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Socioeconomic impacts of wind farm development: a case study of Weatherford, Oklahoma

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Abstract

Background: There have been increasing efforts nationally and internationally to promote renewable energy as a response to the awareness of the limited supply of fossil fuels, to meet growing energy demand, and to reduce the harmful environmental impacts of fossil fuel use. To address these efforts, there have been numerous studies to address the impact to local communities. However, these studies have typically focused on either the economic or the social aspects of the wind farm development. This study analyzes the combined and varied socioeconomic impacts as well as the stakeholder perceptions associated with wind power development in Weatherford, Oklahoma.

Methods: This project uses a mixed-method approach to investigate the impact on a small city when a substantial wind farm is built nearby. This approach consists of three components: a survey, in-depth personal interviews, and economic modeling. The economic modeling is performed to determine both direct and indirect economic impacts.

Results: Results from this research show the economic impact on the local community and estimate the number of construction and other types of jobs. In addition, the interviews and surveys illustrate other aspects of the socioeconomic impact and describe overall attitudes of the population to the wind farm development.

Conclusions: The study uses a case study and a mixed methods approach to illustrate the socioeconomic impacts of wind farm development. As the world moves increasingly toward green energy, studies like this are important to be able to fully understand impacts on the local community of this type of development.

Keywords: Wind energy, Economic impact, Societal perceptions

Background

The use of wind as an energy source in Oklahoma has a long history [1]. For example, wind energy was used by early settlers and farmers in Western Oklahoma to power well pumps. The early settlers were able to use these pumps to irrigate and make farming possible in areas where climate may have otherwise prohibited it. Similarly, today's society could choose to continue to use fossil fuels, which have significant harmful effects [2], or could choose to create a diversified energy portfolio [3]. Schiermeier et al. in 2008 [4] illustrate the potential mechanisms and impacts of 'electricity without carbon,' as utilities and policymakers move toward a low carbon economy. Nationally, there have been increasing efforts to promote renewable energy as a response to the awareness of the limited supply of fossil fuels, to meet the growing energy demand, and to reduce the harmful environmental impact of fossil fuel use. Organizations such as the National Renewable Energy Laboratory, the American Wind Energy Association, and others have been researching and promoting renewable energy in the USA. State and local governments as well as the federal government have realized that not only can renewable energy be a way to meet future energy demands but it could also promote economic growth in rural communities. Some of these rural communities have experienced job losses and declining population in recent years [5].

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At the same time the groups mentioned above have been highlighting and promoting potential impacts, wind farm developers have also been looking for potential markets and locations for expansion. Figure 1 shows the wind resources across Oklahoma (the study location is indicated by the square in the figure). The geographic distribution of this resource varies severely from east to west. In the eastern part of the state, rough terrain helps to reduce wind resources. However, western Oklahoma has large areas of commercially viable wind resources, particularly associated with a series of west–east running ridge lines across the western portion of the state. The class 3 wind areas in Figure 1 show those areas in which a wind farm could be potentially economically viable. Rural communities have been some of the hardest hit areas economically in recent decades, suffering large losses of population and jobs [5]. Figure 2 overlays the commercially viable wind in Oklahoma with those counties undergoing population and job loss. This figure shows that wind-driven economic development would have an even greater impact in these areas.

Wind farms have different impacts on local economies. They provide both short-term and long-term employment during different phases of development. Landowners also benefit in the form of annual royalty payments. Local economies will benefit greatest if the local community can provide a wide range of goods and services that can be used during the construction of the wind farms. The extent to which the local economy offers goods and services will determine how significant the ultimate impact will be on the local economy. Local ownership can also play an important role in the overall impact of the wind farm development. As stated by Phiminster and Roberts (2012), development of the wind energy sector is often listed as a way to support rural economies [6]. As they conclude 'with no local ownership, while rural GDP increases, there is almost no effect on household incomes due to the limited direct linkages of the on-shore wind sector.' Similarly, while local ownership can result in a benefit to household incomes, 'there are still limited positive spill-over effects on the wider economy unless factor income is re-invested in local capital' [6].

If the local economy does not offer a wide range of goods and services, these goods and services must be brought in from elsewhere; thus, this income will leave the local economy. The income leaving the community to pay for these goods and services is referred to as 'leakage' [7,8]. Leakage occurs when the developer of the wind farm must leave the local community and contract with companies outside of the local community.

