08
50th	19.02	3.74
95th	22.14	4.68
100th	24.79	5.36

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Output from a 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $7.33 million or less Output from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Output from a 60 MW Wind Farm will be $7.33 million or less. The 50th percentile represents the median.

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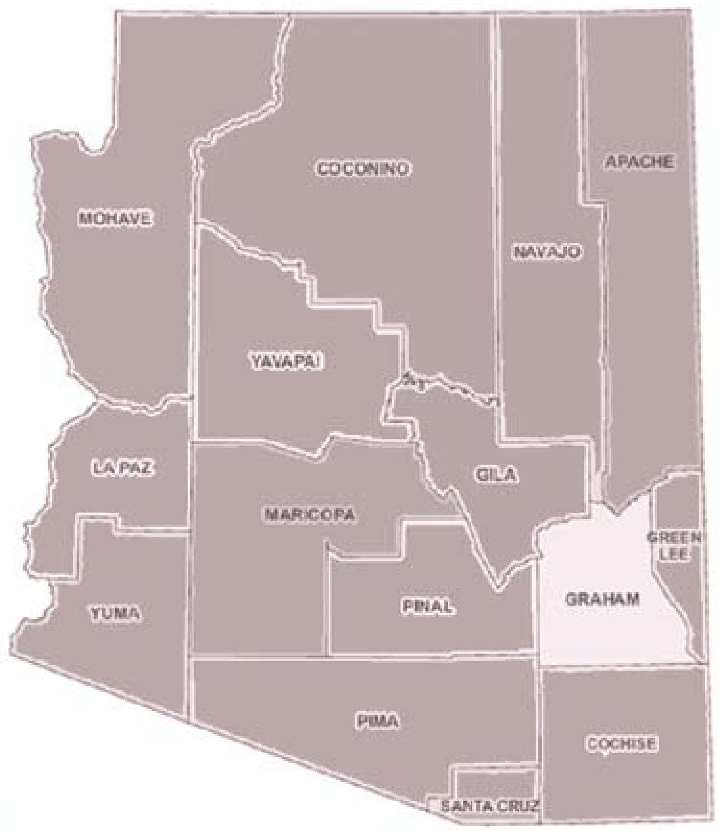
NORTHERN ARIZONA UNIVERSITY

Sustainable Energy Solutions

Arizona Wind Energy Assesment

Graham County

Developable Windy Land
and Economic Benefits



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April 2007

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Abstract

This report contains two wind energy analyses for the southeastern-Arizona's Graham County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class in each county was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Graham County was estimated to be 340 MW. The majority of developable windy land, 82%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Graham County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 10.5 MW wind energy project

- *Jobs during construction*: median was 1 job
- *Jobs during operations and maintenance phase (O&M phase)*: median was 3 jobs
- *Earnings during construction*: the median was $0.03 million
- *Earnings during O&M phase*: median was $0.09 million annually
- *Output (economic activity) during construction*: median was $0.15 million
- *Output during O&M phase*: median was $0.21 million annually

For a 60 MW wind energy project

- *Jobs during construction*: median was 9 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 17 jobs
- *Earnings during construction*: the median was $0.16 million
- *Earnings during O&M phase*: median was $0.51 million annually
- *Output (economic activity) during construction*: median was $0.88 million
- *Output during O&M phase*: median was $1.20 million annually

For a 180 MW wind energy project

- *Jobs during construction*: median was 26 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 51 jobs
- *Earnings during construction*: the median was $0.48 million
- *Earnings during O&M phase*: median was $1.53 million annually
- *Output (economic activity) during construction*: median was $2.63 million
- *Output during O&M phase*: median was $3.60 million annually
- *Output during O&M phase*: median was $3.74 million annually

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Introduction

The wind energy development potential and economic benefits were determined for a southeastern Arizona county, Graham (see Figure 1). Using Geographic Information System (GIS) techniques on wind map data an estimate was made of the amount of developable windy land and potential installed. Secondly, an analysis was made of the economic impacts of constructing and operating wind energy projects in this county utilizing the Job and Economic Development Impact * (JEDI) model developed for National Renewable Energy Laboratory (NREL). Wind energy projects of three representative sizes were considered: 10.5 MW, 60 MW, and 180 MW. The JEDI model was used in conjunction with Monte Carlo simulation to estimate economic impacts at the county level. Direct, indirect and induced economic effects were estimated and categorized by jobs, earnings, and output (economic activity).

The wind maps and information in this report are *not* appropriate for siting wind energy projects. It is useful for discussing policy and locations that might be appropriate for further study. In order to site a wind energy project, an anemometer should be installed on the property and two years of data collected. More Arizona wind maps are available at www.ses.nau.edu.

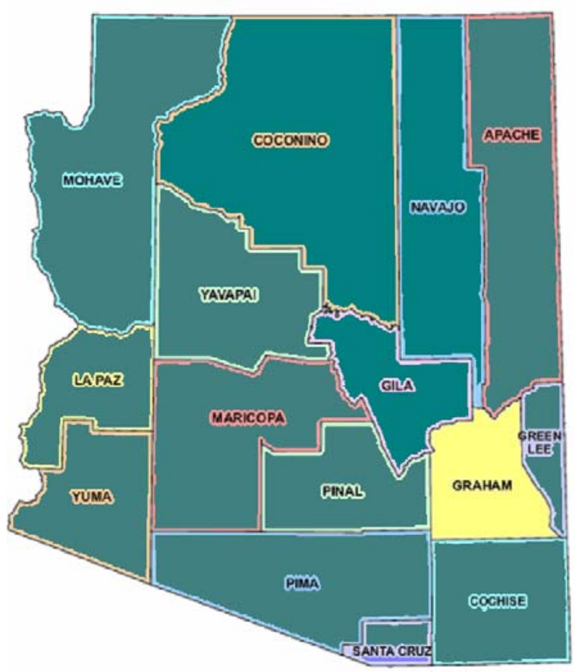


Figure 1 Graham County in northern Arizona

* The JEDI model was designed by Marshall Goldberg, of MRG & Associates, under contract with NREL.The model is posted on the Wind Powering America website: http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=707 in June 2005.

State of Arizona

According to the US Census Bureau Quick Facts[1] the population in the state of Arizona increased 40% from 1990 to 2000. During this period US population increased 13.1%. Due to this rapid population and economic growth, electricity demand increased at the rate of 2.6% per year[2].

In 2001, the average electricity retail price for Arizona residents and businesses was 7.2 cents/kwh. This is the 16th highest average electricity price in the nation behind the six New England states, New York, New Jersey, Pennsylvania, California, Alaska, Hawaii, Texas, Florida, and Nevada. In addition to Arizona's increasing population, the hot climate and resulting need for air conditioning in the summer affect the increasing demand and price of electricity. Arizona has a larger than average residential demand largely due to the demand for air conditioning. The residential sector purchases 41% of the electricity as compared to 36% nationally[2].

Arizona primarily relies on coal and nuclear fuels for electrical generation. In 2000, approximately 45% of electricity was coal-generated and 35% was nuclear with only 10% generated from natural gas and another 10% by hydroelectric. However, the balance will be shifting to natural gas in the future as there are 16,000 MW of planned generation units by 2007, of which 15,000 MW are planned to be natural gas[2].

Graham County

Graham County, in southeastern Arizona, is 4,630 square miles with a 2003 population of 34,490. A rich agricultural area, recreation and tourism are also significant industries. The Gila River traverses the county from east to west and Mount Graham (10,516 ft) is the county's namesake. Safford is the county seat and largest community with a population of 9,410 in 2003[3]. Demographic information is given in Table 1[4] and industry sector information is given in Table 2[5].

The largest land ownership category in Graham County, approximately 38% is US Forest Service and BLM land. One third of land ownership is the San Carlos Indian Reservation (see Table 3)[3]. In 1990, 14.2% of nation-wide reservation households had no access to electricity as compared to 1.2% of all households nationally.

Table 1 Graham County Demographics

Demographic	Graham
Population, 2005 estimate	33,073
Population, percent change, April 1, 2000 to July 1, 2005	-1.2%
Population, percent change, 1990 to 2000	26.1%
High school graduates, percent of persons age 25+, 2000	75.6%
Bachelor's degree or higher, pct of persons age 25+, 2000	11.8%
Per capita money income, 1999	$12,139
Median household income, 2003	$29,993
Persons below poverty, percent, 2003	20.5%
Private nonfarm establishments, 2003	502
Private nonfarm employment, 2003	4,805
Private nonfarm employment, percent change 2000-2003	-2.7%
Retail sales, 2002 ($1000)	226,262
Retail sales per capita, 2002	$6,808
Land area, 2000 (square miles)	4,629
Persons per square mile, 2000	7.2
Metropolitan or Micropolitan Statistical Area	Safford

Table 2 Graham County Industry Sectors

Industry Sectors in Graham County	Percent	Employed
Agriculture, forestry, fishing and hunting, and mining	13.4	1432
Construction	8.7	930
Manufacturing	3.1	333
Wholesale trade	2	210
Retail trade	12.4	1,326
Transportation and warehousing, and utilities	3.1	336
Information	1.4	148
Finance, insurance, real estate, and rental and leasing	2.9	315
Professional, scientific, management, administrative, and waste management services	3.7	393
Educational, health and social services	24.9	2,662
Arts, entertainment, recreation, accommodation and food services	9	963
Other services (except public administration)	4.3	461
Public administration	11.1	1,183

Table 3 Land Ownership in Graham County

Land owner	Graham
US Forest Service & BLM	38%
Indian reservation	35%
State of AZ	18%
Private	9%
	100%

Windy Land Analysis using GIS

Methodology

For the purpose of this analysis, *windy land* is defined as land with a wind resource greater than or equal to class three as predicted by the Arizona Wind Map (the wind map will be discussed in the section on Input Data). That is, predicted average annual wind speeds are large enough that wind energy may be produced economically. However, not all windy land may be developed for wind power. There are many *development exclusions* that must be considered. For instance, land that is owned by the National Park Service must be excluded 100% from consideration for development. *Developable windy land*, therefore, is the windy land that remains after all development exclusions have been applied. Finally, *excluded windy land* is windy land (class 3 and above) that falls within a development exclusion.

Consistent with the methodology applied by NREL, there are three general *exclusion* categories of land unsuitable for development[6]:

- environmental exclusions
- land use exclusions
- additional windy land factors

These development exclusions are summarized in Table 4. Any windy land with 1 or more exclusion is excluded windy land and is not appropriate to be used for wind energy projects. After removing excluded windy land, the remaining land is developable and an estimate of the potential installed capacity by wind class for each county was made by assuming a conservative 5 MW of installed capacity per square kilometer.

Input Data for Windy Land Analysis

TrueWind Solutions, in collaboration with NREL, developed a high-resolution wind map and GIS data for the state of Arizona in 2003. The data for this wind map was created using a numerical weather model coupled with climactic data and a wind flow model. The wind map provides 200-meter resolution data sufficient for identifying the most promising areas for wind development in the state. The data from this map was used to analyze the wind resource of Graham County.

A *data layer* is a geographic data set that can be represented visually using GIS software. Several data layers were required for the windy land and exclusion analysis. For the exclusions analysis, the data layers, their exclusion category (environmental, land use, other factors), source and brief description are listed in Table 4.

Table 4 Wind Development Exclusions

Broad Exclusion Category	Exclusion	Exclusion[†] Percentage	Exclusion Description	GIS Layer Source
Environmental Exclusions	**National Park Service**	100%	United States National Park Service Land	ALRIS [‡]
	Fish and Wildlife Service	100%	United States Fish and Wildlife service	ALRIS
	Congressionally Specially Designated Areas	100%	Special Areas, like wilderness or wild, and scenic rivers, congressionally designated as such	USFS
	Inventoried Roadless Areas	100%	These are roadless areas of the country on federal land that have been congressionally designated as such	USFS
	State and Other Environmental Land (State GAP Data)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP
	Other: Wildlife, Wilderness and Recreation Areas on Federal land of any designation (predominately USFS and BLM lands)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP[§]
	Remaining USFS & DOD Land	50%	United States Forest Service and Department of Defense lands that remain after all other windy land exclusions are removed	ALRIS
Land Use Exclusions	**Urban/Developed Areas**	100%	Urban or Developed land as described by USGS ReGAP data	USGS AZ ReGAP
	Airports	100%	Airports	National Atlas of the United States, USGS, ESRI
	Wetlands	100%	Wetland ecosystems as described by USGS ReGAP data	USGS AZ ReGAP
	Water bodies (includes seasonal and dry lakes)	100%	Areas covered by water all year or part of the year. Does not include Rivers and Streams	USGS AZ ReGAP
	Non-ridge Crest Forests	50%	Areas of forest cover that are not considered ridge crests by TPI analysis	ReGAP + TPI [**]
Additional Windy Land Factors	**Slopes > 20%**	100%	These are landscapes with slopes greater than 20%	Grant Brummels

[†] Windy land exclusions were excluded 100%, with the exception of "non-ridge crest forests" and "remaining USFS and DOD Land," which were excluded 50%. Additionally, all 100% exclusions were buffered 3km, except for wetlands (100m), open water (no buffer), and slopes > 20% (no buffer).[†] Non-ridge crest forests have had all 100% exclusions removed. Remaining USFS and DOD land has had all non-ridge crest forests and 100% exclusions removed.

[‡] ALRIS—Arizona Land Resource Information System

[§] ReGAP—Regional Gap Analysis Program, 30m satellite data

[**] Jenness, J. 2005. Topographic Position Index (tip_jen.avx) extension for ArcView 3.x. Jenness Enterprises. Available at: http://www.jennessent.com/arview/tpi.htm. TPI was applied to a 90m Digital Elevation Model.

Results of Windy Land Analysis

The windy land in Graham County is shown in Figure 2. Using GIS, the square kilometers of land was then totaled by wind class. Approximately 1.5% of the land is considered windy land. Of the windy land, the majority is class 3.

The development exclusions for Graham County are mapped in Figure 3. As displayed, the land areas highlighted in blue show the areas that cannot be developed for wind energy regardless of how windy since this land was classified as a development exclusions. In Graham County, 2.6% of the total county land area is classified as development exclusions.

Exclusions are significant in Graham County – 88.9% of windy land is excluded from consideration for development. See Figure 4 to compare the wind class breakdown of the amount of windy land with the wind class breakdown of the amount of developable windy land. When exclusions are considered, much of the excluded windy land is higher than class 3. As a result, the proportional amounts of class 4 and above decrease with a corresponding increase in the proportional amount of class 3.

Some land is excluded under multiple categories. For instance, a cell may have a slope greater than 20% and also be a Specially Designated Area. The largest exclusion affecting windy land is Slopes>20% and excludes 63.5% of windy land. Other exclusion categories that remove windy land are given in Table 5. The percentages will not add to 100% because trivial categories have not been included and because some land is excluded by multiple categories.

Table 6 provides a summary of the results of the windy land analysis for Graham County. Organized by wind class, the total area of windy land, area of developable windy land, and potential developable capacity are shown. These tables also show that the total developable capacity in Graham County is 339 MW. When restricting this estimate to windy lands of class 4 or better, the developable capacity is 60 MW. Finally, the developable windy land mapped by wind class is shown in Figure 5.

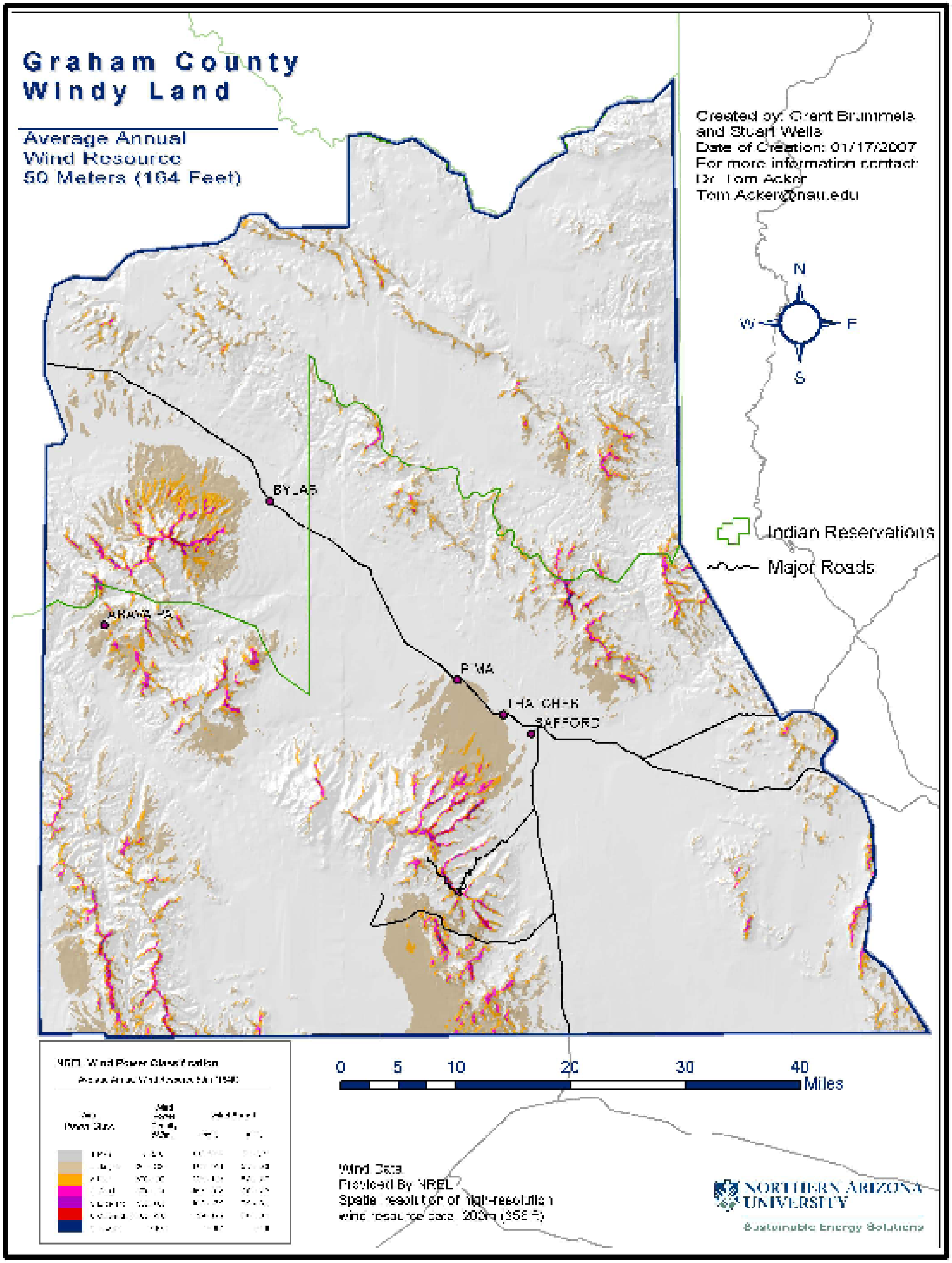


Figure 2 Map of Windy Land for Graham County, AZ

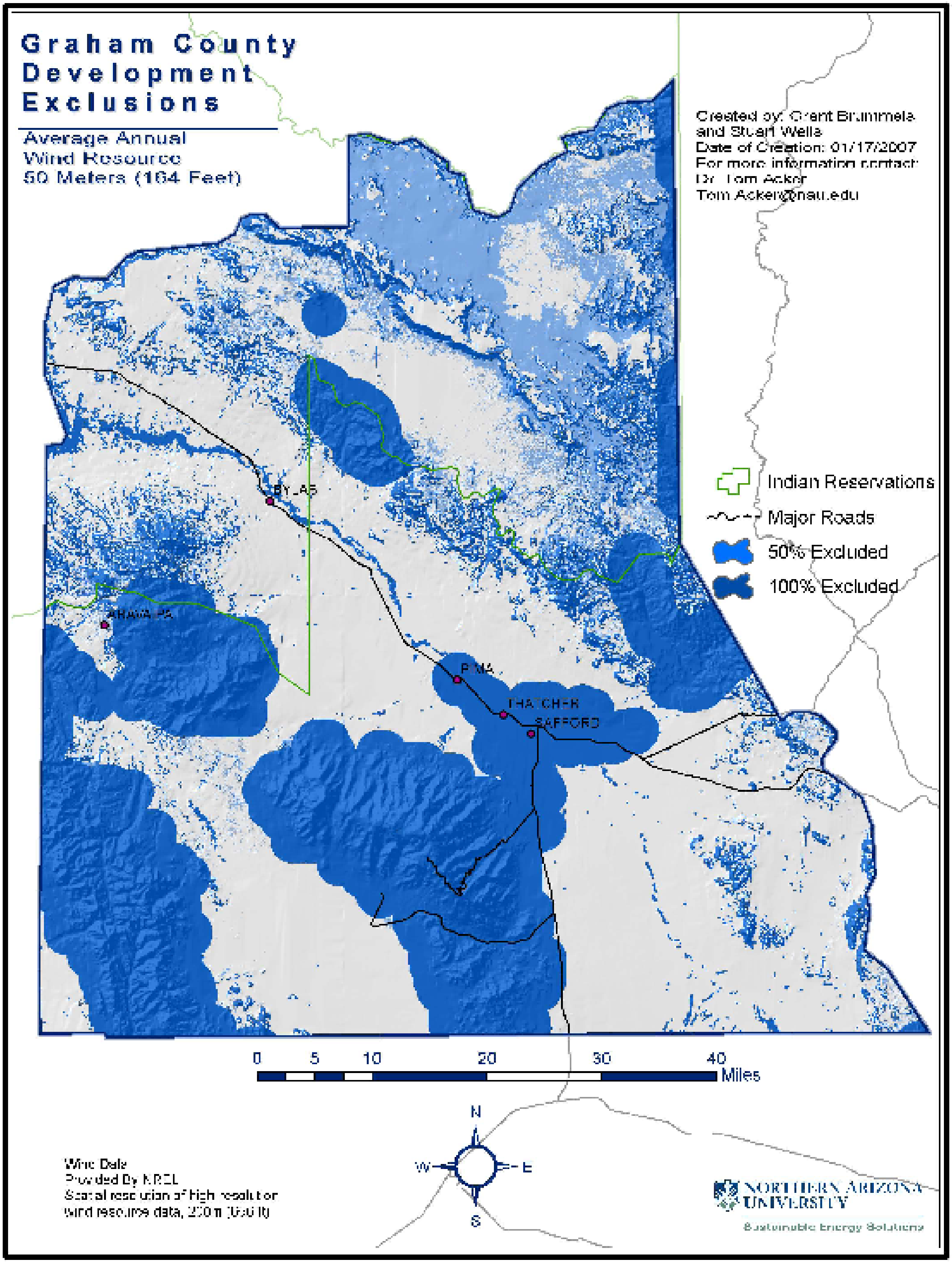
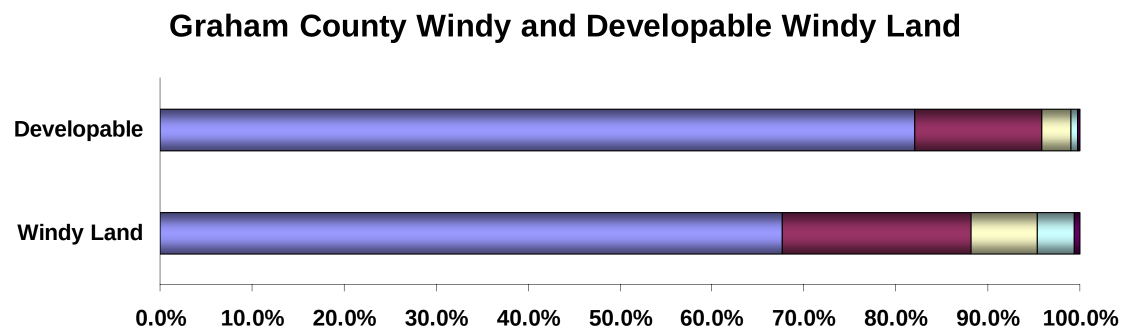


