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Social impact of wind energy in the Isthmus of Tehuantepec, Mexico, using Likert-fuzzy

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ABSTRACT

This research used a model with fuzzy measurement on 132 surveys to assess the social acceptance of the wind industry in the Isthmus of Tehuantepec-Mexico. This study uses diffuse analysis in a region where people are difficult to interview due to cultural barriers. The results were categorized globally and internally in environmental, economic, and social impacts. The results demonstrate the rejection of the inhabitants by the installation of wind farms in their region. There is a lack of information, poor transparency, and involvement of communities within the decision-making processes, and it seems that the only beneficiaries are the farmers who rent their land for the installation of the wind turbines. Mexico has to develop a guidelines framework to improve wind energy development, according to the best international practices.

1. Introduction

The trend of tapping into wind energy will continue to grow in the coming decades, and it is expected, on average, 47 GW will be installed per year. An investment of up to US$3.2 trillion is needed to achieve 12% of global electricity generated from wind energy by 2050 [1].

Wind energy has notably reached a low cost of US$0.02 per kWh [2,3]. It is estimated that costs will continue to decrease, reaching US $40.7/MWh by 2022 in regions with the high wind power potential and US$77.3/MWh where the wind power potential is lower or the capital costs are higher. These costs are comparable with conventional energy sources [4]. In 2017, wind energy levelized costs have reached US $0.03/kWh [5]. According to Ref. [6,7] Mexico has reached the lowest production cost of wind energy in the world US$17.7/MWh.

"In contrast to fossil fuels and nuclear power, wind turbines do not pollute our atmosphere with greenhouse gases, nor do they cause any problems for future generations with radioactive waste" (Leung and Yang 2012, 1036). Moreover, wind farms do not need water to work [9]. Thus, wind power is considered environmentally benign" [8]. Wind power and other renewable energy sources are fundamental for reducing greenhouse gases and eliminating the dangers to public health [9].

In general, the development of wind energy shows strong public support [10–13], but also it causes problems such as disrupting landscapes [14,15], noise pollution [12,16], erosion, and possible endangerment to wildlife ecosystems [17].

These negative impacts have caused wind energy to be contested despite its promising environmental advantages. These effects against land and wildlife are the most significant in countries where renewable energy laws have not been adequately developed including wind farm and operation, guaranteed stakeholders' inclusion, and the formation of cooperatives. In contrast, leaders of the industry like Denmark and Germany, that have implemented applicable laws show improved social acceptance [18–21].

To evaluate the social acceptance of wind energy, the Likert-scale has been used [10,11,22–24]. In the Isthmus of Tehuantepec landowners have positive opinions concerning their farming production. This beneficial mindset has come about because wind energy development both creates employment and is friendly to the environment. However, for the most part these landowners are ignorant of wind energy's negative impacts and wind up signing contracts in the absence of legal

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counsel [25].

In the Isthmus of Tehuantepec, many social sectors have rejection perceptions, as evidenced by multiple social protests. Some of these protests have been the result of the violation of human and community rights; for example, the wind energy investors are not taking into account the opinion of the inhabitants in the decision-making processes when installing these industries [26–30].

In the Isthmus of Tehuantepec, wind energy development has faced social conflicts between communities, which has resulted in bitterness, violence, legal proceedings, a canceled project, and even one death [27, 30–34]. Additional significant events should be noted: a recent popular referendum suspension under the Agreement 169 of the International Labor Organization (LBO) in Union Hidalgo municipality owing to social protests [31]; protests at a wind turbine blade manufacturing plant in Comitancillo municipality [32]; Mareña Renovables project was cancelled [28]; and, a popular referendum by Southern Wind Energy project was suspended and had to pass a legal process due to the opponents' appeals [35].

This article supported by a fuzzy Likert-scale questionnaire presents results of social perceptions about wind energy in the Isthmus of Tehuantepec Mexico, as well as the benefits and rejection perceived by the Zapotec communities who live in the municipalities where wind farms were installed.

Studying wind development in the Isthmus of Tehuantepec is a relevant social topic, because "It is not an exaggeration to say that the situation of the south of the Isthmus of Tehuantepec in relation to wind energy, with its mobilizations and demands, mark the political agenda of renewable energies in the country [Mexico]" [36]. Following this same reasoning, we see the statistical importance as extrapolated to other realities in Latin American countries [36] where the energy transition faces similar problems, as: Chile, Colombia, Honduras and Brazil [36–39].