County demographics, including population levels, education levels, and amount of economic diversity, help to further identify the economic impacts of wind farm development [9]. For example, by looking at a range of factors across wind-rich counties in the central USA, Brown et al. in 2012 found that there is a median of 0.5 jobs per megawatt of wind power capacity [9]. For the study period of 2000 to 2008, this represents a 'median increase in total county personal income and employment of 0.2% and 0.4% for counties with installed wind power'.

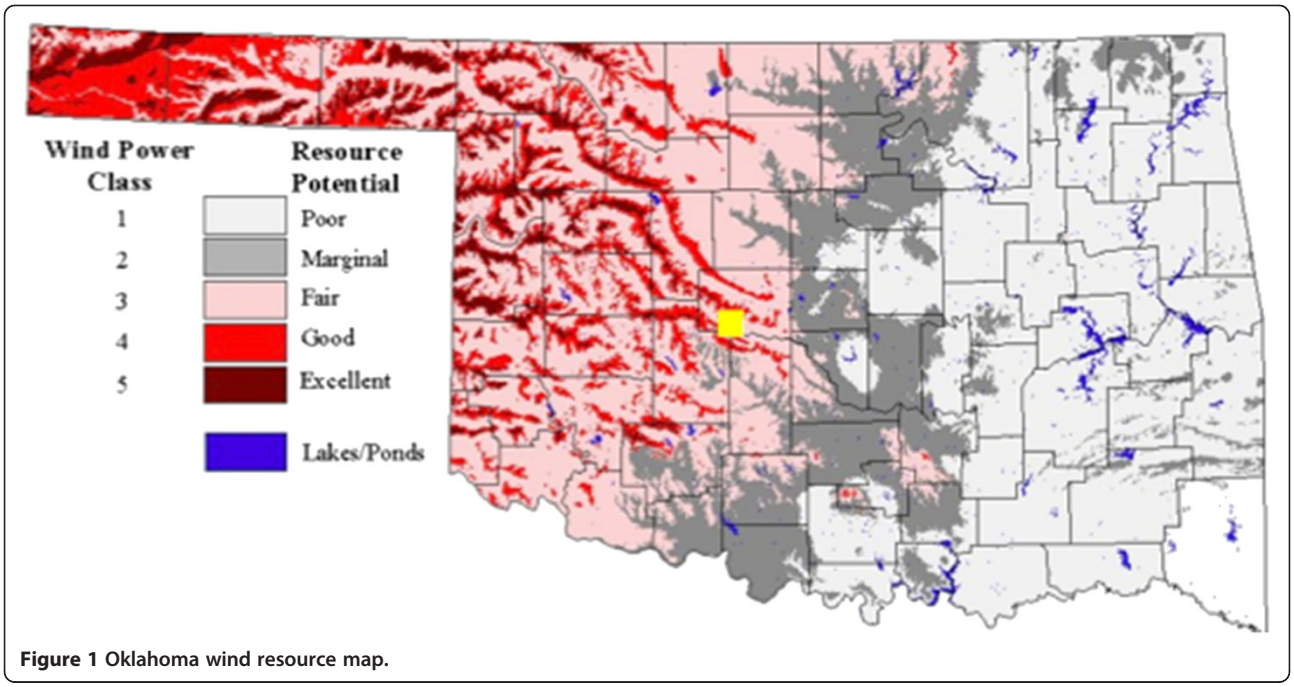

Figure 1 Oklahoma wind resource map.