Figure 3 Map of Development Exclusions in Graham County



	Windy Land	Developable
Class 7	0.6%	0.2%
Class 6	4.1%	0.8%
Class 5	7.1%	3.2%
Class 4	20.6%	13.8%
Class 3	67.7%	82.0%

Figure 4 Windy Land and Developable Windy Land by Wind Class for Graham County

Table 5 Graham County Exclusion Categories that Remove Windy Land

Exclusion Category	Windy Land Excluded
Slopes > 20%	63.5%
Inventoried Roadless Areas	43.4%
Specially Designated Areas	37.9%
Environmental Lands	24.8%

Table 6 Windy Land and Developable Windy Land in Graham County

Graham County Wind Class Area Analysis						
Wind Class	Power (w/m^2)	Total Area (km^2)	Windy Land as Percent of Total Land Area	Developable Windy Land (km^2)#	Developable Windy Land as Percent of Total Land Area	Developable Installed Capacity (MW)*
3	300-400	256	1.00%	56	0.22%	279
4	400-500	78	0.30%	9	0.04%	47
5	500-600	27	0.11%	2	0.01%	10
6	600-800	15	0.06%	0	0.00%	2
7	>800	2	0.01%	0	0.00%	1
		11,911	**Graham County Total**			339

*Assuming 5 MW per sq. km.
#Exclusions determined using GIS analysis

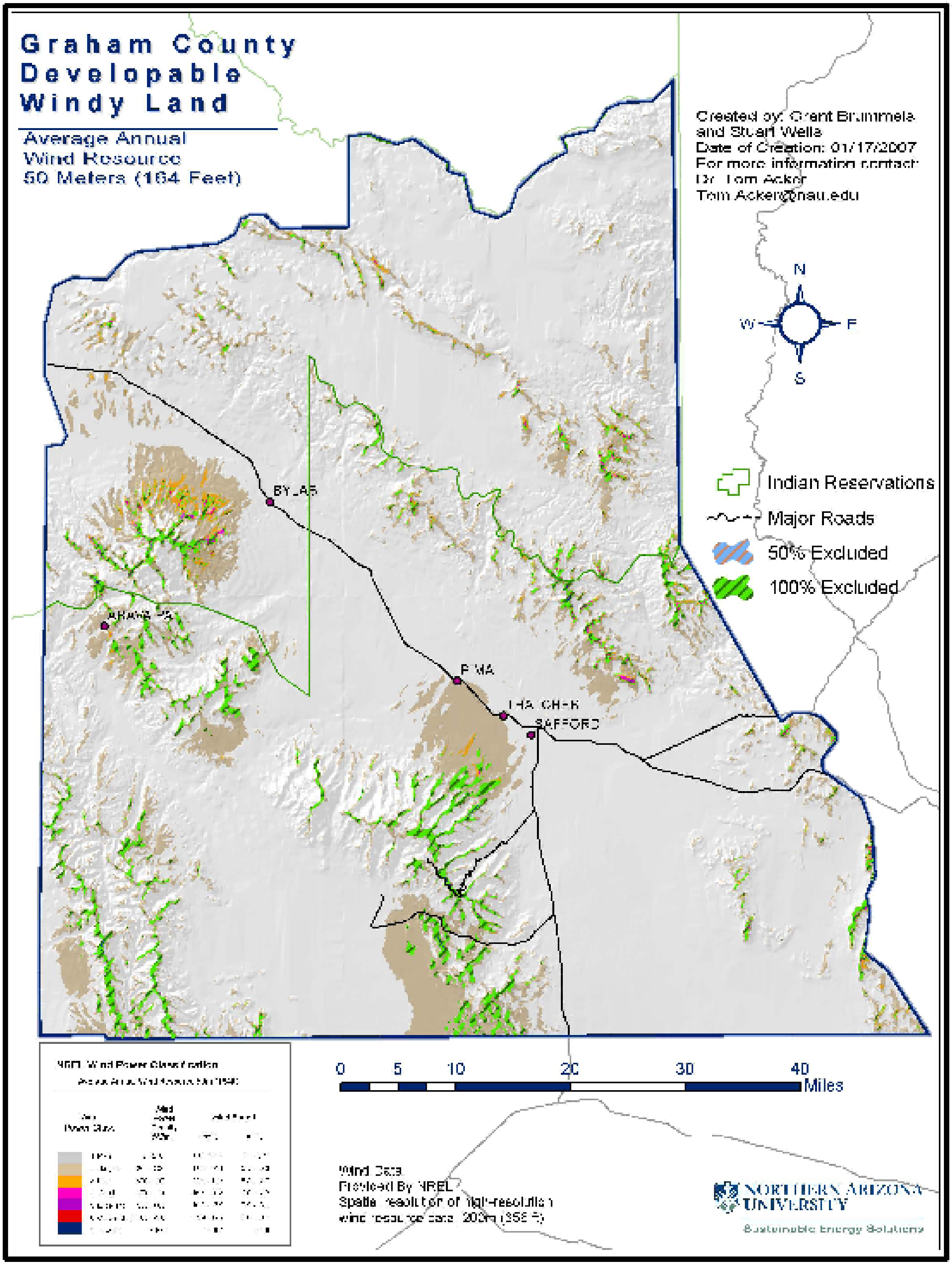


Figure 5 Map of Developable Windy Land for Graham County

Economic Impact Analysis

In this study, economic input/output (I/O) analysis in conjunction with Monte Carlo simulation was used to estimate the economic impact for wind energy projects. The JEDI model performs I/O analysis with an Excel add-in, *@Risk*[7], used to perform the Monte Carlo simulation.

In I/O analysis, a project expenditure may have up to three impacts on the local economy:

- **Direct effects –** on-site effect created by expenditure (i.e., on-site jobs of contractors and crews, jobs at the turbine).
- **Indirect effects –** increase in economic activity that occurs when a contractor, vendor or manufacturer receives payment for goods or services and in turn is able to pay others who support their business.
- **Induced effects –** change in wealth and income that is induced by the spending of those persons directly and indirectly employed by the project (i.e., spending on food, clothes, utilities, transportation, insurance, medical, etc.).

The results of I/O analysis estimate these effects (direct, indirect, and induced) on the jobs, earnings, and economic output.

Methodology

JEDI Model

JEDI is a spreadsheet economic input/output model that accepts wind project data and estimates the direct, indirect, and induced effects of the expenditure to build and operate a wind energy project. The model separates a wind energy project into two distinct phases: construction phase and operations and maintenance (O&M) phase. The construction phase is approximately a year while the O&M phase is from the time the project is brought on-line until it is decommissioned. JEDI estimates the jobs, earnings, and economic activity for the one-time impact of the construction phase and the annual impact of the O&M phase.

JEDI was designed for users that have a variety of experience-levels in I/O analysis or with wind energy projects. To obtain results from JEDI, a user can input as little as the year of installation, the size of the project, and the state for which the economic impacts will be estimated. The remaining input has default values designed for a state-level analysis. As the user gains additional experience or information about the project, additional details can be entered into the model[8].

Why Monte Carlo simulation?

Monte Carlo simulation is a statistical simulation technique which allows input parameters that are uncertain to be randomly varied over a specified range of values. Multiple trials of the Monte Carlo model allow the user to observe and average the results of the output.[9] @Risk by Palisade Corporation[8], an add-in to Microsoft Office Excel, was utilized for Monte Carlo simulation.[10] Using Monte Carlo simulation in conjunction with the I/O analysis provided two advantages over an analysis with JEDI only:

1) Increased input flexibility – cost estimates may be entered as a range of values instead of a single estimate.

2) Increased output information –a range of output values was obtained instead of a single value.

The data required by the JEDI model to estimate the economic impact of constructing and operating a wind energy project can be difficult to accurately estimate. Some input parameters are specific to the site and design. However, estimates for economic impacts are often desired before a site and design have been selected. In addition some of this data is proprietary and industry norms must be relied on to estimate the parameters.

The approach in other work[11,12] has been to use a single estimate representing the most likely value or industry average. For each of the outputs, the JEDI model then produced a single value. By using Monte Carlo simulation any input parameters can be approximated by a range of input values. For each of these input parameters, three estimates were determined: (1) the most likely estimate, (2) the minimum estimate, and (3) the maximum estimate.

Running a simulation with these input parameters as random variables provides an expected value and a variance of the output variables. Therefore, the output is a range of values instead of a single number. This provides a measure of certainty or risk: the smaller the range, the more certainty in the results. When using the JEDI model, the economic impact is estimated using six measures: jobs during construction phase, jobs during O&M phase, earnings during construction phase, earnings during O&M phase, output during construction phase, and output during O&M phase.

Finally, the input parameter(s) which have the most influence on the output can be determined using Monte Carlo simulation. Effort can then be focused on accurately estimating those input parameters that have the most significant effect on the outputs.

Input Data for Economic Impact Analysis

Sources of information are documented. However, many modeling decisions are also based on information gained from discussion with wind energy professionals and experts. These discussions have occurred over time in many venues including the Arizona Wind Working Group and the AWEA Windpower meetings.

County Multipliers

In order to utilize JEDI for county-level analysis, appropriate multipliers for Graham County were obtained from Marshal Goldberg via NREL. Specifically, the direct, indirect and induced multipliers for employment, earnings and output (per million dollars change in final demand) and personal consumption expenditures (i.e., average consumer expenditures on goods for the counties) were obtained[13]. Using the state-level multipliers that are provided with JEDI would overstate the economic benefits so it was important to obtain county-level multipliers for this analysis.

Wind Energy Project Size

Three wind energy project sizes were selected for the economic impact analysis. The sizes that were selected are based on discussions with wind energy experts and professionals, examination of the results of the windy land analysis and surveying the projects that came on-line in 2003-2004 in the southwest. For all analysis, 1.5 MW wind turbines were assumed.

The smallest project size considered was 10.5 MW and the largest was 180 MW. The mid-sized project was assumed to be 60 MW, which is the size of the wind project planned for Coconino County (Sunshine Wind Park near Winslow, Arizona) and the size of two wind energy projects built in the southwest in 2003-2004, Caprock Wind Ranch in New Mexico and the Oasis Wind Power Project in southern California. In the southwest during 2003-04, three wind energy projects were built that were in the size range of 160-200 MW (New Mexico Wind Energy Center, Colorado Green Lamar, Brazos Wind Ranch in Texas) [14]. To date, no utility-scale wind energy projects have been built in Arizona.

Construction Cost and Operations & Maintenance Cost

Construction cost and O&M cost depend on site and design specific data. Since the site and design were not known, these costs were estimated by a range of values. The estimates used for construction cost and operations and maintenance (O&M) cost are given in Table 7. Estimates for these costs are based on several sources including conversation with a wind developer[11,12,15,16].

Table 7 Input Parameter Estimates

Input Parameter	Minimum	Most Likely	Maximum
Construction Cost ($/kw)	$1,000	$1,200	$1,500
Annual Operating Cost ($/kw)	$9.50	$12.50	$25.00
Property Tax Rate	5.5%	6.9%	11.3%

Both construction cost and O&M cost were uncertain input parameters and were therefore simulated. The triangular distribution was used to generate these costs. The triangular distribution is often used in practice because it is uni-modal and may be non-symmetrical. In addition, there are fixed endpoints for the range of values. Finally, the triangular distribution is a good distribution to use in the absence of data. In the absence of data, experts can be surveyed and industry data consulted for averages. Experts can be asked for their subjective estimates of the minimum, most likely, and maximum values.[17]

Property tax calculation

To calculate the property tax in Arizona the construction cost which includes the cost of the equipment (wind turbines), building and installation costs, must first be determined. Typically, the *full-cost value* is 80% of the construction cost. Property taxes are based on the *assessed value* which is 25% of the full-cost value. The *property tax* is the tax rate multiplied by the assessed value, see Table 8

Table 8 Arizona Property Tax Calculation

Full Cost Value = 80% * Construction Cost
Assessed Value = 25% of Full Cost Value
Tax = Tax Rate * Assessed value

The tax rate varies significantly depending on the location within the state. Examining the tax tables, it was determined that the range of tax rates vary from a minimum of 5.5% to a maximum 11.3%. Tax rates were estimated from information obtained in conversations with the Graham County Tax Assessor's office[3,18]. The property tax rate was simulated using a triangular distribution.

Local Share

Local share is the percentage of expenditures spent in the state or local region where the wind energy project is constructed. For this work, it represents the percentage of expenditures spent in the county. Currently, the JEDI model provides default values for local share percentages that are estimated at the state-level (See Table 9). The JEDI model default values are not appropriate for a county-level analysis as the results will be considerably overstated.

We developed local share percentages that apply to Graham County by consulting with a wind developer and an economist. Constanti (2004) also provides guidance for setting the local share percentages for rural counties in Montana. Finally, we examined Graham County demographics (Table 1, Table 2) focusing particularly on population and employment. Minimum and maximum local share percentages were established and are also shown in Table 9. The local share percentages were simulated using a uniform distribution which implies that all values between the minimum and maximum (default) are equally likely.

Simulation Parameters

For each county and wind project size, a simulation was run. For each simulation, the number of trials was determined by observing the convergence of the distribution statistics for the output variables (construction phase: jobs, earnings, output; O&M phase: jobs, earnings, output). When the measured statistics changed no more than 1%, the output distribution was considered 'stable' and the simulation was considered to have converged. The number of trials in each simulation varied between 900 and 1100. The output distribution statistics that were measured are the average percent change of the percentiles, the mean, and the standard deviation.

Table 9 Local Shares Values[††]

Project Cost Data	JEDI default State-level Local Share	Graham County Minimum Local Share	Graham County Maximum Local Share
Construction Costs			
Materials			
Construction (concrete, rebar, equip, roads and site prep)	90%	0%	10%
Transformer	0%	0%	0%
Electrical (drop cable, wire,)	100%	0%	10%
HV line extension	100%	0%	10%
Labor			
Foundation	100%	15%	25%
Erection	75%	0%	10%
Electrical	75%	0%	10%
Management/supervision	0%	0%	0%
Equipment Costs			
Turbines (excluding blades and towers)	0%	0%	0%
Blades	0%	0%	0%
Towers	0%	0%	0%
Other Costs			
HV Sub/Interconnection	100%	0%	10%
Engineering	0%	0%	0%
Legal Services	100%	0%	10%
Land Easements	100%	100%	100%
Site Certificate/Permitting	100%	75%	100%
Wind Plant Annual Operating and Maintenance Costs			
Personnel			
Field Salaries	100%	40%	60%
Administrative	100%	40%	60%
Management	100%	40%	60%
Materials and Services			
Vehicles	100%	0%	10%
Misc. Services	80%	0%	10%
Fees, Permits, Licenses	100%	100%	100%
Utilities	100%	100%	100%
Insurance	0%	0%	0%
Fuel (motor vehicle gasoline)	100%	100%	100%
Tools and Misc. Supplies	100%	40%	60%
Spare Parts Inventory	2%	0%	2%

[††] JEDI default values should not be used for a county-level analysis. The JEDI default values are appropriate only for a state-level analysis. If used for a county-level analysis, benefits will be greatly overstated.

Results of Economic Impact Analysis

All economic outputs from JEDI are divided into benefits that occur during the construction phase (usually less than a year) and annual benefits that occur during the operational life of the wind project. For each phase, the model estimates:

- Jobs – the number of full-time equivalent employment for a year.
- Earnings - wage and salary compensation paid to workers.
- Output - economic activity or the value of production in the county economy.

For all three estimates, the simulation in conjunction with the JEDI model produces a frequency distribution. We report the percentiles for these distributions. The 50th percentile is the median. That is there is 50% chance that the number of jobs will be above the median and a 50% chance that the number of jobs will be below the median. We report the minimum, 5th percentile, 50th percentile, 95th percentile and maximum. There is a 95% likelihood that the number of jobs will be less than the 95th percentile.

Jobs

Results pertaining to job creation for each wind energy project size, project phase, and county are given in Figure 6 and Figure 7. A summary table is given in Appendix A-1. Based on simulation, there is a 90% likelihood that the number of jobs created during the construction phase in Graham County will be between 5 and 12 for a 60 MW wind energy project. During the O&M phase, there is a 90% likelihood that the number of jobs created in Graham County will be between 15 and 20.

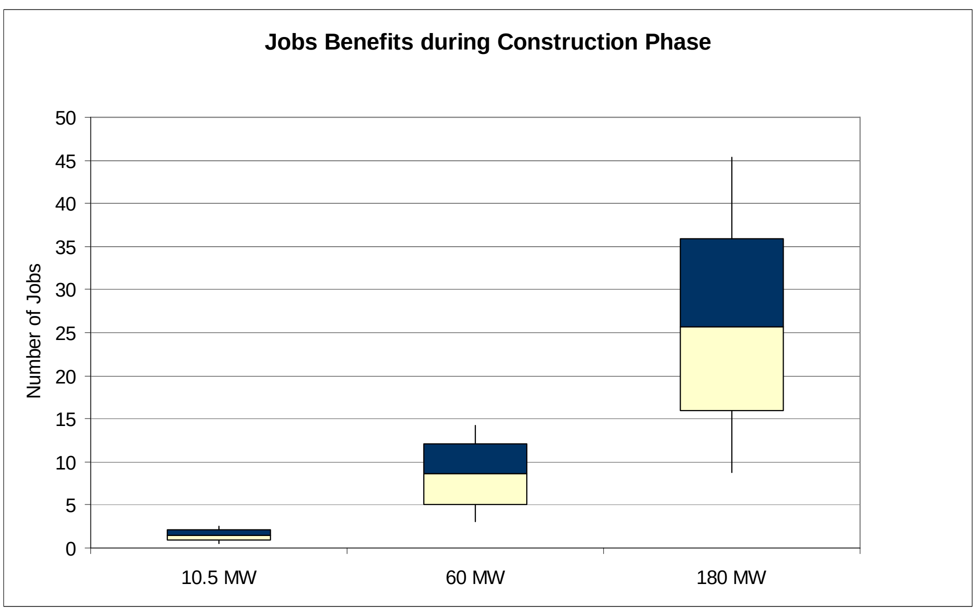


Figure 6 Wind Energy Project Impact on JOBS during Construction Phase

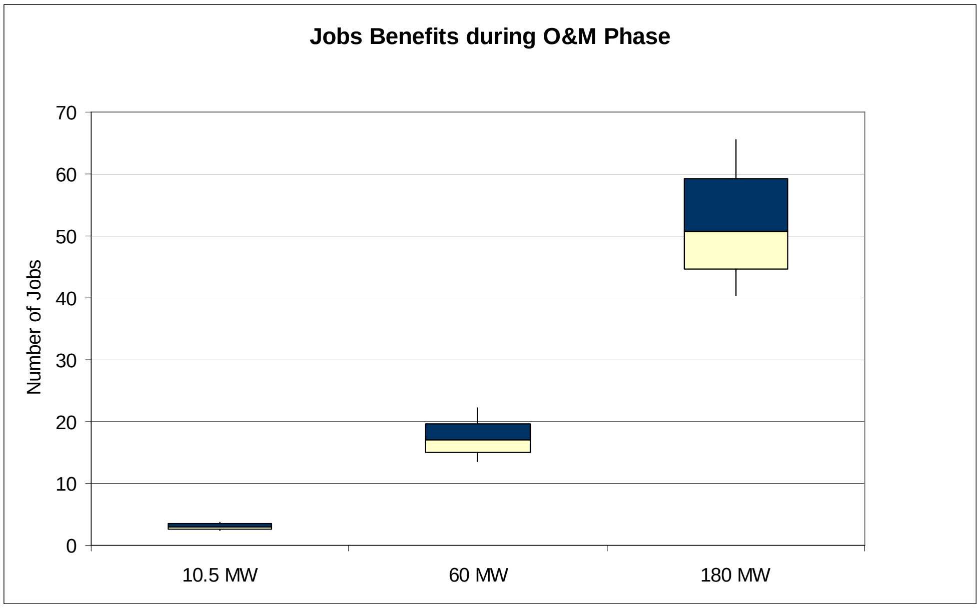


Figure 7 Wind Energy Project Impact on JOBS during O&M Phase

Earnings

Earnings refer to millions of dollars in wages and salary paid to workers. Results for earning for all wind energy project sizes, phases, and counties are given in Figure 8 and Figure 9. A summary table is given in Appendix A-2. Based on simulation, there is a 90% likelihood that the earnings paid during the construction phase in Graham County will be between $0.10 and $0.22 million for a 60 MW wind energy project (in 2007 dollars). During the O&M phase, there is a 90% likelihood that the annual earnings in Graham County will be between $0.42 and $0.64 million.