2. Materials and method

2.1. Study zone

The Isthmus of Tehuantepec is a zone which is considered to be the major wind power potential in Mexico, whose estimated wind energy potential is 44,000 MW [40]. Sustained wind energy development started in 2006 in this region and comprises 58% of Mexico's total wind energy cumulative capacity [41].

Fig. 1 shows municipalities in the study zone (El Espinal (EE), Juchitán de Zaragoza (JZ), Santo Domingo Ingenio (DI), and Unión Hidalgo (UH)). Zapotec communities are found in all of these zones. Using indexes (IM) developed by the National Population Council (CONAPO) in the 1990's, Table 1 shows that the marginalization indexes are both low and very low. At least 7% of the population is illiterate and 23% or more live in overcrowded conditions. These indexes are a summary measure that allow for differentiating localities of the country according to the global impact of the population's deficiencies as a result of the lack of access to education, residence in inadequate housing and lack of property. It shows the territorial disparities that exist between the localities of Mexico and gives account of the existing relations with the level of marginalization of states and municipalities [42] (see Table 2).

Concerning sample size (132 surveys were applied), the estimation of sample size was done setting the confidence level at 95% (z = 1.64), and the sampling error at 0.07, due to the lack of information about the study zone p = q = 0.5, according [44].

$$n = \frac{K^2 pq}{\varepsilon^2} \tag{1}$$

where: n is sample size, k is confidence level, ε is sampling error, p is the percentage of the study phenomena in population, and q = 1-p.

In this work, 132 respondents interviewed were people living in the Isthmus of Tehuantepec, Mexico, in 2017. One of the important challenges of the work was to achieve a larger sample size, in spite of the social conditions in the study area. This was where numerous social conflicts had occurred, including violent clashes between settlers and law enforcement, as well as verbal violence and social division, as described in Ref. [15,28]. The questionnaire solicitation was carried out by means of a home visit following the method of sampling random routes, choosing a starting and ending point of sampling. The surveys were only applied to non-owners (people or families) of land rented for the installation of the wind farm, because, in this area the participation of landowners is one in one hundred.

Of the persons interviewed, 66.7% were men. This was likely due to women preferring that their husbands answered when asked to complete the questionnaire. One example of this was when some of the female interviewees gave a stereotypical answer: "I don't know anything about that. Ask my husband." The explanation for this is found in the traditional role of males in the study zone, where the men assume more participation in decisions.

The average age of people interviewed was 38.8 years old, with a

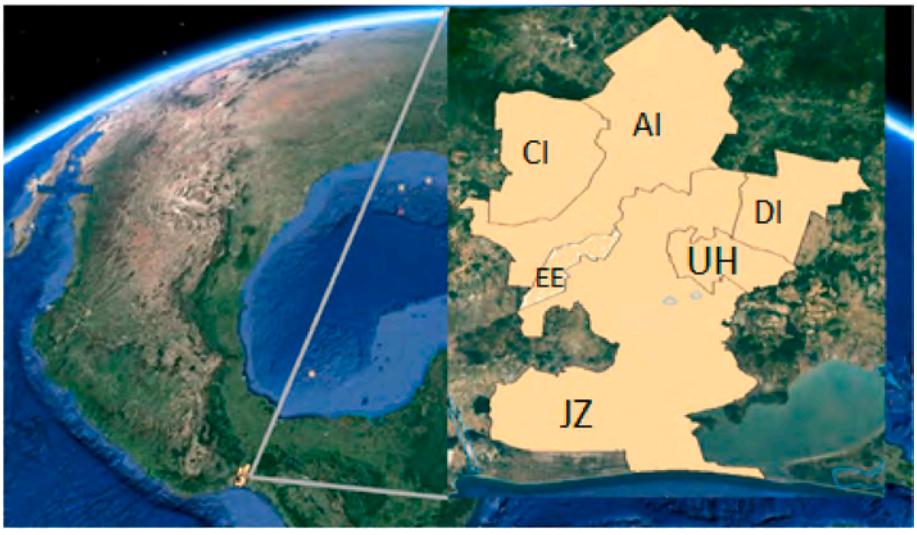


Fig. 1. Study zone.
[42].

Table 1
Level of marginalization.