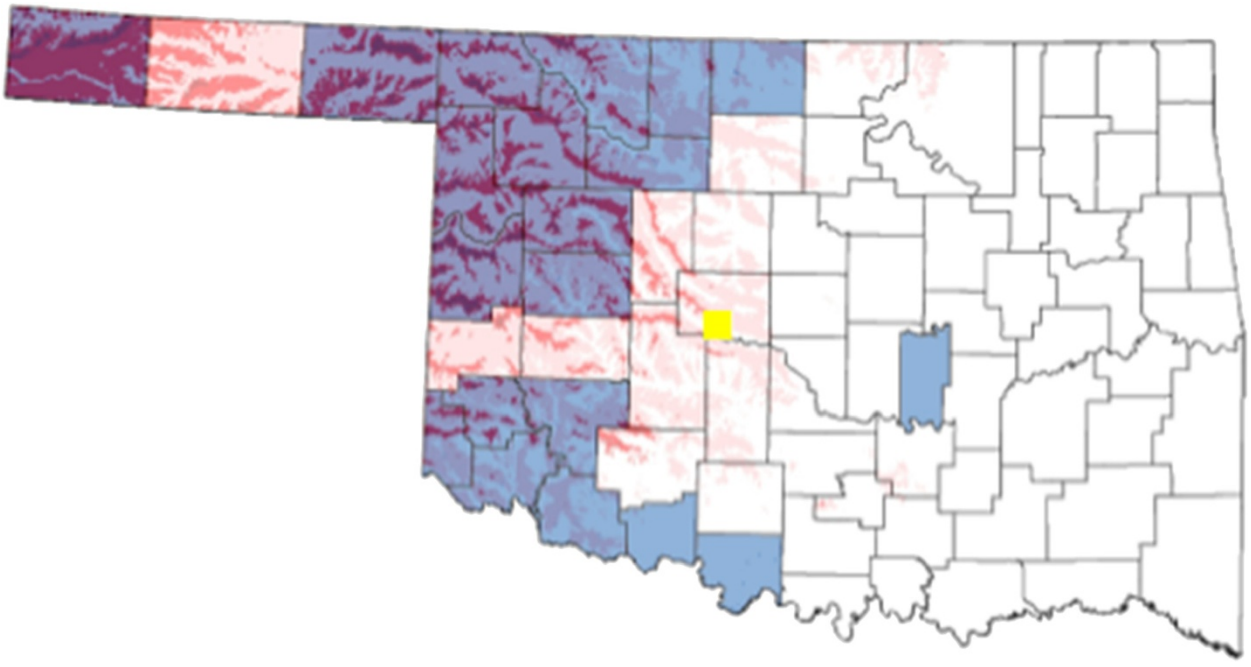

Figure 2 Commercially viable wind and population loss counties.

As can be seen from Figure 2 and Tables 1 and 2, Weatherford provides an excellent location for an analysis of the impact of a wind farm. It is a relatively small city in a rural area and although its county has not experienced population loss, it is near the areas with an overall loss of population. Weatherford, Oklahoma is located in Custer County, approximately 80 miles west of Oklahoma City. Through innovations like using wind to power pumps for irrigation, the city has thrived as an agricultural community for the last several decades. Today, the majority of people make their living in educational or service-related fields followed by construction, manufacturing and agriculture (Tables 1 and 2, data obtained from the US Census Bureau). The addition of the wind farm has helped to add to the business climate and diversify the city's industrial image.

This study analyzes the impact of the Weatherford Wind Energy Center. It is located in West Central Oklahoma, in Custer County, near and around the City of Weatherford. The developer is NextEra Energy and American Electric Power is the purchaser. Located on approximately 5,000 acres of land, the wind farm has 98 GE 1.5 MW turbines with a rated capacity of 147 MW of electricity - enough to power 44,000 homes. The wind regime is rated in the 'good' to 'excellent' range, according the wind resource class analysis, and consists of strong, consistent winds. The wind farm sits on low ridges that are higher in elevation than the city. These provide an additional increase in the winds as compared to the surrounding plains and, thus provide a suitable location for the wind farm. The location of this wind facility is highly visible to the public. Most of the 98 turbines can be seen from the state's major east–west Interstate (Interstate 40).

Table 1 City of Weatherford demographic data

Demographic data	Value
Population	9,859
Number of housing units	3,991
Percent with bachelor degree or higher	37.1%
Unemployment rate	3.0%
Median household income	US$26,908
Percentage below poverty level	11.8%

Table 2 City of Weatherford employment by sector

Type of employment	Percentage
Management, professional occupations	30.8
Sales and office occupations	30.8
Service occupations	16.2
Construction, maintenance occupations	10.6
Production, transportation occupations	10.2
Farming, fishing, and forestry occupations	1.4

Methods

The aim of this study is to use a multi-method approach to examine the impacts of the wind farm on Weatherford. This project consists of three components: economic modeling, surveys, and in-depth interviews. The specific methodological approaches are discussed below. Although

there have been many studies examining economic impacts, as discussed above, and many others looking at public perceptions (e.g., see [10-12]), there are few if any studies that have provided a complete, holistic impact of a wind farm to a small community, and also, in addition, examined the social attitudes of the local populace as well as the key stakeholders and decision makers. In addition, there have been no previous studies in this area of the wind belt of the central US plains. This approach was taken since any one approach would not fully address the multidimensional aspect of the socioeconomic impacts. However, by combining approaches, a more detailed and robust picture of the impacts of the local wind farm can be determined.