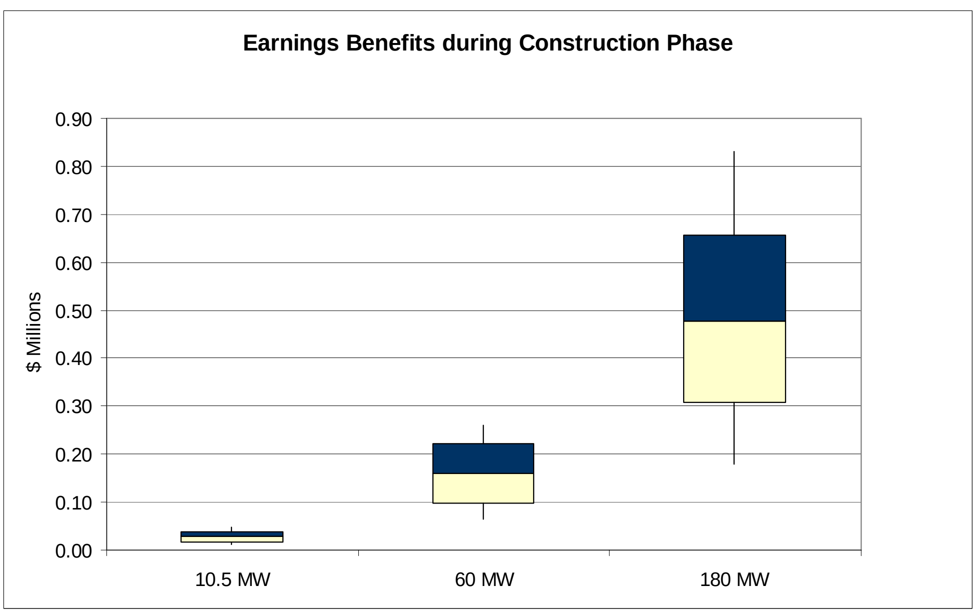


Figure 8 Wind Energy Project Impact on EARNINGS during Construction

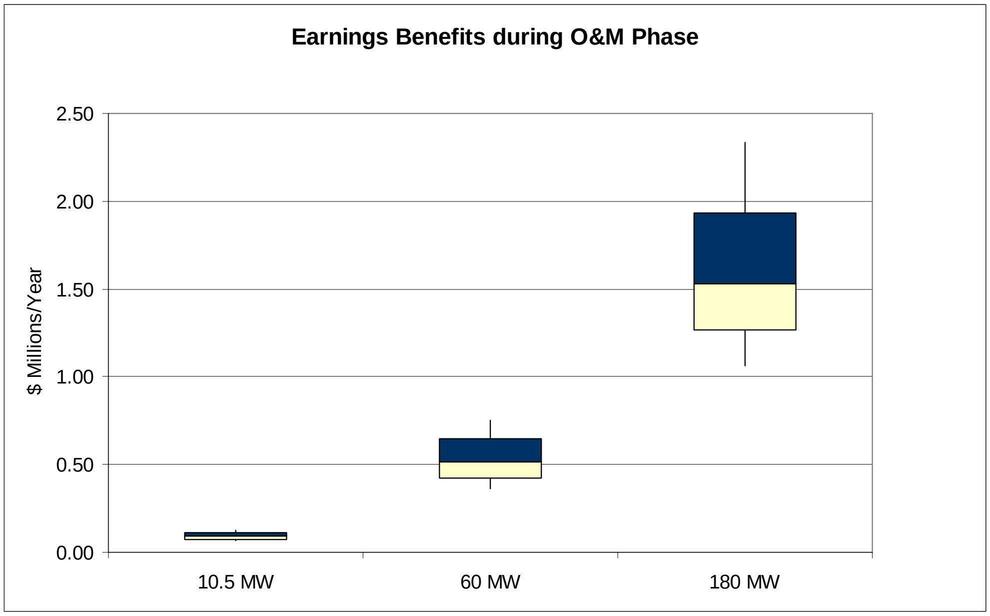


Figure 9 Wind Energy Project Impact on EARNINGS during O&M Phase

Output

Figure 10 and Figure 11 show a summary of output results for all wind energy project sizes and phases. A summary table is given in Appendix A-3. Output refers to economic activity or the value of production in the county and is also in millions of 2007 dollars. Based on the simulation results there is a 90% likelihood that the output will be between $0.5 and $1.27 million for Graham County. During the O&M phase, there is a 90% likelihood that the annual output in Graham County will be between $1.02 and $1.45 million.

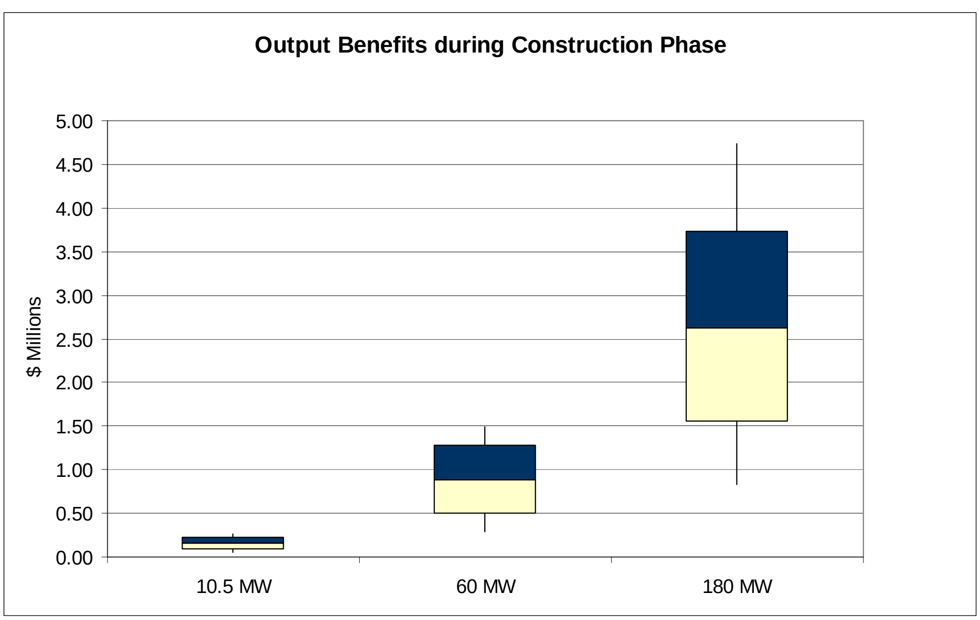


Figure 10 Wind Energy Project Impact on OUTPUT during Construction Phase

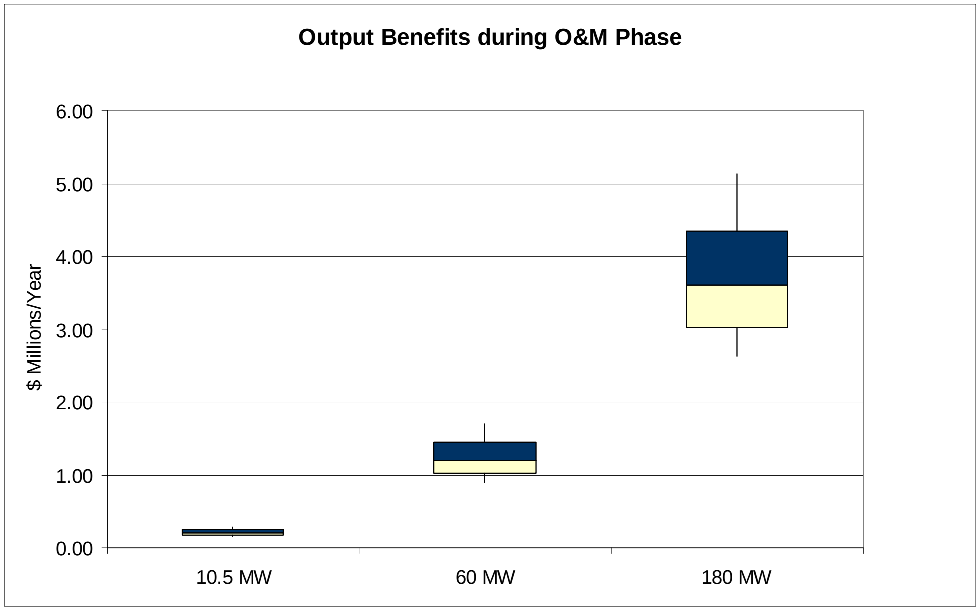


Figure 11 Wind Energy Project Impact on OUTPUT during O&M Phase

Conclusions

The first objective of this project was to estimate the wind energy development potential for Graham County. Based on high-resolution wind map data analyzed in a GIS while considering development exclusions, it was estimated that the developable windy land and potential installed capacity for Graham is approximately 340 MW. The majority of this capacity is from Class 3 wind. When this estimate is restricted to windy lands of class 4 or better, the developable capacity is 60 MW.

The second objective of this work was to estimate the economic impact of constructing and operating wind energy projects of various sizes in Graham County. Monte Carlo simulation was conducted in conjunction with the JEDI model and provided a range of outputs corresponding to a range of estimated input parameters. For a 60 MW wind energy project, there is 90% likelihood that:

- number of jobs created during the construction phase is between 5 and 12 with a median of 9 jobs.
- number of jobs created during the O&M phase is between 15 and 20 with a median of 17.
- earnings during the construction phase is between $0.10 and $0.22 million with a median of $0.16.
- earnings during the O&M phase is between $0.42 and $0.64 million annually with a median of $0.51 million.
- output during the construction phase is between $0.50 and $1.27 million with a median of $0.88 million.
- output during the O&M phase is between $1.02 and $1.45 million annually with a median of $1.20 million.

Appendix A Tables of JEDI/Monte Carlo Simulation Results

Appendix A- 1 Wind Energy Project Impact on JOBS

	Jobs for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	1	2
5th	1	3
50th	1	3
95th	2	3
100th	3	4
	Jobs for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	3	13
5th	5	15
50th	9	17
95th	12	20
100th	14	22
	Jobs for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	9	40
5th	16	45
50th	26	51
95th	36	59
100th	45	66

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Construction Jobs for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had 12 or fewer Construction Jobs for a 60 MW Wind Farm. We interpret this as a 95% probably that the number of Construction Jobs for a 60 MW Wind Farm will be 12 or less. The 50th percentile represents the median.

Appendix A- 2 Wind Energy Project Impact on EARNINGS

($ millions)

	Earnings for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.01	0.07
5th	0.02	0.07
50th	0.03	0.09
95th	0.04	0.11
100th	0.05	0.13
	Earnings for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	0.06	0.36
5th	0.10	0.42
50th	0.16	0.51
95th	0.22	0.64
100th	0.26	0.75
	Earnings for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	0.18	1.06
5th	0.31	1.26
50th	0.48	1.53
95th	0.66	1.93
100th	0.83	2.34

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Earnings for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $0.22 million or less Earnings from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Earnings from a 60 MW Wind Farm will be $0.22 million or less. The 50th percentile represents the median.

Appendix A- 3 Wind Energy Project Impact on OUTPUT

($ millions)

	Earnings for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.01	0.07
5th	0.02	0.07
50th	0.03	0.09
95th	0.04	0.11
100th	0.05	0.13
	Earnings for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	0.06	0.36
5th	0.10	0.42
50th	0.16	0.51
95th	0.22	0.64
100th	0.26	0.75
	Earnings for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	0.18	1.06
5th	0.31	1.26
50th	0.48	1.53
95th	0.66	1.93
100th	0.83	2.34

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Output from a 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $1.27 million or less Output from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Output from a 60 MW Wind Farm will be $1.27 million or less. The 50th percentile represents the median.

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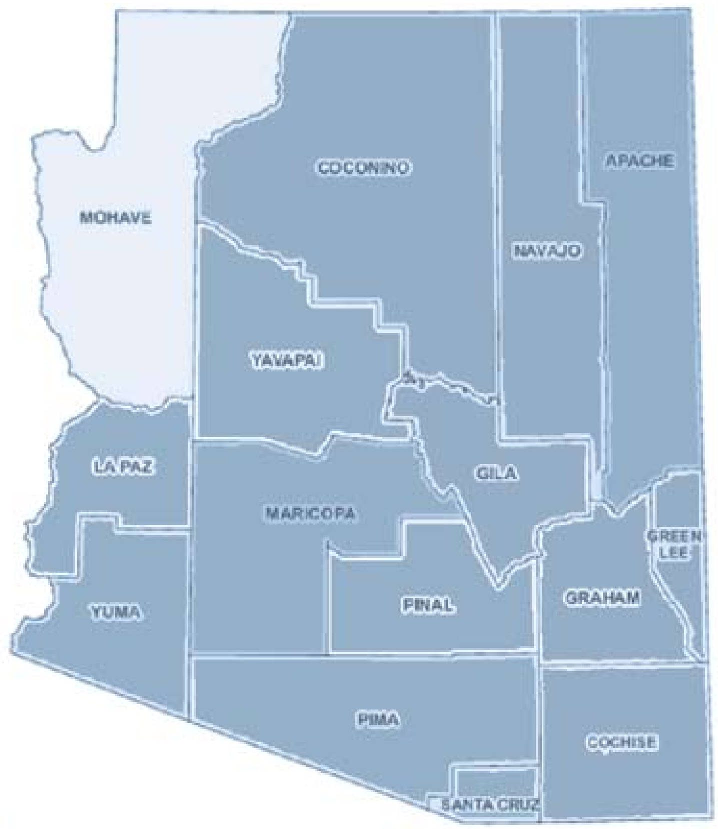
NORTHERN ARIZONA UNIVERSITY

Sustainable Energy Solutions

Arizona Wind Energy Assesment

Mohave County

Developable Windy Land
and Economic Benefits



Prepared for
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April 2007

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Abstract

This report contains two wind energy analyses for the northwestern-Arizona's Mohave County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class in each county was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Cochise County was estimated to be 1100 MW. The majority of developable windy land, 88%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Mohave County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 10.5 MW wind energy project

- *Jobs during construction*: median was 12 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 4 jobs
- *Earnings during construction*: the median was $0.36 million
- *Earnings during O&M phase*: median was $0.14 million annually
- *Output (economic activity) during construction*: median was $1.27 million
- *Output during O&M phase*: median was $0.32 million annually

For a 60 MW wind energy project

- *Jobs during construction*: median was 68 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 24 jobs
- *Earnings during construction*: the median was $2.07 million
- *Earnings during O&M phase*: median was $0.77 million annually
- *Output (economic activity) during construction*: median was $7.25 million
- *Output during O&M phase*: median was $1.82 million annually

For a 180 MW wind energy project

- *Jobs during construction*: median was 206 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 71 jobs
- *Earnings during construction*: the median was $6.23 million
- *Earnings during O&M phase*: median was $2.31 million annually
- *Output (economic activity) during construction*: median was $21.81 million
- *Output during O&M phase*: median was $5.45 million annually

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Introduction

The wind energy development potential and economic benefits were determined for a northwestern Arizona county, Mohave (see Figure 1). Using Geographic Information System (GIS) techniques on wind map data an estimate was made of the amount of developable windy land and potential installed capacity. Secondly, an analysis was made of the economic impacts of constructing and operating wind energy projects in these counties utilizing the Job and Economic Development Impact [*] (JEDI) model developed for National Renewable Energy Laboratory (NREL). Wind energy projects of three representative sizes were considered: 10.5 MW, 60 MW, and 180 MW. The JEDI model was used in conjunction with Monte Carlo simulation to estimate economic impacts at the county level. Direct, indirect and induced economic effects were estimated and categorized by jobs, earnings, and output (economic activity).

The wind maps and information in this report are *not* appropriate for siting wind energy projects. It is useful for discussing policy and locations that might be appropriate for further study. In order to site a wind energy project, an anemometer should be installed on the property and two years of data collected. More Arizona wind maps are available at www.ses.nau.edu.

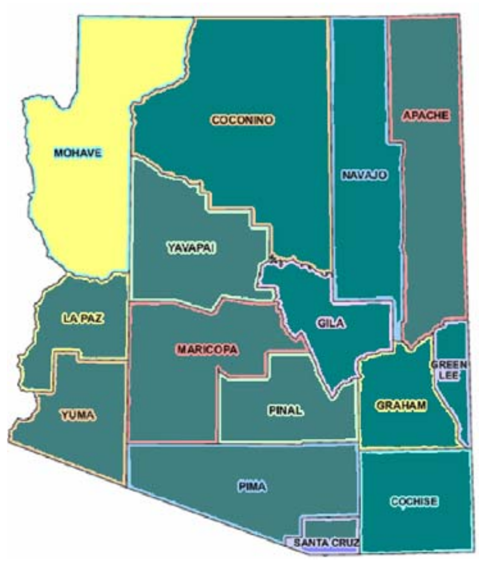


Figure 1 Mohave County in northern Arizona

[*] The JEDI model was designed by Marshall Goldberg, of MRG & Associates, under contract with NREL.The model is posted on the Wind Powering America website: http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=707 in June 2005.

State of Arizona

According to the US Census Bureau Quick Facts[1] the population in the state of Arizona increased 40% from 1990 to 2000. During this period US population increased 13.1%. Due to this rapid population and economic growth, electricity demand increased at the rate of 2.6% per year[2].

In 2001, the average electricity retail price for Arizona residents and businesses was 7.2 cents/kwh. This is the 16th highest average electricity price in the nation behind the six New England states, New York, New Jersey, Pennsylvania, California, Alaska, Hawaii, Texas, Florida, and Nevada. In addition to Arizona's increasing population, the hot climate and resulting need for air conditioning in the summer affect the increasing demand and price of electricity. Arizona has a larger than average residential demand largely due to the demand for air conditioning. The residential sector purchases 41% of the electricity as compared to 36% nationally[2].

Arizona primarily relies on coal and nuclear fuels for electrical generation. In 2000, approximately 45% of electricity was coal-generated and 35% was nuclear with only 10% generated from natural gas and another 10% by hydroelectric. However, the balance will be shifting to natural gas in the future as there are 16,000 MW of planned generation units by 2007, of which 15,000 MW are planned to be natural gas[2].

Mohave County

Mohave County, the second largest county in Arizona, contains 13,470 square miles and a 2003 population of 170,805. Though primarily desert, this northwestern Arizona county has over 1000 miles of shoreline with Lake Mojave, Lake Havasu, and the Colorado River. Kingman is the county seat though Lake Havasu City is the largest community with a population of 48,730 in 2003[3]. Demographic information is given in Table 1[4] and industry sector information is given in Table 2[5].

The largest land ownership category in Mohave County, approximately 61%, is US Forest Service and BLM (see Table 3)[3]. In 1990, 14.2% of reservation households had no access to electricity as compared to 1.2% of all households nationally.