Municipality	(a)	Percentage of people						Marginalization index
		(b)	(c)	(d)	(e)	(f)	(g)	
El Espinal	8575	7.22	0.4	0.67	3.61	23.26	0.73	Very low
Juchitán de Zaragoza	98,043	11.75	0.85	0.33	3.9	38.56	3.92	Low
Santo Domingo Ingenio	7965	13.12	1.53	0.98	5.66	29.5	1.75	Low
Unión Hidalgo	15,347	10.92	1	0.36	0.69	37.67	1.43	Low

Where: (a) Total population. (b) > 15 years old, illiteracy. (c) without drainage. (d) without electricity. (e) without piped water. (f) overcrowding (g) dirt floor. Made with data of [43].

Table 2
Sample description.

Municipality	Location	Population	Surveys applied
El Espinal	J. L. Portillo	236	9
Juchitán de Zaragoza	La Venta	2161	17
	La Ventosa	4884	37
S. D. Ingenio	Centro	5895	41
Unión Hidalgo	Barrio Flojo	1320	11
	Arenas	2342	17
	Total	17,694	132

Made with data of [45].

range of 16–66 years of age. In cases of people over 70, they typically asked their sons or daughters to respond to the survey. During the application of the surveys, these older people refused to respond to the survey because they declared themselves to be ignorant about the subject. They preferred their children to respond for them because they had a higher level of schooling. An example of this is found in Oaxaca, Mexico where the percentage of the population with basic education for the 55–64 age group is 8% with an illiteracy level of 15% [50]. Those in the same age group with a higher than average level of education was found to be only 2.5%.

Table 3 shows the education of the people interviewed. The major presence of men is due to the local socio-cultural characteristics of the study zone, in which men assume an important role of decision, and so women do not provide information.

Within the population interviewed, 13.5% were students, 10% housewives, 10% farmers and 9% manual workers. Other people surveyed were musicians, carpenters, drivers, teachers or categorized as "other". It's noted what 41% of those interviewed had an undergraduate level degree. This percentage increased due to older people declining to respond and calling their children to answer the questionnaire.

2.2. Likert fuzzy as research method

A questionnaire was designed to evaluate five categories: access to information, environmental impacts, economic impacts, social impacts, and social conflicts that have occurred in the study zone since the installation of wind farms. The instrument was developed taking as references [22,23,25,30,46,47], and local academic opinions. The main research topics on the impacts of wind energy were as follows: landscape, noise, wildlife, bird death [23,46,48]; inconveniences during construction, health risks, perception of irrigation [25,30,49]; stakeholder inclusion and social justice [12,23]. Questions that focused on agricultural activity, improvement of irrigation systems and situations of conflict and tensions were included taking into account the particularities of the study area according to Refs. [25,30,36]; with recommendations from local experts interviewed. Due to local considerations and the feedback from these experts, the questionnaire was also used to find out if the community was adequately informed about the wind energy benefits in general and specifically its benefits for nature. The general benefits relate to the economy and the construction of social infrastructure based on taxes or duty payments; while the environmental benefits relate to a more sustainable nature.

The questionnaire consists of 16 items, in a range of 1–5 (1 representing "strongly agree" or "very beautiful", and 5 "strongly disagree" or "very ugly"). To analyze the collected data and reduce ambiguity between respondents' answers, the theory of fuzzy sets was used, as well as

Table 3
People surveyed.

Scholar level	Men	Women	Percent
Elementary school	10	4	11
Middle school	18	4	17
High school	16	22	29
University	42	12	41
Nothing	2	2	3
Total	88	44	

Source: Original

Table 4
Instrument item.

Impact	Item	Ends of the scale	
Environmental	I consider wind farm effects on livestock	Not harmful	Very harmful
	I consider wind farm effects on wildlife	Totally harmless	Very risky
	For me, wind farms are	Very pretty	Very ugly
	When I walk in the wind farms I feel:	Very safe	At risky
	For me, wind farms are	Quiet	Very noisy
Economic	Wind farm construction has brought more money into the village	Totally disagree	Totally disagree
	The installation of wind farms has brought more jobs into the village		
	Due to wind farms, there are more opportunities to earn a living in the village now		
	Due to wind energy, irrigation systems have been improved		
Social	The community was adequately informed about the wind farms construction plans	Totally disagree	Totally disagree
	The community was adequately informed about the wind energy benefits		
	The community was adequately informed about wind energy benefits for nature		
	General public benefit works by wind energy companies have been carried out		
	Wind energy companies have contributed to improving livestock activities		
	I think it is my right to request information about wind energy companies and the impacts of wind farms.		
	The installation of wind farms in my village has brought tension and conflicts.		