Economic modeling

The first component to assess the wind farm impact on the Weatherford area is an economic model analysis. The economic modeling is performed to determine direct economic impacts (e.g., increased local tax revenue) and indirect economic impacts (e.g., increased revenue from other industry sectors). For this study, the economic modeling was performed using a combination of the impact analysis and planning (IMPLAN) and job and economic development index (JEDI) input–output models. IMPLAN is an economic impact assessment modeling system, which can be used at many different geographic levels, from a state to county level. The initial intent of IMPLAN was to assist in land resource and land management. However, there are currently users representing a range of backgrounds from government to academia to private industry [13-16].

IMPLAN is an input–output model that relies on multipliers to quantify interactions between industries [17,18]. Each industry or service activity within the economy (e.g., agriculture, mining, manufacturing, and construction) is assigned to a specific sector (e.g., grain farming and fruit farming are assigned to agriculture; motor and generator construction are assigned to electrical equipment) within the economy. Input–output accounting describes commodity flow from the producer to the intermediate and final consumers. Total industry purchases including, for example, services, employment compensation, and imports, are equal to the good that is being produced [19]. This cycle of buying goods and services (indirect purchases) continues until leakage from the region stop the cycle. The additive features of these indirect and induced effects are compounded in the model through the Leontief Inverse Matrix [20]. The values in the Leontief Inverse Matrix represent the total direct and indirect requirements of any industry supplied by other industries within the region in order for that industry to be able to deliver US$1 worth of output to final demand [20]. Additional file 1 lists an example of some of the multipliers for Custer County.

For this study, the demographic and multiplier data was imported into IMPLAN to begin the model development. IMPLAN contains 528 economic sectors, and wind power is contained within the electric services sector. Wind energy makes up a very small percentage of this sector. To compensate for this, a sub-model of IMPLAN specific to the wind industry, the JEDI has been developed [21]. JEDI has been extensively used in wind energy impact modeling [22-25]. For example, Slattery et al. in 2011 [26] used JEDI to examine over 1,300 MW of wind farms in Texas. Results showed an increase of over 4,000 full time equivalent jobs and overall lifetime impact to the area of these wind farms of almost US$2 billion.

For this study, the county under analysis was selected within IMPLAN (Custer County in this case) and the model and multipliers were created, and this information was transferred into JEDI for further analysis. Several variables, such as project size, location, finance arrangements, and local economic factors influence construction and operating costs. The amount of local resources that are available can significantly impact the costs and economic impacts on a local region. Project specific data can be defined as a bill of goods; these components are considered critical in determining the number of jobs created. The bill of goods includes costs associated with actual construction of the facility, as well as annual operating and maintenance costs. To the extent possible, the model inputs were obtained for the specific project in Oklahoma; however, some of this data is proprietary, and thus in situations where data could not be obtained, best available estimates were used. For this research, the appropriate aggregation was created manually from the 528 sectors within IMPLAN. When the model aggregation was complete, the social accounts and the various multipliers were recomputed and entered in the JEDI model for final analysis.

Survey and interviews

IMPLAN and JEDI modeling provides useful information as part of an economic impact study. However, to try to present a more complete picture of the impact of the wind farm, qualitative methods were also used. First, direct interviews with some of the people responsible for the wind farms were undertaken in an attempt to add additional site-specific information. These interviews attempted to cover the significant aspects of wind farm development from public and elected officials as well as businesses within the community. Finally, a random survey of 108 adults was conducted in the community of Weatherford. This represents a cross-section of approximately 1% of the overall population. The goal of the

survey was to gauge the level of knowledge regarding wind energy that people in the community had. This includes the wind industry in general and the Weatherford Wind Energy Center specifically. Respondents were asked a series of questions regarding their understanding of wind energy, and also a question regarding whether or not they thought the development hurt or helped property taxes. The surveys were handed out at randomly selected locations and times to make sure that the sample was as representative of the population as possible. Although there is no way, of course, to insure that there was no sample bias, we are confident that the bias has been minimized, and that the surveys do not have either a pro-or anti-wind bias.

