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Expert Opinion Fuzzy Model to Assess Energy Systems Resilience in Mexico

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Abstract. The existing energy resilience metrics have primarily focused on the technical aspects of systems, and their evaluation is typically conducted using mathematical algorithms. However, as several authors have noted, the energy resilience of systems involves more than merely recovering from a blackout; it also encompasses social and economic contexts. Accordingly, this study proposes a metric for assessing energy resilience that considers not only technical aspects but also environmental, social, economic, and institutional dimensions. Importantly, the metric has been validated through the opinions of experts with more than 15 years of experience in the field. In these domains, fuzzy logic is employed due to the qualitative nature of the data. Two fuzzy logic models were applied: a simplified model with five variables and a detailed model with fifteen variables, grouped into sub-principles. The findings reveal a national energy resilience value of 1.55 for the simplified model and 2.0 for the detailed model, suggesting that incorporating a broader range of variables results in a more representative assessment. These results demonstrate that fuzzy logic is a valuable tool for this type of evaluation, as it integrates expert knowledge into the assessment process. Furthermore, the proposed approach can be adapted for evaluations at both national and local levels.
Keywords: fuzzy logic; energy system resilience; expert opinion; fuzzy knowledge-based modelling, sustainability.

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1 Introduction

This article presents an evaluation of energy resilience using fuzzy logic and considers the knowledge and opinion of experts in the area. In the last decade, studies on energy resilience have been increasing, with the United States being one of the countries with the most publications on the subject. This may be a result of the different energy crises that it has faced and has left a great impact on society. For example, the 2021 winter storm in Texas, where extreme cold weather caused the freezing of natural gas pipelines and the collapse of the supply infrastructure. This is relevant to Mexico, because the country imports more than 60% of its natural gas from the United States, and the freezing of pipelines caused widespread electricity blackouts in states such as Nuevo León, Chihuahua, and Coahuila, paralyzing industrial operations, and leaving millions of users without power. This event revealed Mexico's high vulnerability due to its energy interdependence with the United States (Reuters, 2021; CFE, 2022, Mejía-Montero et al., 2022). More recently, in October 2023, a Category 5 storm, Hurricane Otis, made landfall in Acapulco, causing catastrophic damage not only to the electrical infrastructure but also to citizens and their belongings. The city was left without access to electricity, telecommunications, and clean water for days, highlighting the fragility of local energy systems in the face of extreme weather events (Reinhart & Reinhart, 2024; Verza, 2023).

Phenomena like these have led to the creation and building of metrics that help to see where the resilience of the systems is and what to do to improve them. However, most energy resilience metrics focus on the technical aspects of the system and are also designed with an approach based on models (physical-mathematical) or quantitative indicators. What is important is that they do not expand to consider more aspects of resilience, such as social or economic, and that allows for a more precise evaluation and at the same time considers both the systems and the people and the environment in which they are found.

In the literature, there are different definitions of energy resilience; Ahmadi et al. consider it as a risk management strategy that aims to minimize vulnerability, improve flexibility, adapt to the environment, and increase the system's tolerance against threats and disturbances (Ahmadi et al., 2011); Hamborg et al. (2020) mention that resilient energy systems not only refer to technical energy systems that can "recover" after a blackout, but also relate to the social and economic aspects of human well-being; while Dickson et al. (2012) define it as "the ability of a system to resist or adapt to stresses and disturbances, such as climate impacts, without ceasing to maintain its functionality". In this article, energy resilience is defined as the capacity of energy sociotechnical systems to mitigate, minimize, recover, and anticipate what is caused by a disturbance in economic, social, environmental, and institutional terms. As mentioned, most studies on energy resilience have a physical-mathematical approach and the few investigations based on indicators have criticism of which indicator is considered adequate to evaluate the state of the energy system (Roege et al., 2014; Sharifi & Yamagata, 2016).

Fuzzy logic has been a widely used tool to evaluate everything from engineering issues to sustainability issues, and, above all, social issues. It has a wide range of applications, from controllers in electro-mechanical processes to decision-making (Zadeh, 1994); it has even been used in economic issues related to energy. In Mexico, fuzzy logic has been widely used by Flores & Durango (2015) on social issues, from the evaluation of social policies and programs to the analysis of sustainable development in local spaces. Even Seuret et al. (2020) used it to measure energy access in the country.