Table 1 Mohave County Demographics

Demographic	Mohave
Population, 2005 estimate	187,200
Population, percent change, April 1, 2000 to July 1, 2005	20.7%
Population, percent change, 1990 to 2000	65.8%
High school graduates, percent of persons age 25+, 2000	77.5%
Bachelor's degree or higher, pct of persons age 25+, 2000	9.9%
Per capita money income, 1999	$16,788
Median household income, 2003	$32,482
Persons below poverty, percent, 2003	14.9%
Private nonfarm establishments, 2003	3,801
Private nonfarm employment, 2003	39,602
Private nonfarm employment, percent change 2000-2003	13.7%
Retail sales, 2002 ($1000)	1,757,951
Retail sales per capita, 2002	$10,604
Land area, 2000 (square miles)	13,312
Persons per square mile, 2000	11.6
Metropolitan or Micropolitan Statistical Area	Lake Havasu City-Kingman

Table 2 Mohave County Industry Sectors

Industry Sectors in Mohave County	Percent	Employed
Agriculture, forestry, fishing and hunting, and mining	1	602
Construction	9.7	5849
Manufacturing	7	4266
Wholesale trade	2.2	1308
Retail trade	13.8	8328
Transportation and warehousing, and utilities	5.7	3476
Information	1.6	978
Finance, insurance, real estate, and rental and leasing	4.6	2770
Professional, scientific, management, administrative, and waste management services	5.2	3133
Educational, health and social services	15	9070
Arts, entertainment, recreation, accommodation and food services	24.8	15020
Other services (except public administration)	4.9	2980
Public administration	4.5	2737

Table 3 Land Ownership in Mohave County

Land owner	Mohave
US Forest Service & BLM	61%
Private	18%
Other public lands	8%
State of AZ	7%
Indian reservation	6%
	100%

Windy Land Analysis using GIS

Methodology

For the purpose of this analysis, *windy land* is defined as land with a wind resource greater than or equal to class three as predicted by the Arizona Wind Map (the wind map will be discussed in the section on Input Data). That is, predicted average annual wind speeds are large enough that wind energy may be produced economically. However, not all windy land may be developed for wind power. There are many *development exclusions* that must be considered. For instance, land that is owned by the National Park Service must be excluded 100% from consideration for development. *Developable windy land*, therefore, is the windy land that remains after all development exclusions have been applied. Finally, *excluded windy land* is windy land (class 3 and above) that falls within a development exclusion.

Consistent with the methodology applied by NREL, there are three general *exclusion* categories of land unsuitable for development[6]:

- environmental exclusions
- land use exclusions
- additional windy land factors

These development exclusions are summarized in Table 4. Any windy land with 1 or more exclusion is excluded windy land and is not appropriate to be used for wind energy projects. After removing excluded windy land, the remaining land is developable and an estimate of the potential installed capacity by wind class for each county was made by assuming a conservative 5 MW of installed capacity per square kilometer.

Input Data for Windy Land Analysis

TrueWind Solutions, in collaboration with NREL, developed a high-resolution wind map and GIS data for the state of Arizona in 2003. The data for this wind map was created using a numerical weather model coupled with climactic data and a wind flow model. The wind map provides 200-meter resolution data sufficient for identifying the most promising areas for wind development in the state. The data from this map was used to analyze the wind resource of Mohave County.

A *data layer* is a geographic data set that can be represented visually using GIS software. Several data layers were required for the exclusion analysis. The data layers, their exclusion category (environmental, land use, other factors), source and brief description are listed in Table 4.

Table 4 Wind Development Exclusions

Broad Exclusion Category	Exclusion	Exclusion[†] Percentage	Exclusion Description	GIS Layer Source
Environmental Exclusions	**National Park Service**	100%	United States National Park Service Land	ALRIS [‡]
	Fish and Wildlife Service	100%	United States Fish and Wildlife service	ALRIS
	Congressionally Specially Designated Areas	100%	Special Areas, like wilderness or wild, and scenic rivers, congressionally designated as such	USFS
	Inventoried Roadless Areas	100%	These are roadless areas of the country on federal land that have been congressionally designated as such	USFS
	State and Other Environmental Land (State GAP Data)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP
	Other: Wildlife, Wilderness and Recreation Areas on Federal land of any designation (predominately USFS and BLM lands)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP[§]
	Remaining USFS & DOD Land	50%	United States Forest Service and Department of Defense lands that remain after all other windy land exclusions are removed	ALRIS
Land Use Exclusions	**Urban/Developed Areas**	100%	Urban or Developed land as described by USGS ReGAP data	USGS AZ ReGAP
	Airports	100%	Airports	National Atlas of the United States, USGS, ESRI
	Wetlands	100%	Wetland ecosystems as described by USGS ReGAP data	USGS AZ ReGAP
	Water bodies (includes seasonal and dry lakes)	100%	Areas covered by water all year or part of the year. Does not include Rivers and Streams	USGS AZ ReGAP
	Non-ridge Crest Forests	50%	Areas of forest cover that are not considered ridge crests by TPI analysis	ReGAP + TPI [**]
Additional Windy Land Factors	**Slopes > 20%**	100%	These are landscapes with slopes greater than 20%	Grant Brummels

[†] Windy land exclusions were excluded 100%, with the exception of "non-ridge crest forests" and "remaining USFS and DOD Land," which were excluded 50%. Additionally, all 100% exclusions were buffered 3km, except for wetlands (100m), open water (no buffer), and slopes > 20% (no buffer).[†] Non-ridge crest forests have had all 100% exclusions removed. Remaining USFS and DOD land has had all non-ridge crest forests and 100% exclusions removed.

[‡] ALRIS—Arizona Land Resource Information System

[§] ReGAP—Regional Gap Analysis Program, 30m satellite data

[**] Jenness, J. 2005. Topographic Position Index (tip_jen.avx) extension for ArcView 3.x. Jenness Enterprises. Available at: http://www.jennessent.com/arview/tpi.htm. TPI was applied to a 90m Digital Elevation Model.

Results of Windy Land Analysis

The windy land in Mohave County is shown in Figure 2. Using GIS, the square kilometers of land was then totaled by wind class. Approximately 3.3% of the land is considered windy land. Of the windy land, the majority is class 3.

The development exclusions for Mohave County are mapped in Figure 3. As displayed, the land areas highlighted in blue show the areas that cannot be developed for wind energy regardless of how windy since this land was classified as a development exclusions. In Mohave County, 1.8% of the total county land area is classified as development exclusions.

The exclusions remove 73.9% of windy land from consideration for development. See Figure 4 to compare the wind class breakdown of the amount of windy land with the wind class breakdown of the amount of developable windy land. When exclusions are considered, much of the excluded windy land is higher than class 3. As a result, the proportional amounts of class 4 and above decrease with a corresponding increase in the proportional amount of class 3.

Some land is excluded under multiple categories. For instance, land may have a slope greater than 20% and also be National Park Service land. The largest exclusion affecting windy land is Slopes>20% and excludes 38.4% of windy land. Other exclusion categories that remove windy land are given in Table 5. The percentages will not add to 100% because trivial categories have not been included and because some land is excluded by multiple categories.

Table 6 provides a summary of the results of the windy land analysis for Mohave County. Organized by wind class, the total area of windy land, area of developable windy land, and potential developable capacity are shown. These tables also show that the total developable capacity in Mohave County is 1,116 MW. When restricting this estimate to windy lands of class 4 or better, the developable capacity for these counties are 133 MW. Finally, the developable windy land mapped by wind class is shown in Figure 5.

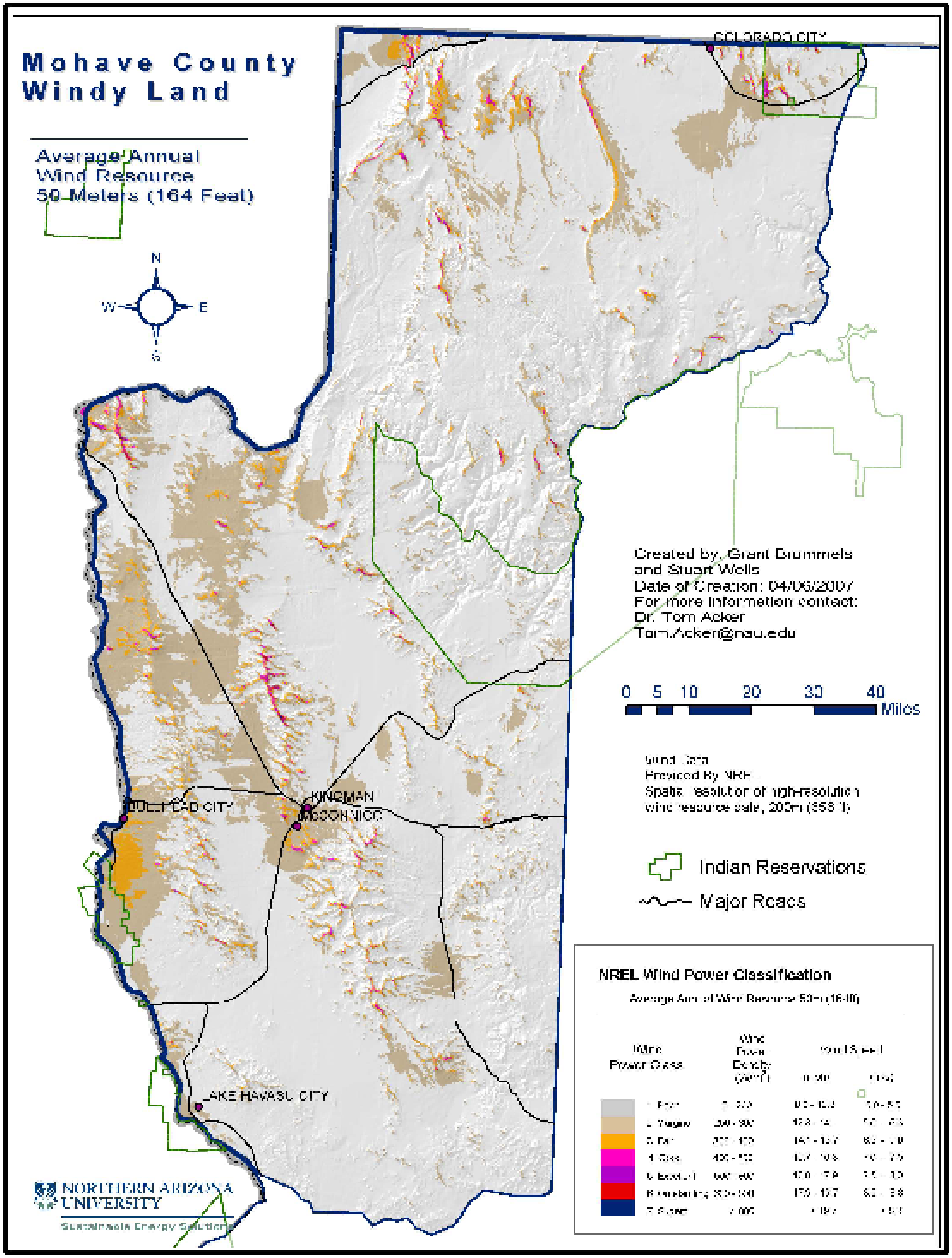


Figure 2 Map of Windy Land for Mohave County, AZ

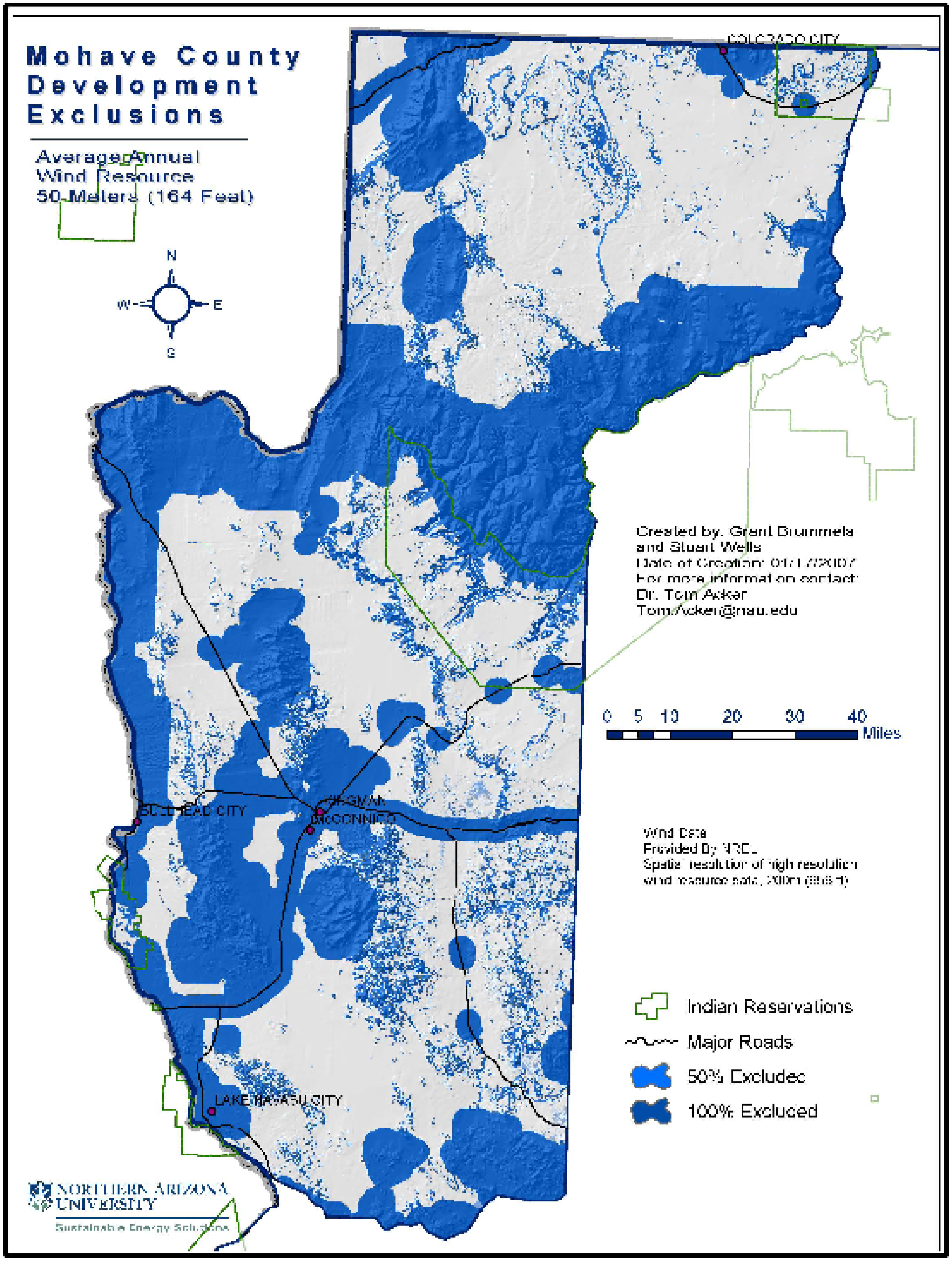
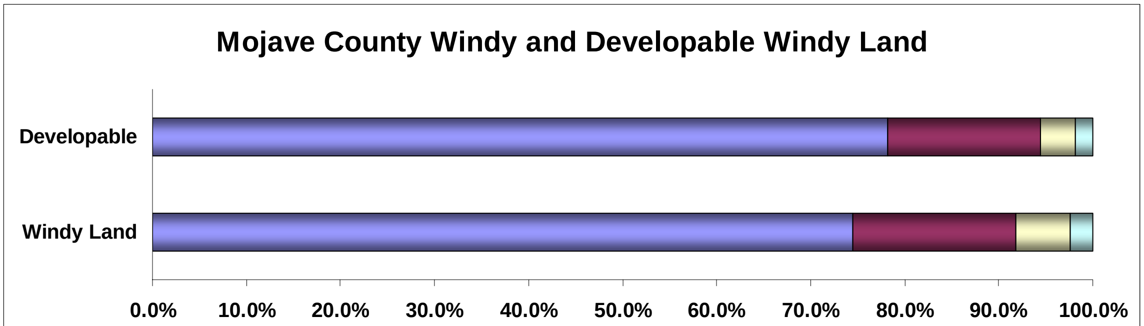


Figure 3 Map of Development Exclusions in Cochise County



	Windy Land	Developable
Class 7	0.0%	0.0%
Class 6	2.4%	1.9%
Class 5	5.8%	3.7%
Class 4	17.3%	16.2%
Class 3	74.5%	78.2%

Class 3 Class 4 Class 5 Class 6 Class 7

Figure 4 Windy Land by Wind Class for Mohave County

Table 5 Mohave County Exclusion Categories that Remove Windy Land

Exclusion Category	Windy Land Excluded
Slopes > 20%	38.4%
Environmental Lands	25.9%
National Park Service	17.9%
Urban/Dev Lands	17.6%

Table 6 Windy Land and Developable Windy Land in Mohave County

Mohave County Wind Class Area Analysis						
Wind Class	Power (w/m^2)	Total Area (km^2)	Windy Land as Percent of Total Land Area	Developable Windy Land (km^2)#	Developable Windy Land as Percent of Total Land Area	Developable Installed Capacity (MW)*
3	300-400	705	2.75%	196.6	0.768%	983
4	400-500	109	0.42%	21.3	0.083%	107
5	500-600	28	0.11%	4.3	0.017%	21
6	600-800	12	0.05%	0.8	0.003%	4
7	>800	1	0.00%	0.1	0.001%	1
		34,809	**Mohave County Total**			1,116

*Assuming 5 MW per sq. km.
#Exclusions determined using GIS analysis

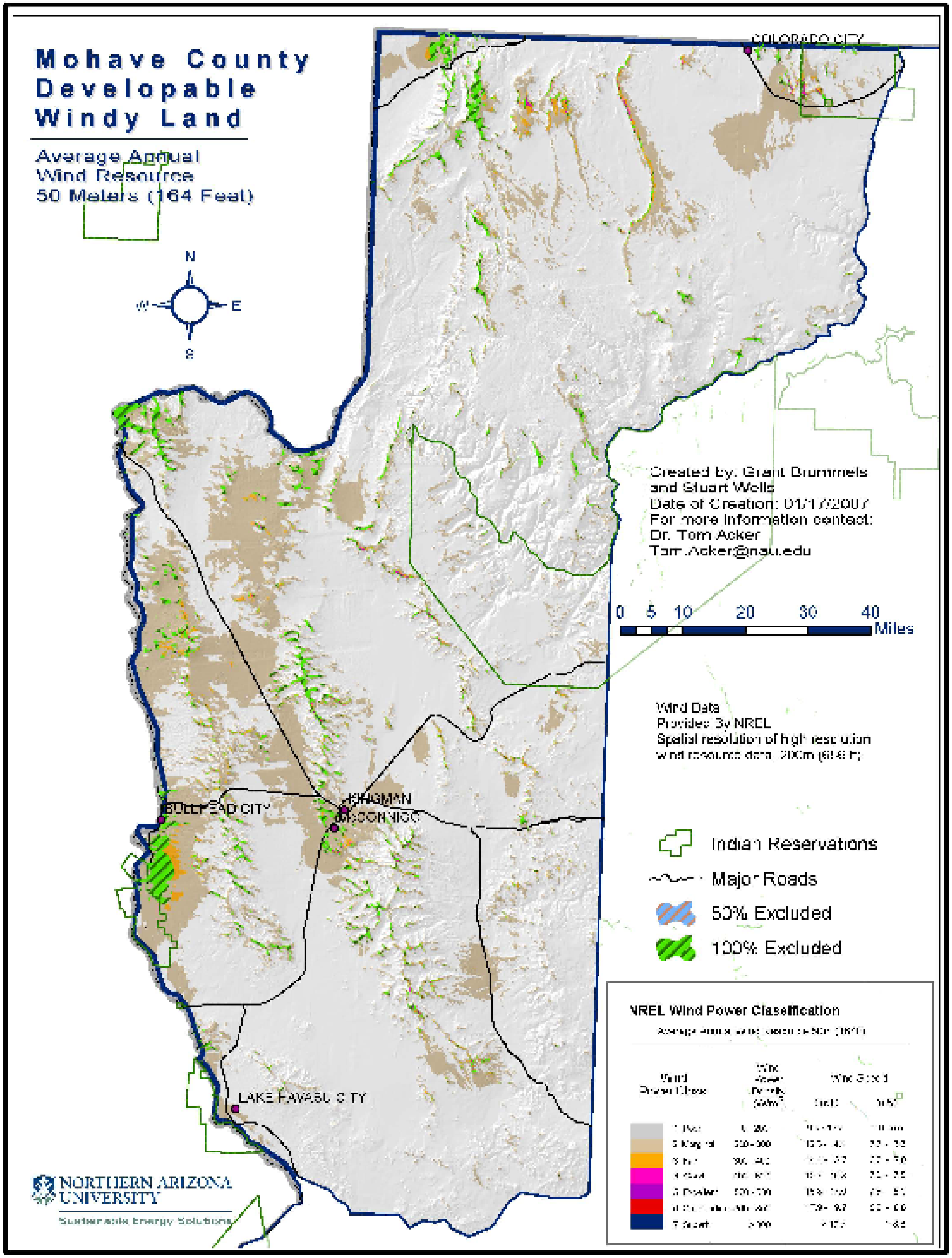


Figure 5 Map of Developable Windy Land for Mohave County

Economic Impact Analysis

In this study, economic input/output (I/O) analysis in conjunction with Monte Carlo simulation was used to estimate the economic impact for wind energy projects. The JEDI model performs I/O analysis with an Excel add-in, *@Risk*[7], used to perform the Monte Carlo simulation.