Results and discussion

Results will be presented in order from most quantitative (e.g., the economic modeling) to most qualitative and descriptive (e.g., the interviews). This will provide not only a numerical assessment of the impact of the wind farm to the community but will also provide additional illustrative information.

Economic modeling results

The economic analysis consists of efforts to characterize the impacts of the wind farm on Weatherford and focuses on the results of the combined IMPLAN and JEDI modeling. Tables 3 and 4 represent the JEDI output. For this analysis, the construction cost in dollars per kilowatt (US$/kW) and annual operations and maintenance costs (US$/kW) are areas where the model shows sensitivity to changes [27]. A sensitivity analysis was conducted and the results suggested the best fit numbers to be used; those were the ones selected for the final analysis. In addition, the final parameters were determined in consultation with the wind farm operator. Results show that the 147 MW wind farm near Weatherford generated an estimated US$27 million in local spending and created 188 jobs during the construction phase. Once operational, the wind farm supports an estimated 13 jobs directly at the wind farm, including technicians and management. Furthermore, estimates show that US$1.7 million continues to be spent annually in the local economy, with over US$600,000 in additional property tax revenue and almost US$400,000 in direct land lease payments to landowners. The model estimates that the combined direct and induced impact annually is over US $25 million. The property tax is of particular importance, as this represents support for the local infrastructure (e.g., roads and schools) provided by the wind farm.

Table 3 JEDI output: wind plant - project data summary

Data	
Project location	**Custer County**
Project size (MW)	147
Turbine size (kW)	1500
Number of Turbines	98
Construction cost (US$/kW)	1,600
Annual direct O&M cost (US$/kW)	15.50
Project construction cost (US$)	235,200,000
Local spending	27,501,131
Total annual operational expenses (US$)	38,710,980
Direct operating and maintenance costs	2,278,500
Local spending	1,733,354
Other annual costs	36,432,480
Local spending	1,058,400
Debt and equity payments	0
Property taxes	666,400
Land lease	392,000

Table 4 JEDI output: local economic impacts (dollar values in millions)

Economic impacts			
During construction period	**Jobs**	**Earnings (US$)**	**Output (US$)**
Direct impacts	4	9.2	26.9
Indirect impacts	84	1.8	5.7
Induced impacts	100	1.9	7.0
Total impacts (direct, indirect, and induced)	188	12.9	39.6
During operating years (annual)			
Direct impacts	19	11.8	17.5
Indirect impacts	61	1.3	4.4
Induced impacts	68	1.3	4.8
Total impacts (direct, indirect, and induced)	148	14.3	26.7

Survey results

Over 75% of the survey participants responded that they have some knowledge of wind energy. Fourteen percent of those surveyed felt they had a full understanding of wind energy. When asked if their knowledge had increased since the wind farm became operational, 79% of participants indicated that their knowledge had increased. The number that had little or no knowledge dropped down to just below 5%. This would suggest that because of the wind farm's high visibility, public knowledge of wind energy increased.

One area of concern for other wind farms has been whether or not the wind farms decreases property value. Opponents argue that property values drop when a wind farm is constructed in a community; however, there is no documented evidence that this is true [28-30]. For example, Sims et al. in 2008 report, 'no causal link was established between the presence of the wind farm and

house price' Of course, the lack of a distance-price relationship only applies once a given marginal set-back distance has been maintained. Hoen et al. in 2011 state that 'neither the view of the wind facilities nor the distance of the home to those facilities is found to have a statistically significant effect on sales prices.' For Weatherford, 55% of the respondents felt that it had helped property taxes, indicating no evidence that people felt their property values had decreased since the wind farm development. In the next part of the survey, respondents were asked about their perception of the community, how well the State promotes renewable energy, and if they personally had benefited from the development of the wind farm. When participants were asked if they had a favorable opinion of wind energy, 85% responded yes, and less than 5% said they had a negative view. Nearly the same amount, 85%, felt the state should do more to promote wind and other forms of renewable energy. Less than 20% of participants felt that the state is adequately promoting renewable energy. One significant finding of this research was that when participants were asked if they felt their community was different than another community of similar size because of the wind farm, over 70% responded yes. This last point is interesting because of previous research that has been mixed about the impact of a wind farm on the local perceptions of an area [31,32]. Issues such as a negative viewpoint associated with the visual aesthetics do not seem to be present here, another indication of the overall widespread community support for the project.