The evaluation design of using indicators that help evaluate the resilience of the systems at the national level, considering the economic, social, environmental, institutional, and technical areas that make up the national energy system. Furthermore, by considering the opinion of experts in a more reliable and direct way, inaccuracy and uncertainty of the data are avoided. Two models are proposed, a single fuzzification with five linguistic variables and three linguistic values, and a two-step fuzzification, which has fifteen linguistic variables in total with three linguistic values.

The structure followed in this article is as follows: the section presents the base literature that was taken as inspiration to create this methodology; Section 3 describes the selection of variables, the fuzzy model, and the methodology for using expert opinion; Section 4 shows the results obtained; conclusions and discussions are in section 5.

2 State of the art

Assessing the energy resilience of systems should consider social and technical aspects, as Delina et al. (2020) and Hamborg et al. (2020) mention, energy resilience is not just about energy systems being able to recover from a blackout; it is also important to consider social and economic systems. This is why a search was carried out for metrics that consider both aspects, and we reached Erker et al. (2017) who proposed the Regional Energy Resilience Assessment (RERA).

Erker et al. (2017) suggest that the resilience of the energy system should be analyzed and contrasted considering the perceptions and attitudes of society. So, a series of principles and substantial principles are considered in this metric, the principles are taken from Stoeglehner et al. (2016), which consider three principles necessary: learning ability, physical strength, and social strength. Depending on how these three principles are met, the substantial principles are implemented, which represent the ability to contribute or detract from resilient structures, elements, and functions and are therefore classified into exposure, efficiency, diversity, and redundancy. Erker et al. (2017) use colorimetry to report the level of energy resilience of the region and to be able to provide solutions through public policies.

Gamalath et al. (2018) make use of fuzzy logic to propose an evaluation of the conditions of energy systems in multi-unit residential buildings (MURB). Due to the lack of data on the evaluation based on the life cycle of the built residential environment, their model applies fuzzy logic to overcome the uncertainty and imprecision of these, since it uses the rules to combine different categories of performance and be able to obtain a rating on the overall condition of a MURB. They use four criteria, customer satisfaction, energy use, water use, and the age of the building. To evaluate, they use "excellent", "good", "fair", "poor/poor condition". One of the challenges of this model is obtaining the necessary level of responses from the interested groups, since if more contributions are obtained regarding their responses, it can be better refined and obtain a more precise rating and results; however, there is We must optimally ensure what type of users have to be the ones who respond to these criteria (Gamalath et al., 2018).).

By wanting to consider the knowledge and opinions of experts, it was found that Canavese et al. (2014) conducted a study using fuzzy logic and considered experts. This was done to assess the local sustainability of the Algarve, Portugal. They selected local people from the region considering that they had a job related to the topic and the seniority they had in it, resulting in 4 expert people who not only evaluated the region but also selected the relevant indicators and the values that they should have.

Canavese et al. (2014) showed how fuzzy logic contributes to the conception of a system based on expert opinion, which conceptually shows that it is possible to integrate human expertise in evaluations.

3 Methodology

Fuzzy logic is composed of linguistic variables and values, membership functions, and rules. Linguistic variables are indicators that serve to evaluate or characterize the fuzzy system. Each one has a set of values which are divided into ranges that are normally related to everyday language, such as low, medium, high, etc. The rules of the system are formed with linguistic variables and values, that is:

$$A = B^C \tag{1}$$

Where B is the number of linguistic values and C is the number of variables. Membership functions show us the degree to which an element is related to a linguistic value.

3.1 Linguistic variables, values and indicators

The fuzzifier design is built to evaluate the energy resilience at the national level. A review of the literature on energy resilience was carried out and the variables and indicators that were considered to carry out metrics and evaluations were extracted. A total of 121 variables were extracted, which were analyzed in detail and classified into five groups: technical, environmental, economic, institutional, and social. Leaving a total of 73 variables. One of the limitations of fuzzy logic is the number of variables and linguistic values to use, since these determine the number of rules to evaluate, as shown in equation 1. Therefore, using 73 variables obtained is not convenient, so A very specific classification was made, following the following steps:

1. Check if the variable is fuzzy.
2. Consider whether the variable is related to any principle and sub-principle of RERA.
3. Relate the variable to some category of sustainability (Environmental, economic, social, and institutional).
4. If the variable is related to two or more categories of sustainability and at least one principle or sub-principle of RERA, it is considered fundamental.