In I/O analysis, a project expenditure may have up to three impacts on the local economy:

- **Direct effects –** on-site effect created by expenditure (i.e., on-site jobs of contractors and crews, jobs at the turbine).
- **Indirect effects –** increase in economic activity that occurs when a contractor, vendor or manufacturer receives payment for goods or services and in turn is able to pay others who support their business.
- **Induced effects –** change in wealth and income that is induced by the spending of those persons directly and indirectly employed by the project (i.e., spending on food, clothes, utilities, transportation, insurance, medical, etc.).

The results of I/O analysis estimate these effects (direct, indirect, and induced) on the jobs, earnings, and economic output.

Methodology

JEDI Model

JEDI is a spreadsheet economic input/output model that accepts wind project data and estimates the direct, indirect, and induced effects of the expenditure to build and operate a wind energy project. The model separates a wind energy project into two distinct phases: construction phase and operations and maintenance (O&M) phase. The construction phase is approximately a year while the O&M phase is from the time the project is brought on-line until it is decommissioned. JEDI estimates the jobs, earnings, and economic activity for the one-time impact of the construction phase and the annual impact of the O&M phase.

JEDI was designed for users that have a variety of experience-levels in I/O analysis or with wind energy projects. To obtain results from JEDI, a user can input as little as the year of installation, the size of the project, and the state for which the economic impacts will be estimated. The remaining input has default values designed for a state-level analysis. As the user gains additional experience or information about the project, additional details can be entered into the model[8].

Why Monte Carlo simulation?

Monte Carlo simulation is a statistical simulation technique which allows input parameters that are uncertain to be randomly varied over a specified range of values. Multiple trials of the Monte Carlo model allow the user to observe and average the results of the output.[9] @Risk by Palisade Corporation[8], an add-in to Microsoft Office Excel, was utilized for Monte Carlo simulation.[10] Using Monte Carlo simulation in conjunction with the I/O analysis provided two advantages over an analysis with JEDI only:

1) Increased input flexibility – cost estimates may be entered as a range of values instead of a single estimate.
2) Increased output information –a range of output values was obtained instead of a single value.

The data required by the JEDI model to estimate the economic impact of constructing and operating a wind energy project can be difficult to accurately estimate. Some input parameters are specific to the site and design. However, estimates for economic impacts are often desired before a site and design have been selected. In addition some of this data is proprietary and industry norms must be relied on to estimate the parameters.

The approach in other work[11,12] has been to use a single estimate representing the most likely value or industry average. For each of the outputs, the JEDI model then produced a single value. By using Monte Carlo simulation any input parameters can be approximated by a range of input values. For each of these input parameters, three estimates were determined: (1) the most likely estimate, (2) the minimum estimate, and (3) the maximum estimate.

Running a simulation with these input parameters as random variables provides an expected value and a variance of the output variables. Therefore, the output is a range of values instead of a single number. This provides a measure of certainty or risk: the smaller the range, the more certainty in the results. When using the JEDI model, the economic impact is estimated using six measures: jobs during construction phase, jobs during O&M phase, earnings during construction phase, earnings during O&M phase, output during construction phase, and output during O&M phase.

Finally, the input parameter(s) which have the most influence on the output can be determined using Monte Carlo simulation. Effort can then be focused on accurately estimating those input parameters that have the most significant effect on the outputs.

Input Data for Economic Impact Analysis

Sources of information are documented. However, many modeling decisions are also based on information gained from discussion with wind energy professionals and experts. These discussions have occurred over time in many venues including the Arizona Wind Working Group and the AWEA Windpower meetings.

County Multipliers

In order to utilize JEDI for county-level analysis, appropriate multipliers for Coconino County were obtained from Marshal Goldberg via NREL. Specifically, the direct, indirect and induced multipliers for employment, earnings and output (per million dollars change in final demand) and personal consumption expenditures (i.e., average consumer expenditures on goods for the counties) were obtained[13]. Using the state-level multipliers that are provided with JEDI would overstate the economic benefits so it was important to obtain county-level multipliers for this analysis.

Wind Energy Project Size

Three wind energy project sizes were selected for the economic impact analysis. The sizes that were selected are based on discussions with wind energy experts and professionals, examination of the results of the windy land analysis and surveying the projects that came on-line in 2003-2004 in the southwest. For all analysis, 1.5 MW wind turbines were assumed.

The smallest project size considered was 10.5 MW and the largest was 180 MW. The mid-sized project was assumed to be 60 MW, which is the size of the wind project planned for another Arizona county, Coconino County (Sunshine Wind Park near Winslow, Arizona) and the size of two wind energy projects built in the southwest in 2003-2004, Caprock Wind Ranch in New Mexico and the Oasis Wind Power Project in southern California. In the southwest during 2003-04, three wind energy projects were built that were in the size range of 160-200 MW (New Mexico Wind Energy Center, Colorado Green Lamar, Brazos Wind Ranch in Texas) [14]. To date, no utility-scale wind energy projects have been built in Arizona.

Construction Cost and Operations & Maintenance Cost

Construction cost and O&M cost depend on site and design specific data. Since the site and design were not known, these costs were estimated by a range of values. The estimates used for construction cost and operations and maintenance (O&M) cost are given in Table 7. Estimates for these costs are based on several sources including conversation with a wind developer[11,12,15,16].

Table 7 Input Parameter Estimates

Input Parameter	**Minimum**	**Most Likely**	**Maximum**
Construction Cost ($/kw)	$1,000	$1,200	$1,500
Annual Operating Cost ($/kw)	$9.50	$12.50	$25.00
Property Tax Rate	10.5%	12.2%	12.6%

Both construction cost and O&M cost were uncertain input parameters and were therefore simulated. The triangular distribution was used to generate these costs. The triangular distribution is often used in practice because it is uni-modal and may be non-symmetrical. In addition, there are fixed endpoints for the range of values. Finally, the triangular distribution is a good distribution to use in the absence of data. In the absence of data, experts can be surveyed and industry data consulted for averages. Experts can be asked for their subjective estimates of the minimum, most likely, and maximum values.[17]

Property tax calculation

To calculate the property tax in Arizona the construction cost which includes the cost of the equipment (wind turbines), building and installation costs, must first be determined. Typically, the *full-cost value* is 80% of the construction cost. Property taxes are based on the *assessed value* which is 25% of the full-cost value. The *property tax* is the tax rate multiplied by the assessed value, see Table 8

Table 8 Arizona Property Tax Calculation

Full Cost Value = 80% * Construction Cost
Assessed Value = 25% of Full Cost Value
Tax = Tax Rate * Assessed value

The tax rate varies significantly depending on the location within the state. Examining the tax tables, it was determined that the range of tax rates vary from a minimum of 10.5% to a maximum 12.6%. Tax rates were estimated from information obtained in conversations with the Mohave County Tax Assessor's office[3,18]. The property tax rate was simulated using a triangular distribution.

Local Share

Local share is the percentage of expenditures spent in the state or local region where the wind energy project is constructed. For this work, it represents the percentage of expenditures spent in the county. Currently, the JEDI model provides default values for local share percentages that are estimated at the state-level (See Table 9). The JEDI model default values are not appropriate for a county-level analysis as the results will be considerably overstated.

We developed local share percentages that apply to Mohave County by consulting with a wind developer and an economist. Constanti (2004) also provides guidance for setting the local share percentages for rural counties in Montana. Finally, we examined Mohave County demographics (Table 1, Table 2) focusing particularly on population and employment. Minimum and maximum local share percentages were established and are also shown in Table 9[112]. The local share percentages were simulated using a uniform distribution which implies that all values between the minimum and maximum (default) are equally likely.

Simulation Parameters

For each county and wind project size, a simulation was run. For each simulation, the number of trials was determined by observing the convergence of the distribution statistics for the output variables (construction phase: jobs, earnings, output; O&M phase: jobs, earnings, output). When the measured statistics changed no more than 1%, the output distribution was considered 'stable' and the simulation was considered to have converged. The number of trials in each simulation varied between 900 and 1100. The output distribution statistics that were measured are the average percent change of the percentiles, the mean, and the standard deviation.

Table 9 Local Shares Values[††]

Project Cost Data	JEDI default State-level Local Share	Mohave County Minimum Local Share	Mohave County Maximum Local Share
Construction Costs			
Materials			
Construction (concrete, rebar, equip, roads and site prep)	90%	50%	75%
Transformer	0%	0%	0%
Electrical (drop cable, wire,)	100%	25%	50%
HV line extension	100%	0%	10%
Labor			
Foundation	100%	75%	100%
Erection	75%	15%	25%
Electrical	75%	50%	75%
Management/supervision	0%	0%	0%
Equipment Costs			
Turbines (excluding blades and towers)	0%	0%	0%
Blades	0%	0%	0%
Towers	0%	0%	0%
Other Costs			
HV Sub/Interconnection	100%	25%	50%
Engineering	0%	0%	10%
Legal Services	100%	50%	75%
Land Easements	100%	100%	100%
Site Certificate/Permitting	100%	100%	100%
Wind Plant Annual Operating and Maintenance Costs			
Personnel			
Field Salaries	100%	75%	100%
Administrative	100%	75%	100%
Management	100%	75%	100%
Materials and Services			
Vehicles	100%	75%	100%
Misc. Services	80%	50%	75%
Fees, Permits, Licenses	100%	100%	100%
Utilities	100%	100%	100%
Insurance	0%	0%	0%
Fuel (motor vehicle gasoline)	100%	100%	100%
Tools and Misc. Supplies	100%	75%	100%
Spare Parts Inventory	2%	2%	2%

[††] JEDI default values should not be used for a county-level analysis. The JEDI default values are appropriate only for a state-level analysis. If used for a county-level analysis, benefits will be greatly overstated.

Results of Economic Impact Analysis

All economic outputs from JEDI are divided into benefits that occur during the construction phase (usually less than a year) and annual benefits that occur during the operational life of the wind project. For each phase, the model estimates:

- Jobs – the number of full-time equivalent employment for a year.
- Earnings - wage and salary compensation paid to workers.
- Output - economic activity or the value of production in the county economy.

For all three estimates, the simulation in conjunction with the JEDI model produces a frequency distribution. We report the percentiles for these distributions. The 50th percentile is the median. That is there is 50% chance that the number of jobs will be above the median and a 50% chance that the number of jobs will be below the median. We report the minimum, 5th percentile, 50th percentile, 95th percentile and maximum. There is a 95% likelihood that the number of jobs will be less than the 95th percentile.

Jobs

Results pertaining to job creation for each wind energy project size and project phase are given in Figure 6 and Figure 7. A summary table is given in Appendix A-1. Based on simulation, there is a 90% likelihood that the number of jobs created during the construction phase in Mohave County will be between 58 and 79 for a 60 MW wind energy project. During the O&M phase, there is a 90% likelihood that the number of jobs created in Mohave County will be between 22 and 26.

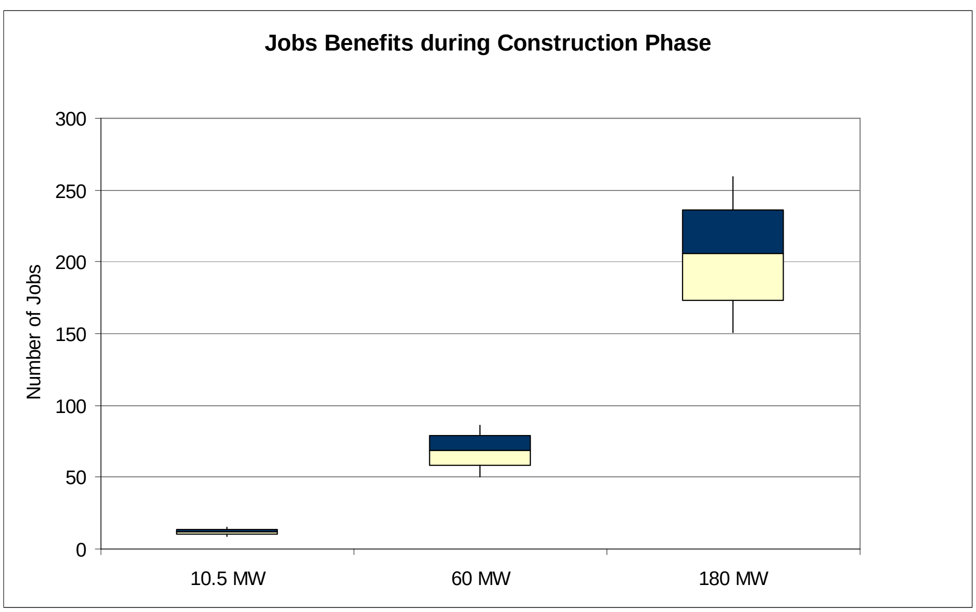


Figure 6 Wind Energy Project Impact on JOBS during Construction Phase

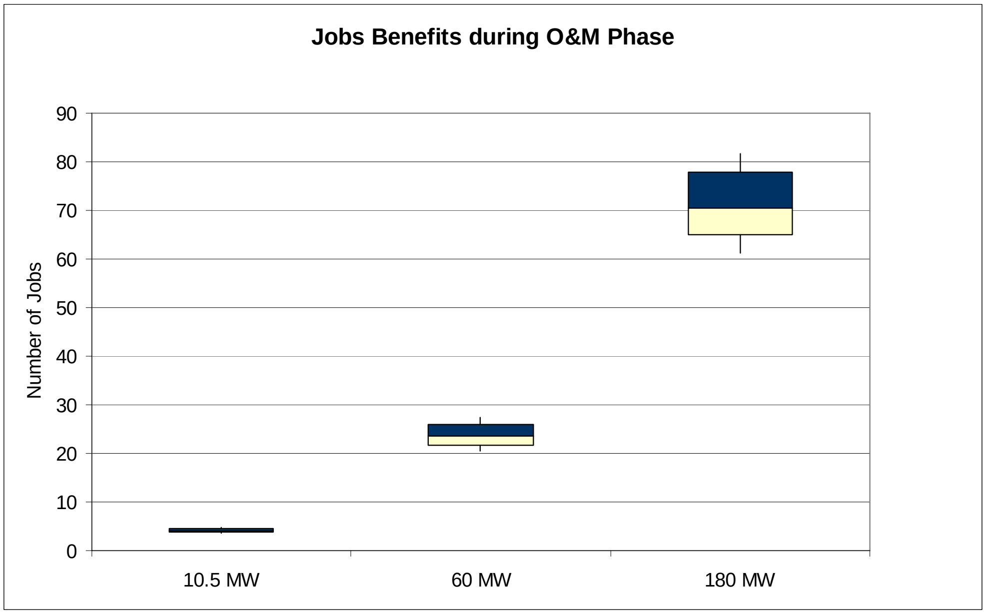


Figure 7 Wind Energy Project Impact on JOBS during O&M Phase

Earnings

Earnings refer to millions of dollars in wages and salary paid to workers. Results for earnings for all wind energy project sizes and phases are given in Figure 8 and Figure 9. A summary table is given in Appendix A-2. Based on simulation, there is a 90% likelihood that the earnings paid during the construction phase in Mohave County will be between $1.76 and $2.40 million annually for a 60 MW wind energy project (in 2007 dollars). During the O&M phase, there is a 90% likelihood that the annual earnings in Mohave County will be between $0.64 and $0.97 million.

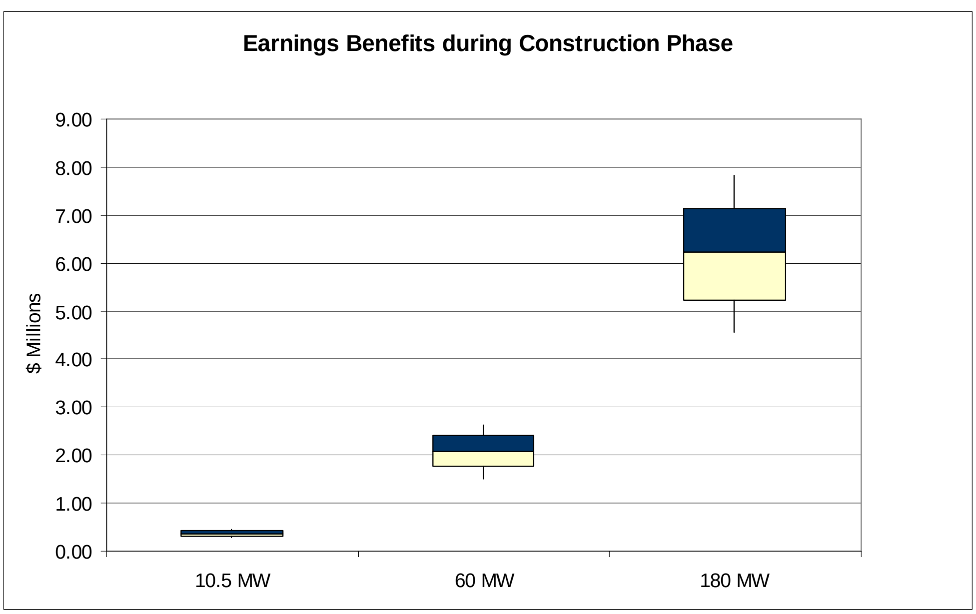


Figure 8 Wind Energy Project Impact on EARNINGS during Construction

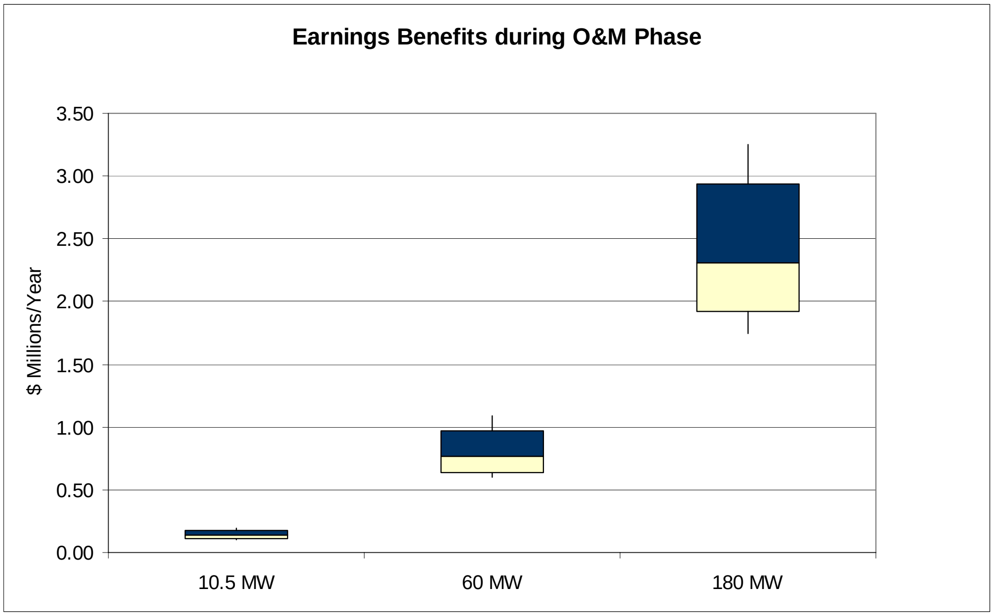


Figure 9 Wind Energy Project Impact on EARNINGS during O&M Phase

Output

Figure 10 and Figure 11 show a summary of output results for all wind energy project sizes and phases. A summary table is given in Appendix A-3. Output refers to economic activity or the value of production in the county and is also in millions of 2007 dollars. Based on the simulation results there is a 90% likelihood that the output will be between $6.16 and $8.41 million annually for Mohave County. During the O&M phase, there is a 90% likelihood that the annual output in Mohave County will be between $1.60 and $2.15 million.