When visiting Weatherford, it is clear that the local citizens exhibit noticeable civic pride in their community and that the wind farm has become a pivotal and productive facility now and for their community's future. However, in other locations, such as Europe, attitudes toward wind energy vary. This is often a 'not in my backyard' (NIMBY) perception. For example, visual evaluation is often mentioned as the most important factor for those opposed [33]. This type of NIMBYism is not evident in the study area in Oklahoma. In other areas, however, it is used by opponents of wind farms and often linked with wider environmental causes [34,35]. For example, Devine-Wright in 2005 conducted research examining the public's perception of wind farms, especially in areas where the NIMBY concept was the primary concern. This research examined the public's perception of the following: switching from conventional energy sources to renewable energy, wind turbines and people's negative perceptions of them, the physical proximity of wind turbines, the acceptance of wind farms over time, NIMBYism as an explanation of negative perceptions, and local involvement with these perceptions [36].

For the current study, one question that generated a wide range of answers was when participants were asked to provide their best estimate of the tax revenue Custer County received on a yearly basis from the wind farm. The amount the county can expect to receive each year will vary, but as Tables 3 and 4 show, this is estimated at over US$500,000. Participants had answers ranging from US$100 to US$1.75 million. The median value was approximately US$275,000. The large range in numbers suggests that the true economic impact of the wind farm is not as yet fully understood or realized. Fifty-three people or 49% did not provide an answer. People may have a perception and awareness of the wind farm, but are not well informed about the revenue that is coming into the city from the development. These numbers reflect that, and perhaps, the city can do better in highlighting the specific tax benefits from the wind farm to its citizens.

The final question asked participants to make a closing comment positive or negative on the wind farm. Below are some of the responses that were left by participants. These comments provide some additional qualitative context for how the residents of Weatherford view the wind farm. These comments illustrate a range of knowledge about the topic, but generally show the widespread support for the development.

Comments from survey participants:

1. With the State as windy as it is it has to help.
2. It's crucial, it's beautiful. We need many more farms nationwide.
3. I am a little frightened by the giant wind mills.
4. The people that I have worked with have been very responsible people.
5. Who cares how it looks if it helps.
6. I think the wind farm is great!! It helps the people with turbines on their land and the economy of Weatherford.
7. I think it is wonderful for the environment.
8. I think they are really neat to see and when you're coming back to Weatherford you know you are home.
9. All Oklahoma communities should have wind generated energy, it wastes nothing and does no harm to the environment.
10. It has only helped economically, our community has yet to see a negative impact.
11. It's highly fantastic for our community.
12. I think it's a good thing for Weatherford.
13. Anything that saves energy is a good thing.

Interview analysis

The final piece of this case study consisted of a series of lengthy in-depth personal interviews. These interviews were with local politicians, public officials, and business owners. Over a dozen interviews were undertaken and

the results here are indicative of the overall feelings of the stakeholders questioned. Not one local politician spoke out against the wind farm in our surveys and interviews. One key figure interviewed was the mayor of Weatherford. The mayor described the support of the community for the project. From the beginning, the mayor did not see any real opposition to the project, in fact in his words, he 'could count on one hand the number of people against it.' When the City was first approached, they examined it as they might any new development. The City benefited from knowing what had occurred in other communities with wind farms. The mayor was able to meet with city leaders from other locations and discuss how their communities had benefited. The mayor discussed some of the minor inconveniences such as torn up roads, but quickly added these were not significant in comparison to the long-term benefits. The City expects to fully benefit from new tourism associated with the wind farm and make Weatherford 'the Wind Capital of Oklahoma.' The mayor said that the state legislature had been cooperative in assisting Weatherford in any way it could and appreciated the balance of work that had been done at that level.

As anyone who goes to Western Oklahoma knows its wide open space and big sky produce nice and beautiful sunsets and horizons. The mayor was asked to put a value on that view and what may be lost when the turbines were installed, 'well, how do you put a price on such a thing?' the mayor asked. According to the mayor, to compensate the city and citizens of Weatherford, the wind farm developer agreed to pay the city US$25,000 a year for lost aesthetic beauty and community improvement projects. This is a huge benefit to the city and is not part of the city's normal budget. The city has used some of the money to install a security and surveillance system on the city government complex, a new city building, gym, and playground. Another interview was with the city's economic development manager and he could not have been more enthusiastic. He stated that all major sectors of the city's economy have benefited tremendously from the local wind farm development. Businesses, from hotels and apartment complexes to local restaurants, were all filled to capacity during construction.