3.2 CASE A (Five fundamental variables)

Those variables that met the 4 points of the previous section were selected, giving a total of 9 variables; however, using these nine variables with the three linguistic values would give us a total of 19,693 rules, which makes the fuzzy system complex. In this case, a variable was selected from each group ((1) technical, (2) environmental, (3) economic, (4) institutional, and (5) social), and there were also the three principles ((1) ability to learn, (2) physical strength, and (3) social strength) and the subprinciples ((1) exposure, (2) efficiency, and (3) diversity and redundancy), in addition that the context of the variable can be applied to the evaluation at the national level. This left us with a total of five variables, as shown in Table 1.

Table 1. Classification of variables (F= Fundamental, D= Diffuse, En=environmental, S=social, E= economic, I=institutional).

F	Diffuse	Group	Principle	Sub principle	En	S	E	I	Variable
F	D	1	1	3	x			x	Diversity of renewable or clean energy. (DRCE)
F	D	4	1	2	x		x	x	The risk of natural gas (NG) import from third countries. (RNG)
F	D	5	2	2		x	x	x	Community response to mitigate impacts (e.g. demand curtailment). (CRMI)
F	D	3	3	1			x	x	Access to financial resources, is necessary to rebuild a system. (AFR)
F	D	2	3	2	x			x	Robust risk analysis of the energy system in the event of a natural disaster. (RRA)

This selection leaves us with a total of 243 rules, all of which are of the “if-then” type, as shown below:

If (RRA is high) and (AFR is high) and (RNG is high) and (DRCE is high) and (CRMI is high) then (ER is high)

Table 1 shows the selected variables, and a brief description of their importance is given below. The risk of importing natural gas: according to SENER, in 2022 Mexico had a consumption of 8,341 million standard cubic feet per day (MMcfd) of natural gas, of which 5,824 MMcfd are imported and only 2,517 MMcfd are produced. Of the 100% of natural gas that Mexico needs, more than 69% is imported (SENER, 2022). If, due to some external event, that amount of natural gas cannot be imported, the electrical system would present a huge number of interruptions due to its high dependence on imported gas. As was the case in 2021, due to the storms in Texas, gas imports stopped and the system presented blackouts in the north of the country, causing millions of people to be affected (CFE, 2022). The electrical system would collapse. Diversity of renewable energies: having an energy matrix with a percentage greater than 30% of renewable energies is essential, since it not only helps to reduce greenhouse gases and comply with the Paris Agreement, or the objectives of the Agenda 2030 but also helps more people have access to clean and affordable energy. Community response to mitigate impacts: The idea of how to make communities resilient in the face of a crisis is a topic that can be analyzed on its own since the literature contains publications about communities that have been destroyed by natural events and those who managed to survive. In Mexico some climates are extreme, there are states that suffer from floods year after year, the coasts suffer from hurricanes, and if that were not enough Mexico is one of the countries with the highest seismic activity. The attitude of the community is not enough to move forward, public policies are needed that help the community to be resilient and not only with its energy systems.

Access to financial resources to rebuild the system: when a crisis occurs in the energy system caused by natural events or external events; it is necessary to have financial resources that help rebuild the system as quickly as possible so that the negative impact is minimized and do not escalate to a higher grade. However, in Mexico, depending on the degree of impact, it often takes a long time to minimize the negative impact. Robust analysis of system risks in the event of natural events or disasters: public policymakers must be clear about the importance of developing a better understanding of risks, whether in the national electrical system or in any other plant that involves energy generation (refineries, hydroelectric plants, etc.); they must be clear about the impact that an error caused naturally or not can affect from a person to a nation.

Once the variables, linguistic values, and rules had been defined, a questionnaire was developed based on them to allow experts in the field to easily assess energy resilience. The questionnaire was divided into two sections. The first section aimed to assess the level of expertise of respondents in topics related to the five variables, while the second section invited them to evaluate, using the linguistic values, the level they considered appropriate for each variable. For further details, see Annex A.