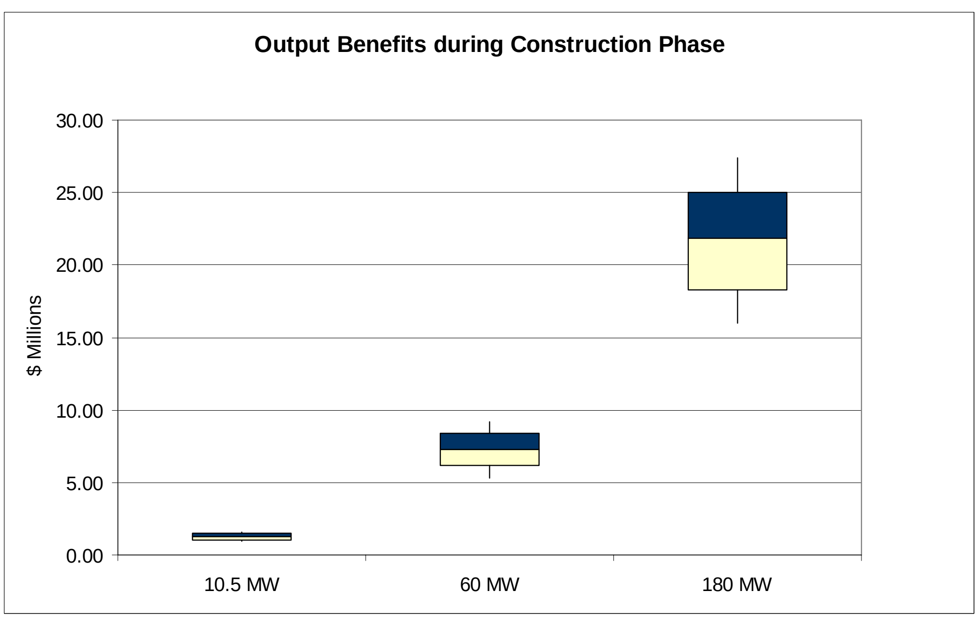


Figure 10 Wind Energy Project Impact on OUTPUT during Construction Phase

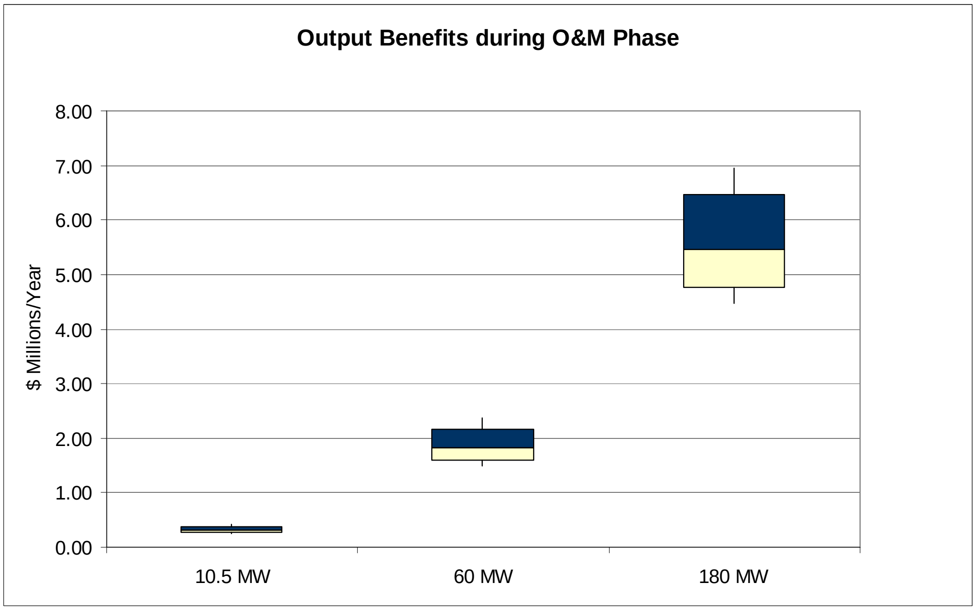


Figure 11 Wind Energy Project Impact on OUTPUT during O&M Phase

Conclusions

The first objective of this project was to estimate the wind energy development potential for Mohave County. Based on high-resolution wind map data analyzed in a GIS while considering development exclusions, it was estimated that the developable windy land and potential installed capacity for Mohave is approximately 1100 MW. The majority of this capacity is from Class 3 wind. When this estimate is restricted to windy lands of class 4 or better, the developable capacity is 130 MW.

The second objective of this work was to estimate the economic impact of constructing and operating wind energy projects of various sizes in Mohave County. Monte Carlo simulation was conducted in conjunction with the JEDI model and provided a range of outputs corresponding to a range of estimated input parameters. For a 60 MW wind energy project, there is 90% likelihood that:

- number of jobs created during the construction phase is between 58 and 79 with a median of 68 jobs.
- number of jobs created during the O&M phase is between 22 and 26 with a median of 24.
- earnings during the construction phase is between $1.76 and $2.40 million with a median of $2.07 million in Cochise.
- earnings during the O&M phase is between $0.64 and $0.97 million annually with a median of $0.77 million.
- output during the construction phase is between $6.16 and $8.41 million with a median of $7.25 million.
- output during the O&M phase is between $1.60 and $2.15 million annually with a median of $1.82 million.

Appendix A Tables of JEDI/Monte Carlo Simulation Results

Appendix A- 1 Wind Energy Project Impact on JOBS

	Jobs for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	9	4
5th	10	4
50th	12	4
95th	14	5
100th	15	5
	Jobs for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	50	20
5th	58	22
50th	68	24
95th	79	26
100th	86	27
	Jobs for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	151	61
5th	173	65
50th	206	71
95th	236	78
100th	259	82

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Construction Jobs for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had 79 or fewer Construction Jobs for a 60 MW Wind Farm. We interpret this as a 95% probably that the number of Construction Jobs for a 60 MW Wind Farm will be 79 or less. The 50th percentile represents the median.

Appendix A- 2 Wind Energy Project Impact on EARNINGS

($ millions)

	Earnings for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.28	0.10
5th	0.31	0.11
50th	0.36	0.14
95th	0.42	0.17
100th	0.46	0.19
	Earnings for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	1.51	0.60
5th	1.76	0.64
50th	2.07	0.77
95th	2.40	0.97
100th	2.62	1.09
	Earnings for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	4.56	1.75
5th	5.23	1.92
50th	6.23	2.31
95th	7.14	2.93
100th	7.84	3.25

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Earnings for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $2.40 million or less Earnings from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Earnings from a 60 MW Wind Farm will be $2.40 million or less. The 50th percentile represents the median.

Appendix A- 3 Wind Energy Project Impact on OUTPUT

($ millions)

	Output for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.96	0.26
5th	1.07	0.28
50th	1.27	0.32
95th	1.47	0.38
100th	1.59	0.42
	Output for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	5.31	1.49
5th	6.16	1.60
50th	7.25	1.82
95th	8.41	2.15
100th	9.18	2.37
	Output for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	15.98	4.48
5th	18.30	4.76
50th	21.81	5.45
95th	25.01	6.47
100th	27.42	6.95

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Output from a 60 MW Wind Farm). The 95^{th} percentile tells us that 95% of those 1000 simulations had $8.41 million or less Output from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Output from a 60 MW Wind Farm will be $8.41 million or less. The 50^{th} percentile represents the median.

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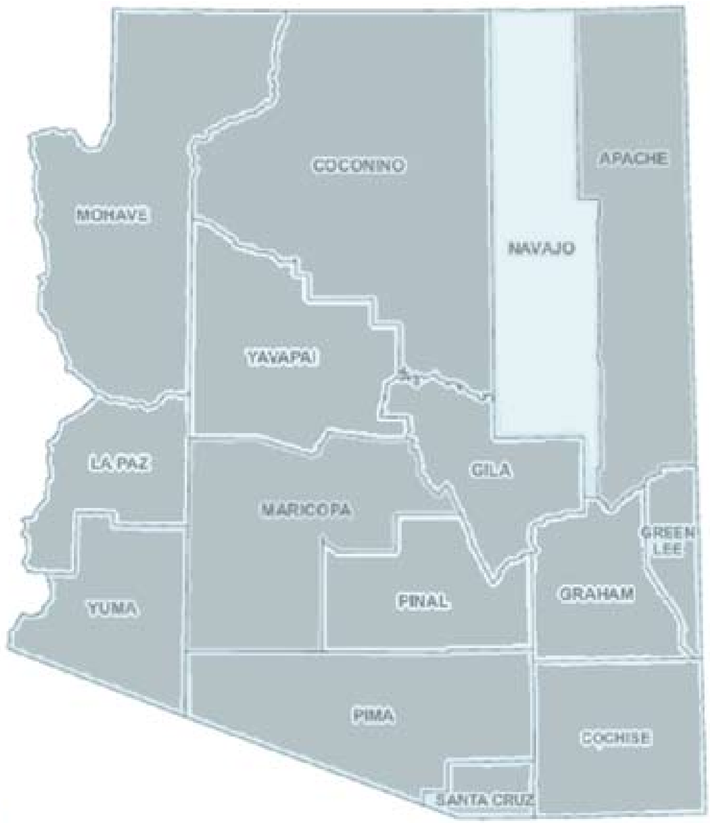
NORTHERN ARIZONA UNIVERSITY

Sustainable Energy Solutions

Arizona Wind Energy Assesment

Navajo County

Developable Windy Land
and Economic Benefits



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Abstract

This report contains two wind energy analyses for the northern Arizona county, Navajo County. In the first analysis, the developable wind energy capacity was estimated using a geographic information system. Specifically, the amount of windy land by wind class was determined. Development exclusions were then applied and the developable windy land was determined. The wind energy potential in Coconino County was estimated to be 7200 MW. The majority of developable windy land, 97%, was Class 3.

The second analysis determined the economic impact of constructing a wind energy project in Coconino County. Utilizing National Renewable Energy Laboratory's Job and Economic Development Impact (NREL's JEDI) model in conjunction with Monte Carlo simulation, economic benefits categorized by jobs, earnings, and economic output were estimated for three different sized wind energy projects, 10.5 MW, 60 MW and 180 MW.

For a 10.5 MW wind energy project

- *Jobs during construction*: median was 6 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 3 jobs
- *Earnings during construction*: the median was $0.15 million
- *Earnings during O&M phase*: median was $0.09 million annually
- *Output (economic activity) during construction*: median was $0.62 million
- *Output during O&M phase*: median was $0.20 million annually

For a 60 MW wind energy project

- *Jobs during construction*: median was 32 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 14 jobs
- *Earnings during construction*: the median was $0.86 million
- *Earnings during O&M phase*: median was $0.51 million annually
- *Output (economic activity) during construction*: median was $3.54 million
- *Output during O&M phase*: median was $1.15 million annually

For a 180 MW wind energy project

- *Jobs during construction*: median was 96 jobs
- *Jobs during operations and maintenance phase (O&M phase)*: median was 43 jobs
- *Earnings during construction*: the median was $2.60 million
- *Earnings during O&M phase*: median was $1.51 million annually
- *Output (economic activity) during construction*: median was $10.67 million
- *Output during O&M phase*: median was $3.47 million annually

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Introduction

The wind energy development potential and economic benefits were determined for a northern Arizona county, Navajo (see Figure 1). Using Geographic Information System (GIS) techniques on wind map data an estimate was made of the amount of developable windy land and potential installed. Secondly, an analysis was made of the economic impacts of constructing and operating wind energy projects in this county utilizing the Job and Economic Development Impact* (JEDI) model developed for National Renewable Energy Laboratory (NREL). Wind energy projects of three representative sizes were considered: 10.5 MW, 60 MW, and 180 MW. The JEDI model was used in conjunction with Monte Carlo simulation to estimate economic impacts at the county level. Direct, indirect and induced economic effects were estimated and categorized by jobs, earnings, and output (economic activity).

The wind maps and information in this report are *not* appropriate for siting wind energy projects. It is useful for discussing policy and locations that might be appropriate for further study. In order to site a wind energy project, an anemometer should be installed on the property and two years of data collected. More Arizona wind maps are available at www.ses.nau.edu.

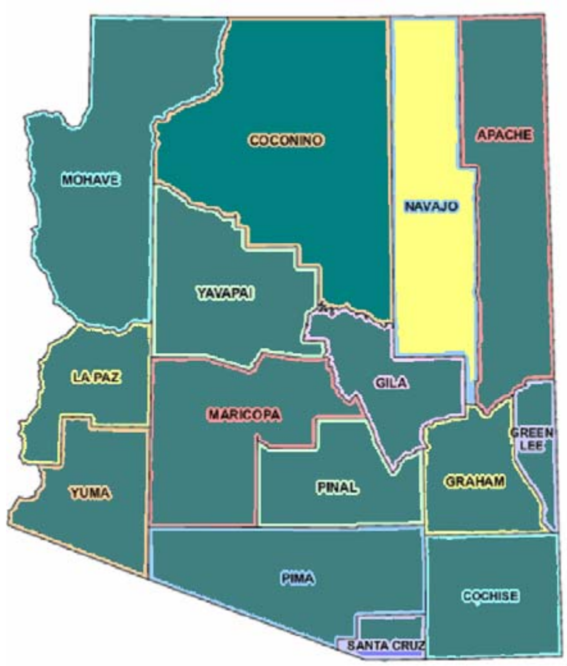

Figure 1 Navajo County in northern Arizona

* The JEDI model was designed by Marshall Goldberg, of MRG & Associates, under contract with NREL.The model is posted on the Wind Powering America website: http://www.eere.energy.gov/windandhydro/windpoweringamerica/filter_detail.asp?itemid=707 in June 2005.

State of Arizona

According to the US Census Bureau Quick Facts[1] the population in the state of Arizona increased 40% from 1990 to 2000. During this period US population increased 13.1%. Due to this rapid population and economic growth, electricity demand increased at the rate of 2.6% per year[2].

In 2001, the average electricity retail price for Arizona residents and businesses was 7.2 cents/kwh. This is the 16th highest average electricity price in the nation behind the six New England states, New York, New Jersey, Pennsylvania, California, Alaska, Hawaii, Texas, Florida, and Nevada. In addition to Arizona's increasing population, the hot climate and resulting need for air conditioning in the summer affect the increasing demand and price of electricity. Arizona has a larger than average residential demand largely due to the demand for air conditioning. The residential sector purchases 41% of the electricity as compared to 36% nationally[2].

Arizona primarily relies on coal and nuclear fuels for electrical generation. In 2000, approximately 45% of electricity was coal-generated and 35% was nuclear with only 10% generated from natural gas and another 10% by hydroelectric. However, the balance will be shifting to natural gas in the future as there are 16,000 MW of planned generation units by 2007, of which 15,000 MW are planned to be natural gas[2].

Navajo County

Navajo County is 9,959 square miles and is divided by the Mogollon Rim, an escarpment that defines the southwestern edge of the Colorado Plateau. The northern part of the county is desert-like mesas and plateaus while the southern part is rugged mountains heavily wooded with pinyon-juniper and ponderosa pine. Of note for wind energy is the pinyon-juniper covered Black Mesa geographic feature. The population in 2003 for Navajo County was 101,615. The county seat is Holbrook with a population of 5,320[3]. Demographic information is given in Table 1[4] and industry sector information is given in Table 2[5].

The largest land ownership category in Navajo County, approximately 55%, is Indian Reservation (see Table 3)[3]. In 1990, 14.2% of reservation households had no access to electricity as compared to 1.2% of all households nationally. On the Navajo Reservation households with no access to electricity is as large as 38%.[6] Thus there is a need for electricity in these two counties.

Table 1 Navajo County Demographics

Demographic	Navajo
Population, 2005 estimate	108,432
Population, percent change, April 1, 2000 to July 1, 2005	11.2%
Population, percent change, 1990 to 2000	25.5%
High school graduates, percent of persons age 25+, 2000	71.2%
Bachelor's degree or higher, pct of persons age 25+, 2000	12.3%
Per capita money income, 1999	$11,609
Median household income, 2003	$30,041
Persons below poverty, percent, 2003	21.4%
Private nonfarm establishments, 2003	1,809
Private nonfarm employment, 2003	18,562
Private nonfarm employment, percent change 2000-2003	11.2%
Retail sales, 2002 ($1000)	797,334
Retail sales per capita, 2002	$7,809
Land area, 2000 (square miles)	9,953
Persons per square mile, 2000	9.8
Metropolitan or Micropolitan Statistical Area	None

Table 2 Navajo County Industry Sectors

Industry Sectors in Navajo County	Percent	Employed
Agriculture, forestry, fishing and hunting, and mining	3.7	1,105
Construction	11.1	3,294
Manufacturing	5.4	1,605
Wholesale trade	1.6	482
Retail trade	13	3,855
Transportation and warehousing, and utilities	7	2,063
Information	1.3	395
Finance, insurance, real estate, and rental and leasing	3.8	1,112
Professional, scientific, management, administrative, and waste management services	3.8	1,115
Educational, health and social services	25.4	7,518
Arts, entertainment, recreation, accommodation and food services	10.7	3,157
Other services (except public administration)	3.9	1,144
Public administration	9.2	2,730

Table 3 Land Ownership in Navajo County

Land owner	Navajo
Indian reservation	55%
US Forest Service & BLM	9%
State of AZ	6%
Other public lands	
Private	30%
	100%

Windy Land Analysis using GIS

Methodology

For the purpose of this analysis, *windy land* is defined as land with a wind resource greater than or equal to class three as predicted by the Arizona Wind Map (the wind map will be discussed in the section on Input Data). That is, predicted average annual wind speeds are large enough that wind energy may be produced economically. However, not all windy land may be developed for wind power. There are many *development exclusions* that must be considered. For instance, land that is owned by the National Park Service must be excluded 100% from consideration for development. *Developable windy land*, therefore, is the windy land that remains after all development exclusions have been applied. Finally, *excluded windy land* is windy land (class 3 and above) that falls within a development exclusion.

Consistent with the methodology applied by NREL, there are three general *exclusion* categories of land unsuitable for development[7]:

- environmental exclusions
- land use exclusions
- additional windy land factors

These development exclusions are summarized in Table 4. Any windy land with 1 or more exclusion is excluded windy land and is not appropriate to be used for wind energy projects. After removing excluded windy land, the remaining land is developable and an estimate of the potential installed capacity by wind class for each county was made by assuming a conservative 5 MW of installed capacity per square kilometer.

Input Data for Windy Land Analysis

TrueWind Solutions, in collaboration with NREL, developed a high-resolution wind map and GIS data for the state of Arizona in 2003. The data for this wind map was created using a numerical weather model coupled with climactic data and a wind flow model. The wind map provides 200-meter resolution data sufficient for identifying the most promising areas for wind development in the state. The data from this map was used to analyze the wind resource of Navajo County.

A *data layer* is a geographic data set that can be represented visually using GIS software. Several data layers were required for the windy land and exclusion analysis. For the exclusions analysis, the data layers, their exclusion category (environmental, land use, other factors), source and brief description are listed in Table 4.

Table 4 Wind Development Exclusions

Broad Exclusion Category	Exclusion	Exclusion[†] Percentage	Exclusion Description	GIS Layer Source
Environmental Exclusions	**National Park Service**	100%	United States National Park Service Land	ALRIS [‡]
	Fish and Wildlife Service	100%	United States Fish and Wildlife service	ALRIS
	Congressionally Specially Designated Areas	100%	Special Areas, like wilderness or wild, and scenic rivers, congressionally designated as such	USFS
	Inventoried Roadless Areas	100%	These are roadless areas of the country on federal land that have been congressionally designated as such	USFS
	State and Other Environmental Land (State GAP Data)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP
	Other: Wildlife, Wilderness and Recreation Areas on Federal land of any designation (predominately USFS and BLM lands)	100%	Land Stewardship Layer (includes Nature Conservancy Land available)	USGS AZ ReGAP[§]
	Remaining USFS & DOD Land	50%	United States Forest Service and Department of Defense lands that remain after all other windy land exclusions are removed	ALRIS
Land Use Exclusions	**Urban/Developed Areas**	100%	Urban or Developed land as described by USGS ReGAP data	USGS AZ ReGAP
	Airports	100%	Airports	National Atlas of the United States, USGS, ESRI
	Wetlands	100%	Wetland ecosystems as described by USGS ReGAP data	USGS AZ ReGAP
	Water bodies (includes seasonal and dry lakes)	100%	Areas covered by water all year or part of the year. Does not include Rivers and Streams	USGS AZ ReGAP
	Non-ridge Crest Forests	50%	Areas of forest cover that are not considered ridge crests by TPI analysis	ReGAP + TPI [**]
Additional Windy Land Factors	**Slopes > 20%**	100%	These are landscapes with slopes greater than 20%	Grant Brummels

[†] Windy land exclusions were excluded 100%, with the exception of "non-ridge crest forests" and "remaining USFS and DOD Land," which were excluded 50%. Additionally, all 100% exclusions were buffered 3km, except for wetlands (100m), open water (no buffer), and slopes > 20% (no buffer).[†] Non-ridge crest forests have had all 100% exclusions removed. Remaining USFS and DOD land has had all non-ridge crest forests and 100% exclusions removed.

[‡] ALRIS—Arizona Land Resource Information System

[§] ReGAP—Regional Gap Analysis Program, 30m satellite data

[**] Jenness, J. 2005. Topographic Position Index (tip_jen.avx) extension for ArcView 3.x. Jenness Enterprises. Available at: http://www.jennessent.com/arview/tpi.htm. TPI was applied to a 90m Digital Elevation Model.

Results of Windy Land Analysis

The windy land in Navajo County is shown in was mapped using a GIS (Figure 2). Using GIS, the square kilometers of land was then totaled by wind class. In Navajo County, approximately 5% of the land is considered windy land. Of the windy land, the majority is class 3.

The development exclusions for Navajo County are mapped in Figure 3. As displayed, the land areas highlighted in blue show the areas that cannot be developed for wind energy regardless of how windy since this land was classified as a development exclusions. In Navajo County, 1.1% of all county land is classified as development exclusions.

The exclusions remove 21.9% of windy land from consideration for development. See Figure 4 to compare the wind class breakdown of the amount of windy land with the wind class breakdown of the amount of developable windy land. When exclusions are considered, much of the excluded windy land is higher than class 3. As a result, the proportional amounts of class 4 and above decrease with a corresponding increase in the proportional amount of class 3.

Some land is excluded under multiple categories. For instance, land may have a slope greater than 20% and also be Urban Developed Land. The largest exclusion affecting windy land is Urban Developed Land and excludes 13.5% of windy land. The 2nd largest exclusion affecting windy land is Slopes>20% and excludes 6.7% of windy land.

Table 5 provides a summary of the results of the windy land analysis for Navajo County, respectively. Organized by wind class, the total area of windy land, area of developable windy land, and potential developable capacity are shown. This table also shows that the total developable capacity in Navajo County, including class 3 or better windy lands, is 4,841 MW. When this estimate is restricted to windy lands of class 4 or better, the developable capacity is 168 MW. Finally, the developable windy land is shown in Figure 5.