In addition to city officials, a variety of local business owners were interviewed to examine how their business was impacted during the construction phase [37]. Local hotels reported that they were at capacity for three to four months at a time during the construction. For example, General Electric was a large client, sending representatives from Japan and Brazil to the area and renting blocks of rooms for a month at a time. This represented a significant impact for both the local Holiday Inn and the Comfort Inn. Other examples include Brundage Bone Concrete, Dolese Brothers Concrete, and Matt's Service Center. Sawatzky Construction benefited with nearly US$300,000 in revenue from the project including building a 5,000-ft^2 operation facility. The Southwest Fence Company supplied all fencing, cattle guards, and other security apparatus for the project. Matt's Service Center located just west of Weatherford along I-40 provided approximately 10,000 gal of diesel fuel and gasoline while also repairing damaged equipment during a two-month period during construction. This represented a total of US$100,000 in revenue during those 2 months. United Rentals saw increase in their revenue to US$70,000 through the rental of various pieces of heavy construction equipment; this equipment was rented for a five-month period.

Conclusions

When this research began, the overall goal was to assess the socioeconomic impact of wind farm development on a local community in Oklahoma through a multimethod approach. Communities that have similar characteristics as the one studied in this research should be able to gain information from this study and apply it.

The first effort was through the use of an economic input–output model. IMPLAN is an input–output modeling program that allows a user to input specific variables for economic analysis. The model results indicate that the county received a substantial economic impact during construction of the wind farm. The model-estimated impact shows the millions of dollars of both short-term and annual economic impact. Much of this money went to local construction companies in the community where the wind project was developed. The most important conclusion to be drawn from the economic modeling is that construction spending can be traced to two important variables. These variables are the size of project and the amount of goods and services that were purchased locally. The amount of goods and services that are purchased locally will ultimately have the greatest impact on a community during construction.

Custer County has already felt the impacts from wind development in Oklahoma. Many other counties across Western Oklahoma with similar wind resources have as well, and this represents the potential for millions of dollars in economic growth and new jobs for Oklahoma. In fact, Oklahoma is projected to continue to move up the list of top states with installed wind power by the end of the next decade. Using the most recent DoE projections, Oklahoma will reach as high as the second most important state in installed wind energy capacity by 2030 [38]. Thus, an industry that has a long history [39] will continue to play an increasing role in the development of western Oklahoma.

Economic modeling provides a quantitative description of the socioeconomic impact. However, any research that

is specific to an area or region also requires direct interviews with local officials and wind farm developers. The interviews that were conducted with community leaders and officials in Weatherford were very informative. There is no doubt that Weatherford has been positively impacted from the wind farm development. Interviews with local officials led to specific evidence of how the community had been impacted, including increases in tax revenue that have been used by the local school districts and other county entities that are essential for a healthy community. Other projects, such as community beautification, may prove difficult to accomplish if it were not for the wind facility operating in the community. Here is a quote from one community leader in western Oklahoma:

'After the wind farm was constructed outside of town, me and a co-worker had the notion to just get a couple of lawn chairs, a bottle of wine and just sit back and listen to the peace and silence that we have known our entire lives, interrupted by the brief, swoosh, and the enormous wind turbine blades cut through the air, and sit back with a smile on our faces and know that our grandchildren and their children have a more secure future because of the economic benefit of the wind turbines.'

This illustrates the impact not only in terms of economic numbers, but also in terms of the view of the community. One final illustration is that Weatherford has advertised itself as wind energy capital of Oklahoma where, to quote Rogers and Hammerstein, 'the wind comes sweeping down the plain.'

Additional file

Additional file 1: Custer County multipliers for IMPLAN modeling. Additional file 1 lists an example of some of the multipliers for Custer County.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

MG collected the survey results, performed the interviews, and undertook the preliminary economic modeling analysis. MG also completed a draft form of sections of the manuscript. JSG conceived of the study, organized its design and coordination, and finalized the economic modeling and results analysis JSG also prepared the preliminary draft of the complete manuscript and performed revisions to produce the final draft, and also edited, read and approved the final manuscript. All authors read and approved the final manuscript.

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