MATLAB software was used to compute the model. The selected membership functions use the Mandani method, which is one of the closest to human reasoning (Mathworks, 2022). Figure 1 shows how the membership functions were defined. The codings of the linguistic values are low (1), medium (2), and high (3).

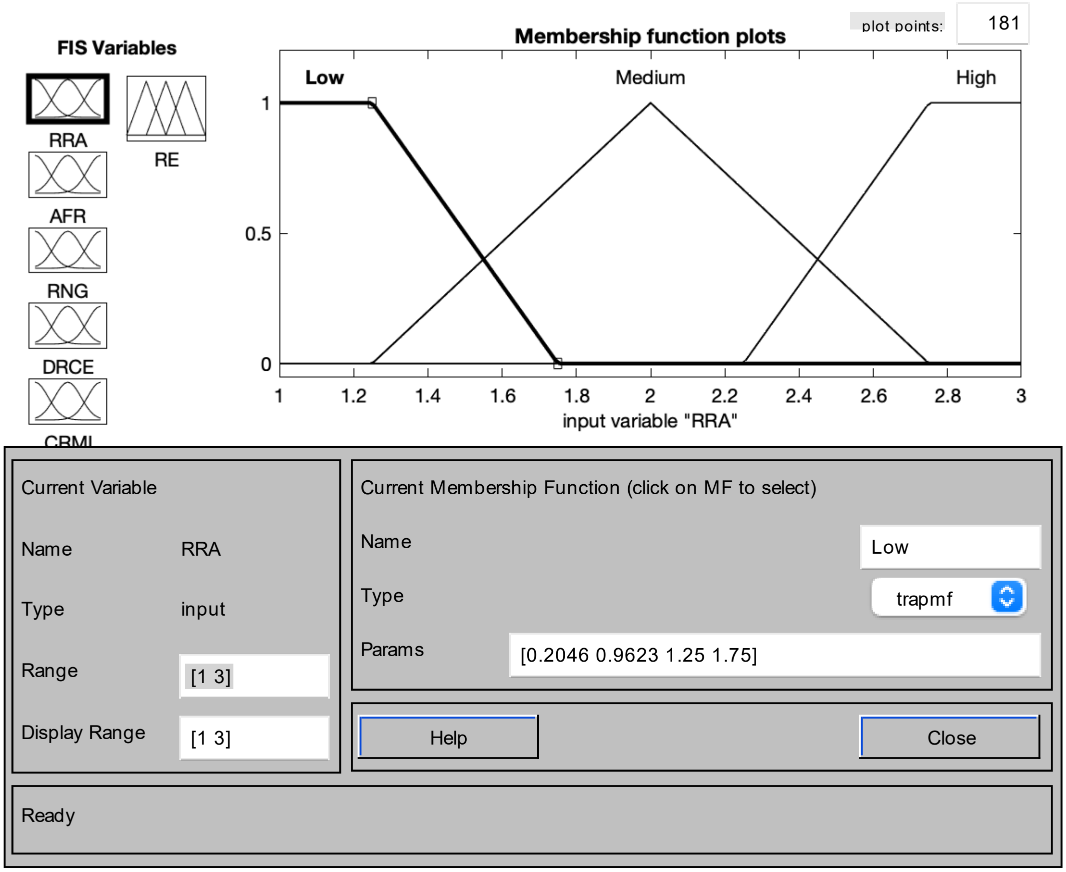

Fig. 1. MATLAB screen results of Membership function.

3.3 CASE B (Two-step fuzzification)

In this case, the same dynamic was implemented to choose variables; however, five were chosen for each RERA subprinciple. In this way there are fifteen variables in total; this does not alter the number of rules, since the fuzzifier will be used individually for each subprinciple.

In this form design, you are asked to answer one question per variable and then rate the level of expertise you have in that question, as in the form in case one. The form was divided into three sections, one for each sub-principle. For more details, see Annex B.

The fuzzifier was implemented with three linguistic variables: three subprinciples and three linguistic values (high, medium, low). This second fuzzifier has 27 rules and the membership functions follow the structure of Figure 1.

Figure 2 represents the visual flow of the methodology in this study, from the identification of the variables to the obtaining of the fuzzy value generated by the opinion of experts through the fuzzy logic model.