Made own.

similarity (SIM) between fuzzy sets, as used by Ref. [50].

Table 4 shows the items within the questionnaire, the variables analyzed and the range of measurement. The data was entered into MS Excel®, and analyzed using the reference method by Ref. [51].

This research was developed following the method used by Ref. [51], implementing the phases which are summarized below:

Phase I: Performance criteria.

1. Establish a triangular fuzzy number A based on responses from questionnaire (Table 4). The set of fuzzy numbers for the linguistic terms are defined and presented in Table 3.

Definition 1. A fuzzy set $\tilde{A}$ in a universe of discourse X is characterized by a membership function $\mu\tilde{A}(x)$ which associates with each element x in X a real number in the interval [0, 1]. The function value $\mu\tilde{A}(x)$ is termed the grade of membership of x in $\tilde{A}$ [52].

$$A_{ij} = \left(1/m\right) \otimes \left(A_{ij}^{1} \oplus A_{ij}^{2}, \ldots, \oplus A_{ij}^{m}\right) \tag{2}$$

where $\otimes$ is the multiplication of fuzzy numbers, $\oplus$ is the add operation of fuzzy numbers and A_{ij} the overall average performance valuation (i under criterion j over m people) [51].

$$A_{ij} = \left(LA_{ij},\ MA_{ij},\ UA_{ij}\right) \tag{3}$$

where LA_{ij}, UA_{ij} are the endpoints, and MA_{ij} is the middle point of fuzzy numbers.

$$BNP_{ij} = \left[\left(UA_{ij} - LA_{ij}\right) + \left(MA_{ij} - LA_{ij}\right)\right] / 3 + LA_{ij}\ \forall i, j, \tag{4}$$

for (a_1,a_2,a_3) of a triangular fuzzy number. $\tilde{A}$

2. Compute overall evaluation of the fuzzy judgement
3. Obtain end point of fuzzy numbers, A_{ij}
4. To point out that a certain variable of wind energy development is rated as good or bad, information defuzzification is required. Defuzzification is a technique to convert the fuzzy number into non-technical real numbers. The procedure of defuzzification is to locate the Best Non-fuzzy Performance (BNP) value
5. The criteria are ranked based on the BNP values. The criterion having a larger BNP value is considered to have a greater impact when compared with another criterion [53].

Phase II. Level and degree of Satisfaction.

6. In this phase, we determined the wind energy perception. Details are shown in Ref. [51].

Table 5 shows linguistic terms used and their characterization by a triangular fuzzy number for representing its approximate value range between 0 and 5, and are encoded as (a_1, a_2, a_3), where $0 \leq a_1 \leq a_2 \leq a_3 \leq 5$. Value of a_2 is the most likely value of the linguistic term, and a_1 and a_3 are the lower and upper range used, respectively, to reflect the fuzziness of the term [51].

Table 5
Triangular fuzzy numbers and Likert scale.

Linguistic term	Code	Relative importance	Universe of discourse			Triangular Fuzzy Numbers (TFN)
Totally disagree (Very Bad)	MM	$\tilde{5}$	4	5	5	(4,5,5)
Disagree (Bad)	M	$\tilde{4}$	3	4	5	(3,4,5)
Undecided (Indifferent)	I	$\tilde{3}$	2	3	4	(2,3,4)
Agree (Good)	B	$\tilde{2}$	1	2	3	(1,2,3)
Totally agree (Very good)	MB	$\tilde{1}$	0	1	2	(0,1,2)

Made from Ref. [51].

Graph 1 illustrates fuzzy sets used. The universe of discourse is defined in the questionnaire applied based on the fuzzy Likert scale.

$$SIM(B(y,m), B(yi,m)) = \frac{1}{1 + \sqrt{\sum \mu_{B'}(yj,m) - \mu_{B}(yj,m)^2}} \tag{5}$$

where $\mu_B$is the fuzzy set defined for linguistic rating, and $\mu_{BB'}$ is the calculated overall value of membership functions [51].