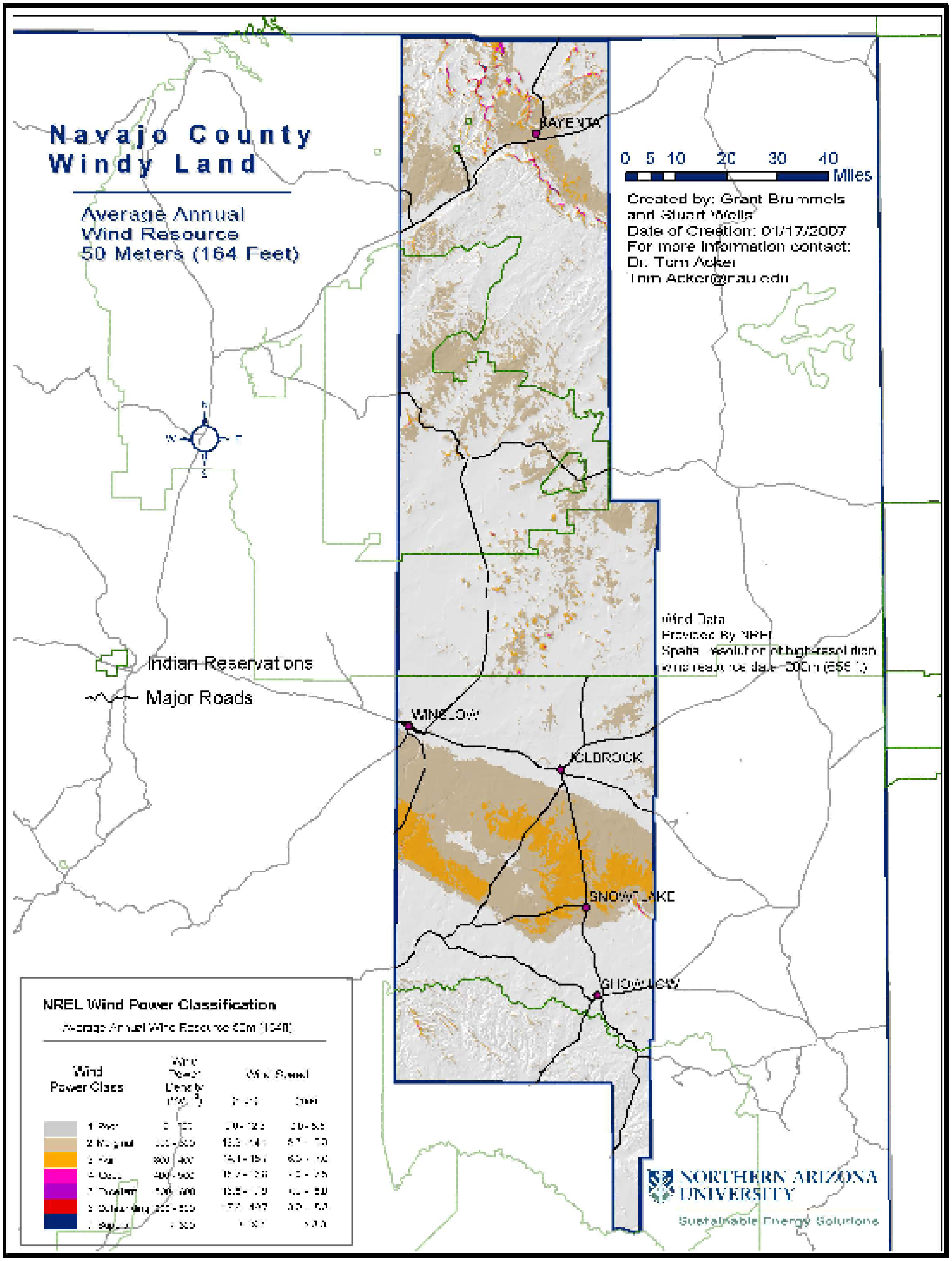

Figure 2 Map of Windy Land for Navajo County, AZ

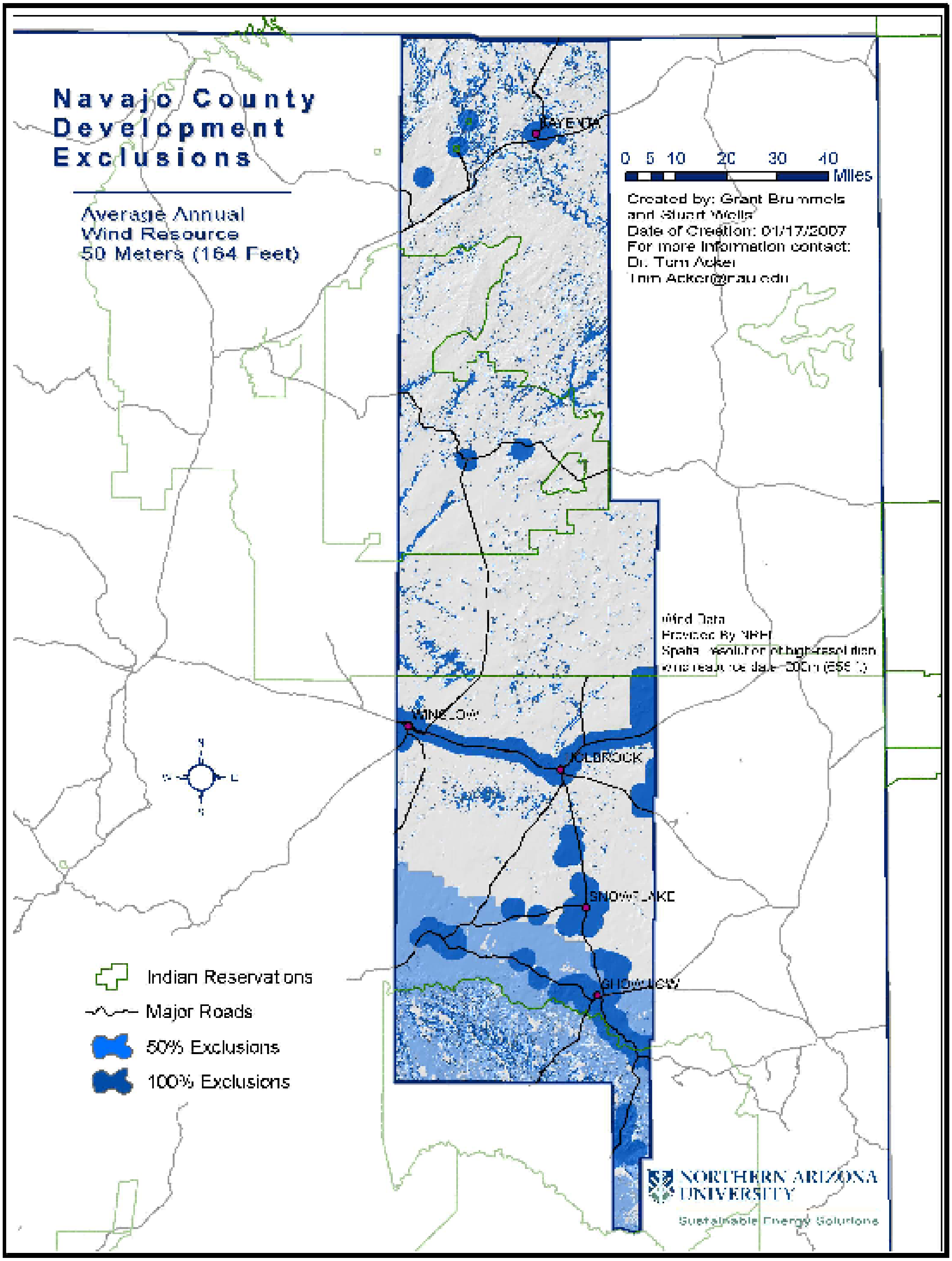

Figure 3 Map of Development Exclusions in Navajo Counties

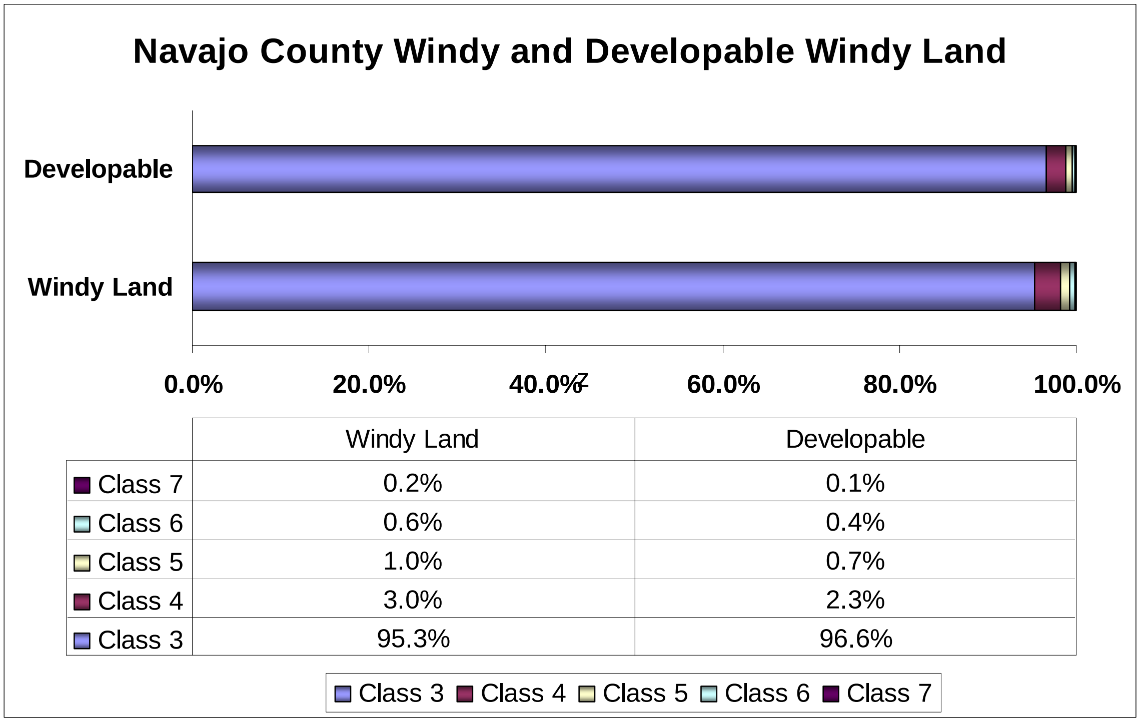

Figure 4 Windy Land and Developable Windy Land by Wind Class for Navajo County

Table 5 Windy Land and Developable Windy Land in Navajo County

Navajo County Wind Class Area Analysis							
Wind Class	Power (w/m^2)	Total Area (km^2)	Windy Land as Percent of Total Land Area	Developable Windy Land (km^2)[#]	Developable Windy Land as Percent of Total Land Area	Developable Installed Capacity (MW)*
3	300-400	1,193	4.66%	935	3.65%	4,673
4	400-500	37	0.15%	23	0.09%	113
5	500-600	12	0.05%	6	0.03%	32
6	600-800	7	0.03%	4	0.01%	18
7	>800	2	0.01%	1	0.00%	5
		25,585	**Navajo County Total**			4,841

*Assuming 5 MW per sq. km.

#Exclusions determined using GIS analysis

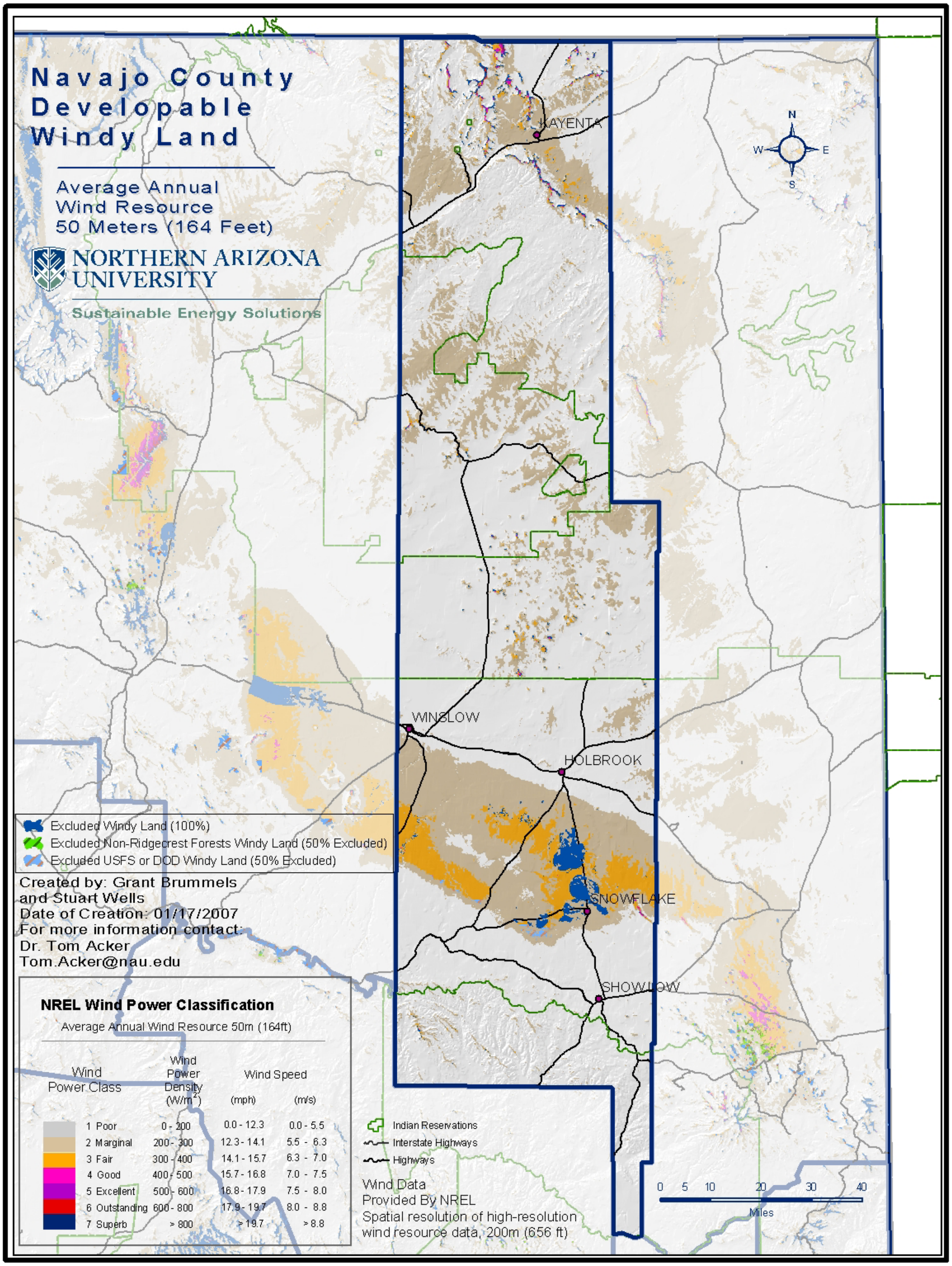

Figure 5 Map of Developable Windy Land for Navajo County

Economic Impact Analysis

In this study, economic input/output (I/O) analysis in conjunction with Monte Carlo simulation was used to estimate the economic impact for wind energy projects. The JEDI model performs I/O analysis with an Excel add-in, *@Risk*[8], used to perform the Monte Carlo simulation.

In I/O analysis, a project expenditure may have up to three impacts on the local economy:

- **Direct effects –** on-site effect created by expenditure (i.e., on-site jobs of contractors and crews, jobs at the turbine).
- **Indirect effects –** increase in economic activity that occurs when a contractor, vendor or manufacturer receives payment for goods or services and in turn is able to pay others who support their business.
- **Induced effects –** change in wealth and income that is induced by the spending of those persons directly and indirectly employed by the project (i.e., spending on food, clothes, utilities, transportation, insurance, medical, etc.).

The results of I/O analysis estimate these effects (direct, indirect, and induced) on the jobs, earnings, and economic output.

Methodology

JEDI Model

JEDI is a spreadsheet economic input/output model that accepts wind project data and estimates the direct, indirect, and induced effects of the expenditure to build and operate a wind energy project. The model separates a wind energy project into two distinct phases: construction phase and operations and maintenance (O&M) phase. The construction phase is approximately a year while the O&M phase is from the time the project is brought on-line until it is decommissioned. JEDI estimates the jobs, earnings, and economic activity for the one-time impact of the construction phase and the annual impact of the O&M phase.

JEDI was designed for users that have a variety of experience-levels in I/O analysis or with wind energy projects. To obtain results from JEDI, a user can input as little as the year of installation, the size of the project, and the state for which the economic impacts will be estimated. The remaining input has default values designed for a state-level analysis. As the user gains additional experience or information about the project, additional details can be entered into the model[9].

Why Monte Carlo simulation?

Monte Carlo simulation is a statistical simulation technique which allows input parameters that are uncertain to be randomly varied over a specified range of values. Multiple trials of the Monte Carlo model allow the user to observe and average the results of the output.[10] @Risk by Palisade Corporation[8], an add-in to Microsoft Office Excel, was utilized for Monte Carlo simulation.[11] Using Monte Carlo simulation in conjunction with the I/O analysis provided two advantages over an analysis with JEDI only:

1) Increased input flexibility – cost estimates may be entered as a range of values instead of a single estimate.
2) Increased output information –a range of output values was obtained instead of a single value.

The data required by the JEDI model to estimate the economic impact of constructing and operating a wind energy project can be difficult to accurately estimate. Some input parameters are specific to the site and design. However, estimates for economic impacts are often desired before a site and design have been selected. In addition some of this data is proprietary and industry norms must be relied on to estimate the parameters.

The approach in other work[12,13] has been to use a single estimate representing the most likely value or industry average. For each of the outputs, the JEDI model then produced a single value. By using Monte Carlo simulation any input parameters can be approximated by a range of input values. For each of these input parameters, three estimates were determined: (1) the most likely estimate, (2) the minimum estimate, and (3) the maximum estimate.

Running a simulation with these input parameters as random variables provides an expected value and a variance of the output variables. Therefore, the output is a range of values instead of a single number. This provides a measure of certainty or risk: the smaller the range, the more certainty in the results. When using the JEDI model, the economic impact is estimated using six measures: jobs during construction phase, jobs during O&M phase, earnings during construction phase, earnings during O&M phase, output during construction phase, and output during O&M phase.

Finally, the input parameter(s) which have the most influence on the output can be determined using Monte Carlo simulation. Effort can then be focused on accurately estimating those input parameters that have the most significant effect on the outputs.

Input Data for Economic Impact Analysis

Sources of information are documented. However, many modeling decisions are also based on information gained from discussion with wind energy professionals and experts. These discussions have occurred over time in many venues including the Arizona Wind Working Group and the AWEA Windpower meetings.

County Multipliers

In order to utilize JEDI for county-level analysis, appropriate multipliers for Coconino County were obtained from Marshal Goldberg via NREL. Specifically, the direct, indirect and induced multipliers for employment, earnings and output (per million dollars change in final demand) and personal consumption expenditures (i.e., average consumer expenditures on goods for the counties) were obtained[14]. Using the state-level multipliers that are provided with JEDI would overstate the economic benefits so it was important to obtain county-level multipliers for this analysis.

Wind Energy Project Size

Three wind energy project sizes were selected for the economic impact analysis. The sizes that were selected are based on discussions with wind energy experts and professionals, examination of the results of the windy land analysis and surveying the projects that came on-line in 2003-2004 in the southwest. For all analysis, 1.5 MW wind turbines were assumed.

The smallest project size considered was 10.5 MW and the largest was 180 MW. The mid-sized project was assumed to be 60 MW, which is the size of the wind project planned for Sunshine Wind Park near Winslow, Arizona and the size of two wind energy projects built in the southwest in 2003-2004, Caprock Wind Ranch in New Mexico and the Oasis Wind Power Project in southern California. In the southwest during 2003-04, three wind energy projects were built that were in the size range of 160-200 MW (New Mexico Wind Energy Center, Colorado Green Lamar, Brazos Wind Ranch in Texas) [15]. To date, no utility-scale wind energy projects have been built in Arizona.

Construction Cost and Operations & Maintenance Cost

Construction cost and O&M cost depend on site and design specific data. Since the site and design were not known, these costs were estimated by a range of values. The estimates used for construction cost and operations and maintenance (O&M) cost are given in Table 6. Estimates for these costs are based on several sources including conversation with a wind developer[12,13,16,17].