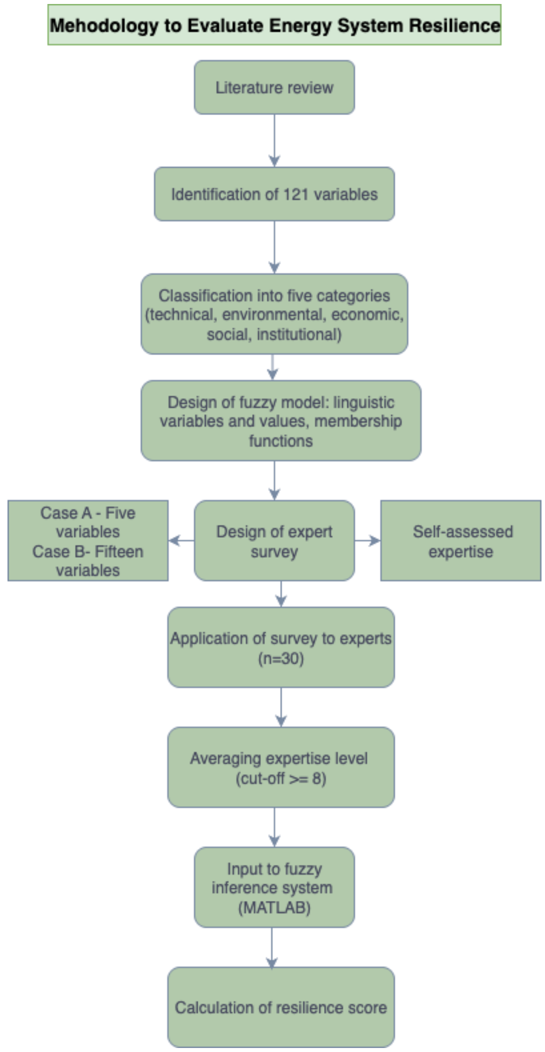

Fig. 2. Methodology to evaluate energy system resilience

4 Results

4.1 Survey data

The survey was applied to a group of 30 professionals with more than 15 years of experience in different areas of the energy sector in Mexico. The population consulted consisted of specialists in energy systems, infrastructure, sustainability, and public policy; they were selected for their proven experience and involvement in energy-related projects at national or local level.

It should be clarified that this study does not seek to generate results that are statistically representative of a population. Fuzzy logic, unlike traditional statistical models, does not rely on probability or representativeness (Lafuente et al., 1998; Di Nardo & Simone, 2019). Instead, it works with the degree of membership derived from qualitative reasoning, which makes it particularly useful in contexts where precise data are not available. So, the aim was to capture expert knowledge, not to generalize the results to a wider population, so concepts such as sample size, confidence intervals, or margins of error are not applicable. Instead, responses were filtered using a cut-off threshold based on self-assessed expertise, ensuring that only opinions with a high degree of expertise were included.

4.2 CASE A

This model uses the opinion of experts on the subject, as in (Canavese et al., 2014; Papas et al., 2022). Experts working in different areas of energy were selected because we are considering the economic, social, institutional, and environmental dimensions in addition to the technical ones. Each person evaluated their level of knowledge from 1 to 10, 10 being an expert level, and assigned a value (high, medium, low) to each question related to the variables.

The level of expertise on the topic was requested because it is understood that not all people are experts in all areas, and this also avoids bias in responses where the level of expertise is low, and the evaluation of the question has value "high". In this way, this type of inconsistency is avoided.

The level of expertise ranges from 1 to 10, and a cutoff point c=8 was defined in the level of expertise to consider the responses valid and register the value of the survey in the fuzzifier. That is, if the self-perceived level of normalized expertise is less than 8, then that person's response is not recorded to prevent it from altering the measurement of the group of people who are experts on that topic. Table 2 shows an example of the responses collected from the form, as well as the cutoff point that was made to consider the response valid. Recall that the low linguistic value is 1, medium is 2, and high is 3. The last five columns are assigned the linguistic value according to the cut c of the questions.

Table 2. Answers case one. (area of interest: question, level of expertise: rating assigned to knowledge, response: linguistic value (H-high, M-medium, L- low)).