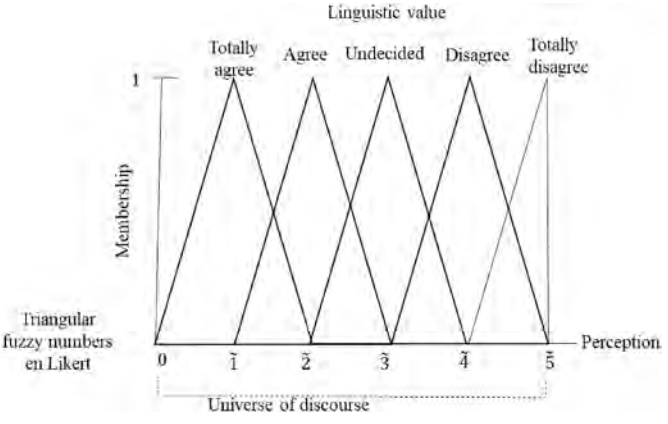
7. Obtain value for each respondent $w_i = \frac{v_i}{\sum_{i=1}^{n} v_i}$, were w is a proportion of the response's linguistic value "v" to the total of linguistic value for all respondents.
8. Obtain the overall value of membership function $\mu_i(x) = \sum_{i=1}^{n} w_i x_i$, where *Xi* represents the i-th linguistic level of respondents, *Wi* is the strength of responses.
9. Obtain the level and degree of satisfaction [50]:

3. Results

Table 6 describes the results of collected and analyzed items through the method of [51]. It shows the BNP value and SIM in hierarchical order for each dimension studied. In the environmental category, people claim that wind farms cause environmental harm, mainly due to noise. They also mention that the turbines cause them feelings of insecurity when they are working in or passing through the vicinity. In an economic dimension, according to SIM perception, people are in disagreement with supposed wind industry beneficial impacts. They do not consider that wind energy development provides more economic opportunities in their village. In the social dimension, according to the BNP values (Table 6), the most important subjects for people concern information access. This information consists of, but is not limited to: wind energy benefits (mainly environmental) and construction plans. According to SIM, people consider themselves under in do not informed in these aspects.

In the global ranking (BNP value), the most important issues for people are: noise generated by the wind installations, local economic opportunities, and access of information about wind industry benefits. It's usually in the last point where people are in most disagreement (SIM).

Despite the discrepancy of benefits among inhabitants by this type of facilities in the study zone, the general consensus of the residents is a perception of improvement in the social infrastructure of their villages. They also perceive a greater economic wealth and an increasing



Graph 1. Fuzzy sets.

Table 6
Results of Likert fuzzy as a research method.

Item	BNP[a]			SIM Perception	Impacts
	Value	Within Ranking	Global		
Noise	3.69	1	1	Bad	Environmental
Security	3.34	2	4	Bad	
Landscape	3.21	3	6	Bad	
Birds	3.19	4	7	Bad	
Livestock	2.87	5	10	Bad	
More opportunities	3.58	1	2	Disagree	Economical
More jobs	3.08	2	8	Disagree	
More money	3.07	3	9	Disagree	
Best irrigation	1.95	4	12	Disagree	
Information about nature benefits	3.57	1	3	Disagree	Social
Information about wind energy benefits	3.31	2	5	Disagree	
Information about construction plans	3.19	3	7	Disagree	
Source of conflicts	2.2	4	11	Totally agree	
Benefits agricultural activities	1.95	5	12	Good	
Right to information	1.52	6	13	Agree	
Social infrastructure	1.15	7	14	Totally agree	

[a] From equation (4).

agricultural activity for the landowners who own the fields where the wind installations are located. In general, most residents consider it to be their right to have access to information on wind energy projects in their region. However, Table 6 shows the villagers consider that wind companies do not provide enough information the about benefits of wind energy development, about wind farms construction or wind energy development in their region.

The most important subject for the interviewers is ambient noise (first position in global BNP). They think that the noise generated by wind farms is bad for them. During the survey, many of them said it was too noisy at night and disrupted sleep.

4. Discussion

According to the results, the most important issues in the region's wind development are: noise pollution, economic opportunities, environmental benefits awareness, wind turbine zone safety, and information access to economic and social benefits.

Noise is an influential factor that must be treated in a serious and adequate manner by the administrators of the wind installations [54]. It is important to highlight that noise is one of the main points of controversy in the study zone for opposition groups [29,55–58]. "Regarding noise, there is no (public) scientific study on noise annoyance by wind farms in Oaxaca" [57]. In Mexico, NOM-081-SEMARNAT-1994 determines the permissible noise limits for fixed sources, and this guideline is taking as reference by wind energy developers. However, this Mexican regulation is not specified for wind farms and does not establish the minimum distance between wind farms and dwellings. In addition, the NOM-151-SEMARNAT-2006 project, to stablish wind farm guidelines in Mexico was cancelled in 2014 [59]. There are regulations in many countries that establish the minimum distance or defined height hub; generally from 500 m to 2 km [21,60,61]. In the study zone, there are wind turbines at 350 m from houses. In addition, the Environmental Impact Studies do not present the evidence of even one noise study in the Isthmus of Tehuantepec [62–64].