Table 6 Input Parameter Estimates

Input Parameter	Minimum	Most Likely	Maximum
Construction Cost ($/kw)	$1,000	$1,200	$1,500
Annual Operating Cost ($/kw)	$9.50	$12.50	$25.00
Property Tax Rate	2.8%	9.4%	13.5%

Both construction cost and O&M cost were uncertain input parameters and were therefore simulated. The triangular distribution was used to generate these costs. The triangular distribution is often used in practice because it is uni-modal and may be non-symmetrical. In addition, there are fixed endpoints for the range of values. Finally, the triangular distribution is a good distribution to use in the absence of data. In the absence of data, experts can be surveyed and industry data consulted for averages. Experts can be asked for their subjective estimates of the minimum, most likely, and maximum values.[18]

Property tax calculation

To calculate the property tax in Arizona the construction cost which includes the cost of the equipment (wind turbines), building and installation costs, must first be determined. Typically, the *full-cost value* is 80% of the construction cost. Property taxes are based on the *assessed value* which is 25% of the full-cost value. The *property tax* is the tax rate multiplied by the assessed value, see Table 7

Table 7 Arizona Property Tax Calculation

Full Cost Value = 80% * Construction Cost
Assessed Value = 25% of Full Cost Value
Tax = Tax Rate * Assessed value

The tax rate varies significantly depending on the location within the state. Examining the tax tables, it was determined that the range of tax rates vary from a minimum of 2.8% to a maximum 13.5%. Tax rates were estimated from information obtained in conversations with the Navajo County Tax Assessor's office[3,19]. The property tax rate was simulated using a triangular distribution.

Local Share

Local share is the percentage of expenditures spent in the state or local region where the wind energy project is constructed. For this work, it represents the percentage of expenditures spent in the county. Currently, the JEDI model provides default values for local share percentages that are estimated at the state-level (See Table 8). The JEDI model default values are not appropriate for a county-level analysis as the results will be considerably overstated.

We developed local share percentages that apply to Navajo County by consulting with a wind developer and an economist. Constanti (2004) also provides guidance for setting the local share percentages for rural counties in Montana. Finally, we examined Navajo County demographics (Table 1, Table 2) focusing particularly on population and employment. Minimum and maximum local share percentages were established and are also shown in Table 8[12]. The local share percentages were simulated using a uniform distribution which implies that all values between the minimum and maximum (default) are equally likely.

Simulation Parameters

For each county and wind project size, a simulation was run. For each simulation, the number of trials was determined by observing the convergence of the distribution statistics for the output variables (construction phase: jobs, earnings, output; O&M phase: jobs, earnings, output). When the measured statistics changed no more than 1%, the output distribution was considered 'stable' and the simulation was considered to have converged. The number of trials in each simulation varied between 900 and 1100. The output distribution statistics that were measured are the average percent change of the percentiles, the mean, and the standard deviation.

Table 8 Local Shares Values[††]

	JEDI default	Navajo County	
Project Cost Data	**State-level Local Share**	**Minimum Local Share**	**Maximum Local Share**
Construction Costs			
Materials			
Construction (concrete, rebar, equip, roads and site prep)	90%	25%	50%
Transformer	0%	0%	0%
Electrical (drop cable, wire,)	100%	10%	25%
HV line extension	100%	0%	10%
Labor			
Foundation	100%	40%	60%
Erection	75%	10%	15%
Electrical	75%	25%	50%
Management/supervision	0%	0%	0%
Equipment Costs			
Turbines (excluding blades and towers)	0%	0%	0%
Blades	0%	0%	0%
Towers	0%	0%	0%
Other Costs			
HV Sub/Interconnection	100%	10%	25%
Engineering	0%	0%	5%
Legal Services	100%	25%	50%
Land Easements	100%	100%	100%
Site Certificate/Permitting	100%	100%	100%
Wind Plant Annual Operating and Maintenance Costs			
Personnel			
Field Salaries	100%	60%	75%
Administrative	100%	60%	75%
Management	100%	60%	75%
Materials and Services			
Vehicles	100%	50%	75%
Misc. Services	80%	25%	50%
Fees, Permits, Licenses	100%	100%	100%
Utilities	100%	100%	100%
Insurance	0%	0%	0%
Fuel (motor vehicle gasoline)	100%	100%	100%
Tools and Misc. Supplies	100%	60%	75%
Spare Parts Inventory	2%	2%	2%

[††] JEDI default values should not be used for a county-level analysis. The JEDI default values are appropriate only for a state-level analysis. If used for a county-level analysis, benefits will be greatly overstated.

Results of Economic Impact Analysis

All economic outputs from JEDI are divided into benefits that occur during the construction phase (usually less than a year) and annual benefits that occur during the operational life of the wind project. For each phase, the model estimates:

- Jobs – the number of full-time equivalent employment for a year.
- Earnings - wage and salary compensation paid to workers.
- Output - economic activity or the value of production in the county economy.

For all three estimates, the simulation in conjunction with the JEDI model produces a frequency distribution. We report the percentiles for these distributions. The 50th percentile is the median. That is there is 50% chance that the number of jobs will be above the median and a 50% chance that the number of jobs will be below the median. We report the minimum, 5th percentile, 50th percentile, 95th percentile and maximum. There is a 95% likelihood that the number of jobs will be less than the 95th percentile.

Jobs

Results pertaining to job creation for each wind energy project size and project phase are given in Figure 6 and Figure 7. A summary table is given in Appendix A-1. Based on simulation, there is a 90% likelihood that the number of jobs created during the construction phase in Navajo County will be between 25 and 39 for a 60 MW wind energy project. During the O&M phase, there is a 90% likelihood that the number of jobs created in Navajo County will be between 12 and 16.

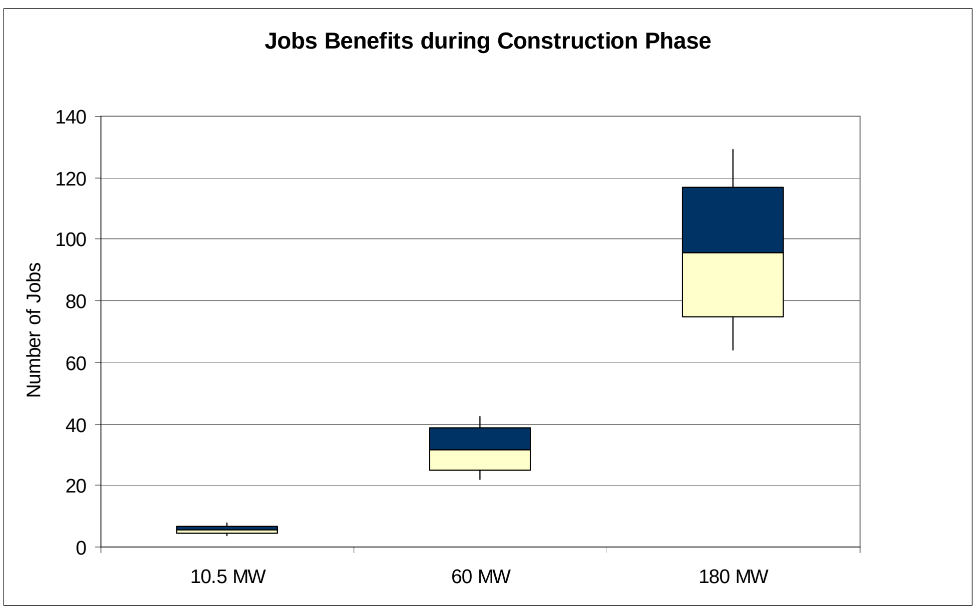

Figure 6 Wind Energy Project Impact on JOBS during Construction Phase

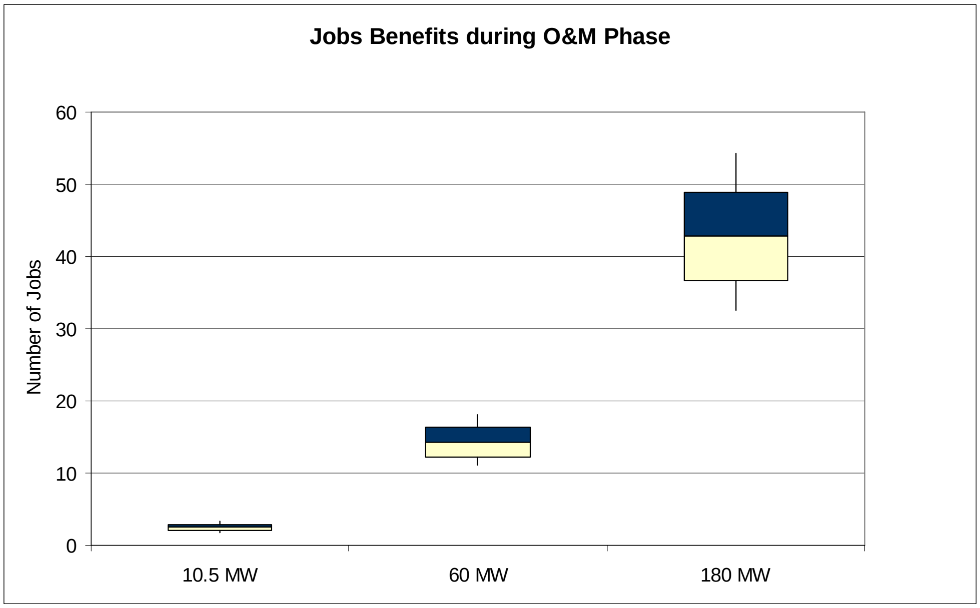

Figure 7 Wind Energy Project Impact on JOBS during O&M Phase

Earnings

Earnings refer to millions of dollars in wages and salary paid to workers. Results for earnings for all wind energy project sizes and phases are given in Figure 8 and Figure 9. A summary table is given in Appendix A-2. Based on simulation, there is a 90% likelihood that the earnings paid during the construction phase in Coconino County will be between $0.69 and $1.06 million annually for a 60 MW wind energy project (in 2007 dollars). During the O&M phase, there is a 90% likelihood that the annual earnings in Navajo County will be between $0.40 and $0.67 million.

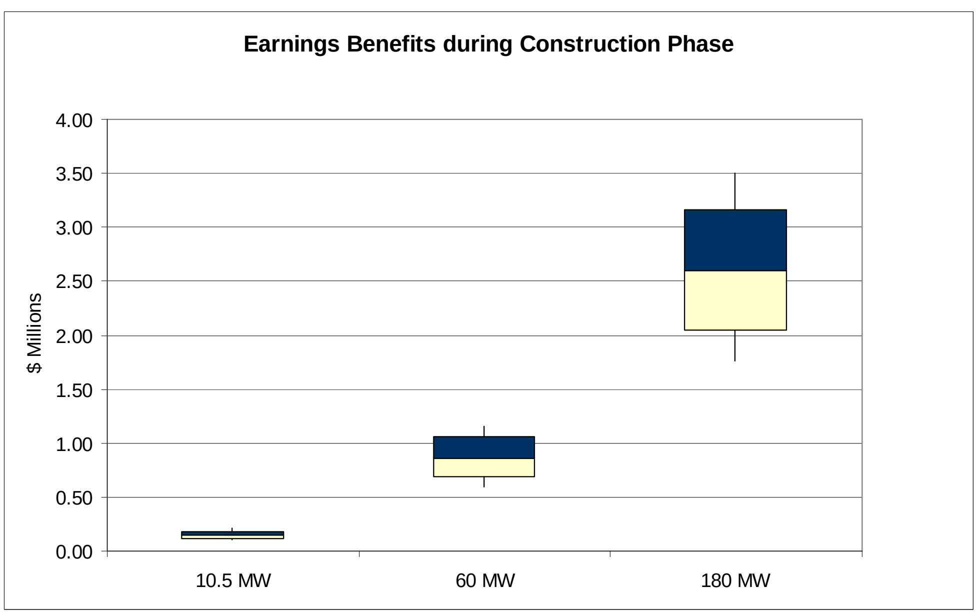

Figure 8 Wind Energy Project Impact on EARNINGS during Construction

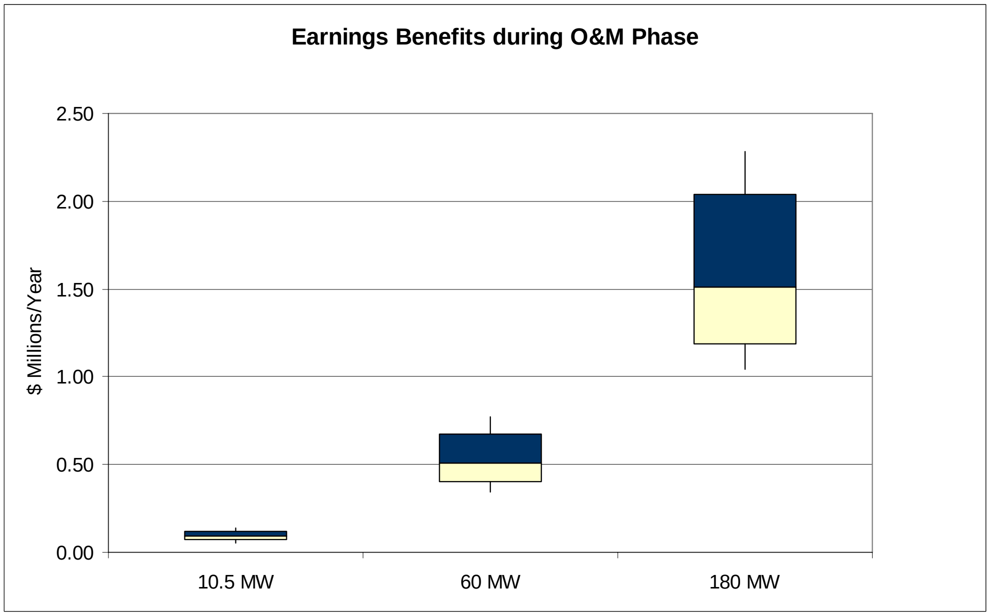

Figure 9 Wind Energy Project Impact on EARNINGS during O&M Phase

Output

Figure 10 and Figure 11 show a summary of output results for all wind energy project sizes and phases. A summary table is given in Appendix A-3. Output refers to economic activity or the value of production in the county and is also in millions of 2007 dollars. Based on the simulation results there is a 90% likelihood that the output will be between $2.8 and $4.34 million annually for Coconino County. During the O&M phase, there is a 90% likelihood that the annual output in Navajo County will be between $0.91 and $1.44 million.

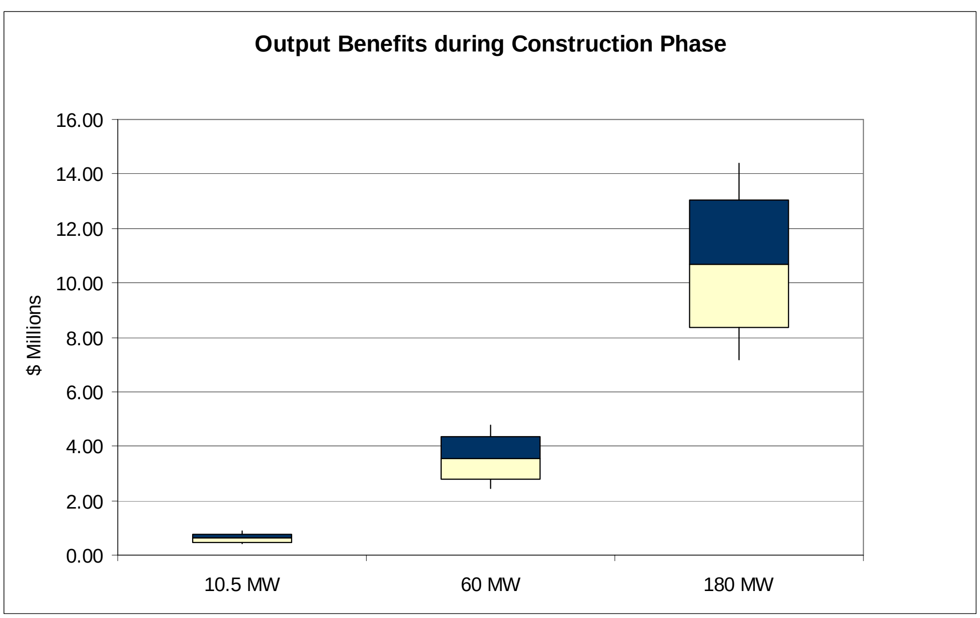

Figure 10 Wind Energy Project Impact on OUTPUT during Construction Phase

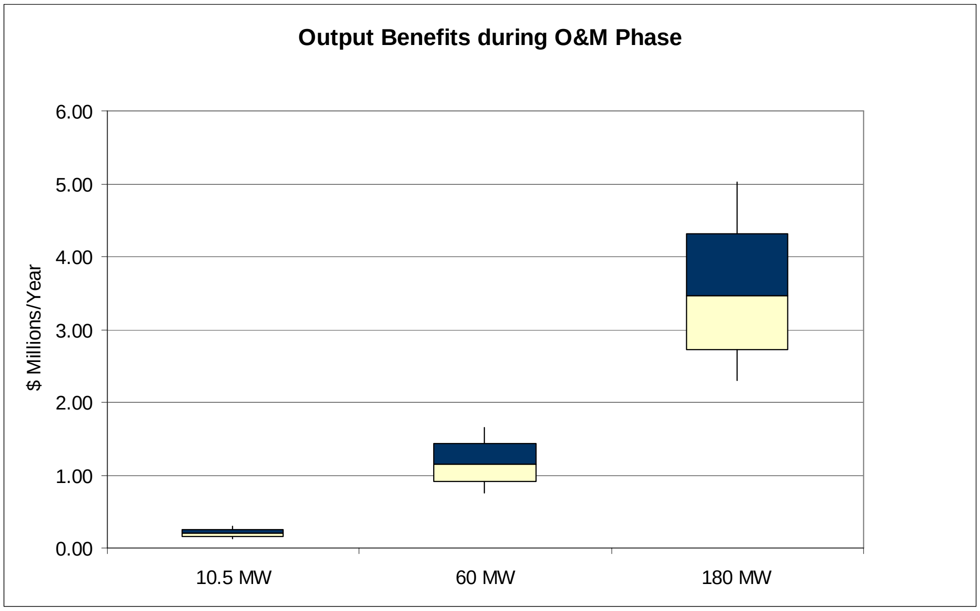

Figure 11 Wind Energy Project Impact on OUTPUT during O&M Phase

Conclusions

The first objective of this project was to estimate the wind energy development potential for Navajo County. Based on high-resolution wind map data analyzed in a GIS while considering development exclusions, it was estimated that the developable windy land and potential installed capacity for Navajo is approximately 4800 MW. The majority of this capacity is from Class 3 wind. When this estimate is restricted to windy lands of class 4 or better, the developable capacity is 160 MW.

The second objective of this work was to estimate the economic impact of constructing and operating wind energy projects of various sizes in Navajo County. Monte Carlo simulation was conducted in conjunction with the JEDI model and provided a range of outputs corresponding to a range of estimated input parameters. For a 60 MW wind energy project, there is 90% likelihood that:

- number of jobs created during the construction phase is between 25 and 39 with a median of 32 jobs.
- number of jobs created during the O&M phase is between 12 and 16 with a median of 16.
- earnings during the construction phase is between $0.69 and $1.06 million with a median of $0.86 million.
- earnings during the O&M phase is between $0.40 and $.67 million annually with a median of $0.51 million.
- output during the construction phase is between $2.04 and $3.17 million with a median of $2.60 million.
- output during the O&M phase is between $1.19 and $2.04 million annually with a median of $1.51 million.

Appendix A Tables of JEDI/Monte Carlo Simulation Results

Appendix A- 1 Wind Energy Project Impact on JOBS

	Jobs for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	4	2
5th	4	2
50th	6	3
95th	7	3
100th	8	3
	Jobs for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	22	11
5th	25	12
50th	32	14
95th	39	16
100th	43	18
	Jobs for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	64	32
5th	75	37
50th	96	43
95th	117	49
100th	129	54

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Construction Jobs for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had 39 or fewer Construction Jobs for a 60 MW Wind Farm. We interpret this as a 95% probably that the number of Construction Jobs for a 60 MW Wind Farm will be 39 or less. The 50th percentile represents the median.

Appendix A- 2 Wind Energy Project Impact on EARNINGS

($ millions)

	Earnings for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.10	0.06
5th	0.12	0.07
50th	0.15	0.09
95th	0.18	0.12
100th	0.21	0.14
	Earnings for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	0.60	0.34
5th	0.69	0.40
50th	0.86	0.51
95th	1.06	0.67
100th	1.16	0.77
	Earnings for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	1.76	1.04
5th	2.04	1.19
50th	2.60	1.51
95th	3.17	2.04
100th	3.51	2.28

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Earnings for 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $1.06 million or less Earnings from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Earnings from a 60 MW Wind Farm will be $1.06 million or less. The 50th percentile represents the median.

Appendix A- 3 Wind Energy Project Impact on OUTPUT

($ millions)

	Output for 10.5 MW Wind Farm	
Percentile	Construction	O & M
0th	0.42	0.12
5th	0.48	0.16
50th	0.62	0.20
95th	0.76	0.25
100th	0.88	0.30
	Output for 60 MW Wind Farm	
Percentile	Construction	O & M
0th	2.45	0.75
5th	2.80	0.91
50th	3.54	1.15
95th	4.34	1.44
100th	4.75	1.65
	Output for 180 MW Wind Farm	
Percentile	Construction	O & M
0th	7.16	2.29
5th	8.35	2.72
50th	10.67	3.47
95th	13.03	4.32
100th	14.40	5.03

Note: Percentile is a descriptive statistic. When we simulate 1000 times, there are 1000 measurements of each output (i.e. Output from a 60 MW Wind Farm). The 95th percentile tells us that 95% of those 1000 simulations had $4.34 million or less Output from a 60 MW Wind Farm. We interpret this as a 95% probably that the amount of Output from a 60 MW Wind Farm will be $4.34 million or less. The 50th percentile represents the median.

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