Expert	**Area of interest**	**Expertise Level**	**Answer in the survey**	**Value recorded by the fuzzifier**				
				RRA	**AFR**	**RNG**	**CRMI**	**DRCE**
Person 1	RRA	5	M					
	AFR	5	L					
	RNG	3	H					
	CRMI	9	L				1	
	DRCE	9	L					1
Person 2	RRA	6	M					
	AFR	10	H		3			
	RNG	10	M			2		
	CRMI	7	L					
	DRCE	10	M					2

The next step was to average each valid question considering its linguistic value since not all of them had the same assigned value. Table 3 shows the results.

Table 3. Average per question of case one

RRA	AFR	RNG	CRMI	DRCE
2 .13	2.07	1.38	1.37	1.9

The numbers obtained were those that were entered into the fuzzifier, to obtain a value of the energy resilience of the systems at the national level in Mexico, said value is 1.55. Figure 3 shows the result in MATLAB.

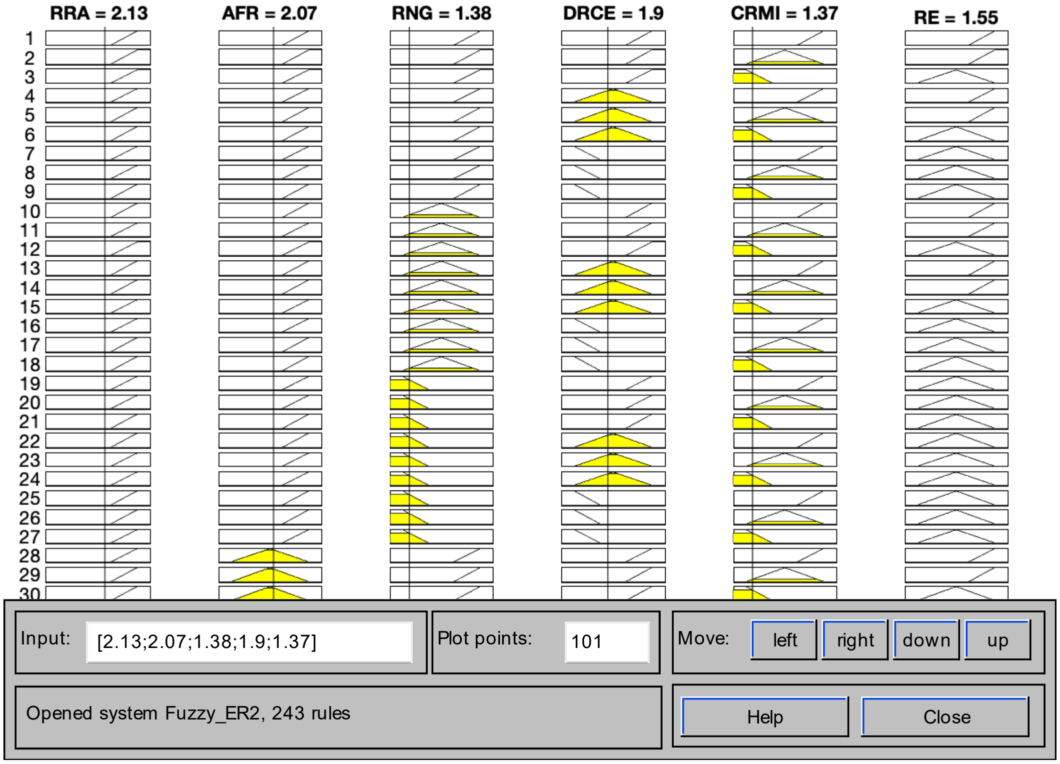

Fig. 3. MATLAB screen results. Energy resilience value, case one.

4.3 CASE B

The second case study was divided into three sections, one section for each RERA sub-principle, i.e., exposure, efficiency, diversity, and redundancy. Each section was built with five questions that were about variables that are linked to the subprinciple. Likewise, the knowledge of each question was evaluated. Following the cut-off and average methodology of case one, the same cut-off c=8 was applied for the three sections and the average of the linguistic value per question was also carried out. As shown in Tables 4 and 5.

Table 4. The average for each question in each section, the second case.