At a national level, visual impact on landscapes is a dominant factor of why many people are opposed to wind power [12,65,66]. In the study area they have also been identified as major opposition claims [25,26,72]. However, they had not previously been categorized according to their local priority level. The results achieved agree that noise is a main priority. However, the landscape takes sixth place in the ranking, behind employment opportunities and economic benefits.

With reference to economic revenues from wind energy development in the study zone, it is considered to be the main issue of interest in the economic dimension (Table 6). The feedback shows that the residents view the economic benefits as unsatisfactory; these results are consistent with [30]. Revenues are temporary, short-term and with preferences to people that rent land [30,57]. One of the most important demands made by local people is job creation [30,67]. The evidence found shows that job creation expectations are practically nil, whereas jobs created are low-added-value and are not available to all people. In addition, it is likely that these jobs have their focus on land owners [30,68,69]. Spanish companies are wind energy leaders in the Isthmus of Tehuantepec, in Ref. [70] we can see the differences in economic benefits between Mexico and Spain. This is due to the fact that Mexico has no private knowledge and technology, and even has developed a wind energy value chain. In Mexico, according to Iberdrola staff, for every 100 MW installed the company disburses around US$640 000 [71]. This is around US$6400 per MW, but landowners affirmed that they received around US$1669 per every wind turbine in 2017 [71]. While in USA under the oft-quoted "$2000 per turbine per year" before the year 2000, in 2008 incomes per turbine were between US$3000–8000 [72].

In the social category, the degree of similarity (Table 6) shows that people think wind farm installation has contributed to social conflicts within the village. This finding coincides with other authors in the study zone [26,29,30]. This finding emphasizes the need to rethink decision-making development processes, as well as to observe compliance with legal mechanisms in the sector. For example, ensuring the proper implementation of indigenous peoples' consultation processes, in accordance with ILO Convention 160.

Lack of information explains why local people do not know what the wind energy impacts are as referred to in Refs. [25,29,73]. The degree of similarity (Table 6) indicates that the installation of wind farms has been harmful to local communities through noise pollution, alteration of the landscape and endangerment to birds and livestock; which are all rated with a negative impact. However, they tend to make this assessment from their ignorance of technology, as described [30, 78, 79]. These communities are immersed in an environment where, in the absence of information, catastrophist versions of some opposition groups are presented [30]. This conflict of information goes beyond a communication problem between companies and their stakeholders. It represents a pattern of behavior in the absence of coordination between 3 entities: different levels of government, compliance with an appropriate legal framework for the wind sector, and international mechanisms such as Convention 169, as referred to [30,80].

According to the results of Table 6, citizens express that it is their right to have access to information regarding the development of wind projects. However, (as noted in section 2.1 [Study zone]) older people and women refuse to express their opinions on this subject, on the basis of their traditional living practices and the low level of schooling in the region. This makes it necessary for planners and decision makers to rethink or create strategies that address the particularities of this population dynamic. In Table 6 it can be observed that, although they declare that it is their right to be informed, they state that they lack information on the benefits associated with wind development. The lack of information and lack of transparency in wind development in this region is often identified as a cause of social conflicts [30, 81]. Our results show in Table 6 that, although people consider access to information as their right, they have not really been exposed to any pertinent

knowledge base. For example, according to Ref. [25], the owners who have wind farms on their land and who use those lands for agriculture, state the lack of information on the operation of the same wind facilities. But at the same time, they support the installation of wind farms, mainly for job creation and as a source of clean energy. At the same time, they declare that they are unclear about the contractual clauses because the contract was hurriedly read to them by the company's staff or (in some cases) by some relatives who are non-specialists on the subject [25]. Lack of information between wind developers and local people, including the lack of knowledge about wind farm impacts in the study zone is similar to other areas (like Baja California, Mexico, for instance) [74]. Although this practice is in dissonance around the world, local stakeholders involved believe it's necessary to avoid opposition and improve trust and acceptance in wind energy projects [75,76]. When local citizens have more information, they may contribute to the discussion with new ideas or proposals. Improving the transparency of the process could raise the acceptance of wind energy [77]. In contrast, in the Istmo de Tehuantepec, there are reports of false assemblies to sign faster lease agreements between landowners and wind companies. Moreover, and wind companies promoted legal modification to change the land social ownership (ejido) to private land, to facilitate the wind farm installation [57].

Our findings show that the existing consensus still continues with regard to the social infrastructure of construction from wind energy companies as an emerging viable social investment. That is, people recognize that wind energy companies have brought economic support to build social infrastructure or facilities (Table 6). According to Ref. [25,30], people recognize that through wind energy companies' investment, improvements have been made such as: pavements, sport parks and educational facilities. However, these economic helps are questioned by some social sectors because people believe that this social infrastructure is used by wind companies to bribe communities into allowing the wind farms a foothold in their territory while reducing the social protest [27,76,77]. In addition, social disagreement increased due to reports indicating that wind companies are not required to pay local taxes [78,79]. It's necessary to study the wind companies' actions with regard to local communities' requests and/or demands to know how the corporate sector is increasing or decreasing in its social responsibilities.

5. Conclusions

This article has presented a measurement of the environmental, economic and social impacts of wind farm construction in the Isthmus of Tehuantepec, Mexico, using the theory of fuzzy logic sets as a tool to reduce the ambiguity of answers. This was necessary due to the inherently high level of subjectivity within the results; among which we found that the majority of local people in the study zone assume that wind energy involves social and environmental negative impacts.

In the environmental dimension there simply are no strategies for information transparency to local stakeholders with regard to the environmental dimension wind farm construction, nor during operation. Local landowners sign wind energy contracts in ignorance to their continued disadvantage. Mexico needs to improve its legal framework to regulate wind energy development, and establish programs to assure that citizens are involved in the decision-making processes before installing wind farms, and during their entire lifetime. This emerging third world country has not established the density of wind farms per km^2, the distance between wind farms and urban zones, nor their long-term strategies to measure the environmental and social impacts. Due to socio-economic conditions, indigenous communities have been negotiating with wind developers in disadvantaged conditions, such as signing land-rent contracts without legal advice, as they point out in Ref. [25,30]. Considering this, it's necessary to start legal support mechanisms to avoid further ill misunderstandings and conflict. Although local communities justly claim that it is their right to have access to information on the development of wind projects, the actual mechanisms for developing these projects with their inherent social dynamics do not make it an easy exercise. It is essential that decision-makers adapt the legal framework and current mechanisms to ensure social participation in all areas of the deciding process.

The absence of local community involvement in the decision processes, lack of transparency, unequal benefits, absence of real corporate social responsibility, unknown cultural context and poor legal framework explain the existence of protest in this zone.

Until now, the social responsibility practiced by the wind industry has focused on donation, leaving aside transparency, communication and the development of local capabilities. Results of international experiences, e.g. Denmark especially, have made it clear that stakeholders' inclusion and partnership are essential to increasing social acceptance and gaining more economic benefits. As of today, these subjects are still pending in Mexico. The Mexican government promotes the increase of wind cumulative capacity, but does not consider local communities as important stakeholders in wind decision processes. Longitudinal studies are necessary to measure the social impact of wind companies' support in the local communities, and to explain if those helps correspond to corporate social responsibility. Of course, some wonder if these actions are to obtain the support and acceptance of the communities, while calming any social protest.

The perception that wind energy benefits have only reached those who rent their land and businesses, is the main cause of dissatisfaction. The fact that the owners substantially improve their economic revenues, while the population is left with the noise and shadows of the air generators, as well as the terror that this infuses in cattle that refuse to eat near these facilities, can be the reasons that fuel the animosity between the Zapotec community and the wind energy companies in the Isthmus of Tehuantepec-Mexico.

Although work has been carried out in the Isthmus de Tehuantepec to understand the socio-economic and environmental implications of wind development in communities, they had not been categorized in order of importance to them. One of the contributions of this work is to use the global Best Non-fuzzy Performance (BNP) to categorize globally and internally the environmental, economic and social dimensions. Another contribution is the use of fuzzy logic sets to reduce ambiguity in categorizing the impacts of wind development. This is a relevant aspect in the study region, where the level of schooling and the access to information on impacts and the decision-making processes on wind development are limited.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.esr.2020.100567.

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