Sub principle	Question 1	Question 2	Question 3	Question 4	Question 5
Efficiency	2.07	2.14	2.5	2.06	1.76
Exposure	2.13	1.9	1.38	1.38	1.69
Diversity and redundancy	1.8	2.13	1.73	2.72	1.6

Once the linguistic values per section are obtained, they are passed through fuzzifier one (fuzzifier intended for the RERA subprinciples) and the energy resilience evaluation is obtained.

Table 5. Energy resilience value by subprinciple

Sub principle	Value
Efficiency	2
Exposure	1.59
Diversity and redundancy	1.98

Once we have the values for each subprinciple, the national energy resilience value is obtained, as shown in Figure 4, which gives us a value of two. In this case, Mexico's energy resilience is considered average.

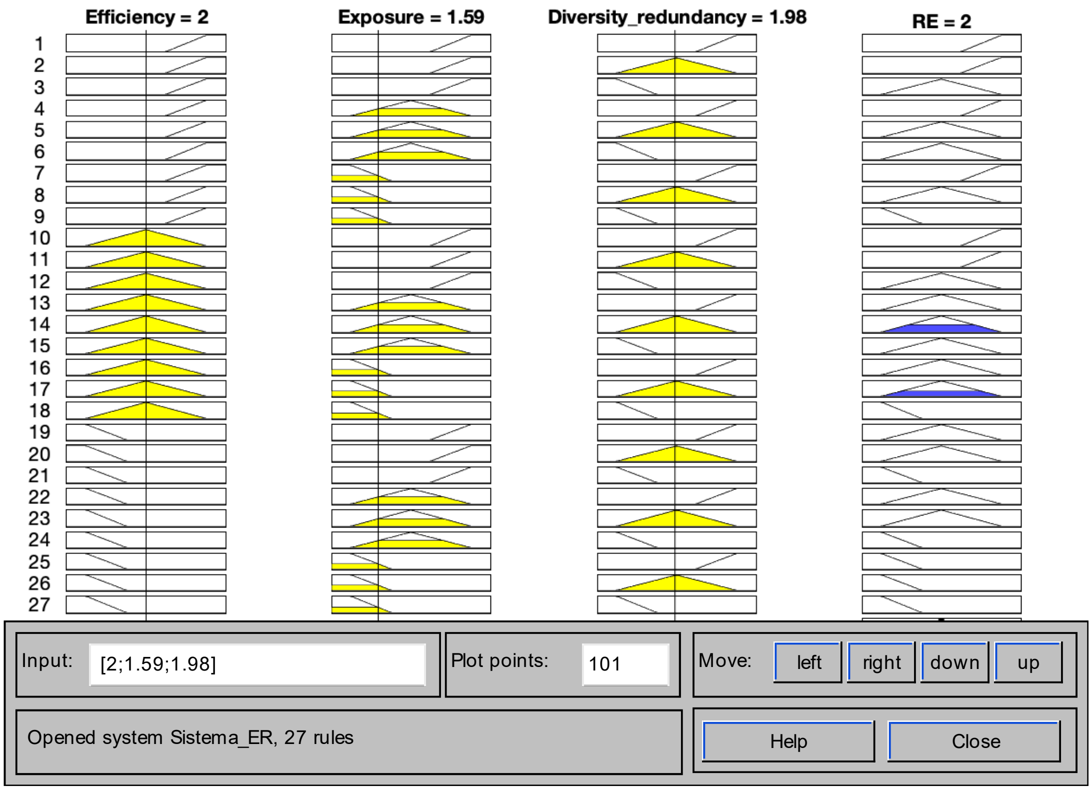

Fig. 4. MATLAB screen results Energy Resilience value, case two.

5 Conclusions

The use of fuzzy logic, combined with expert opinion, makes it possible to fill in gaps in the quantitative method. For example, the social dimension in the quantitative method has very few indicators; however, fuzzy logic incorporates this aspect by taking advantage of the knowledge and perspectives of experts, thus enriching the analysis from a more comprehensive approach.
In the first fuzzy logic method, case A, a value of 1.29 is obtained for energy resilience, and case B, a value of 2 is obtained. Recalling that one is low, two is medium, and three is high, it can be said that in the first case, the degree membership of energy resilience, which is 1.29, is more aligned with "low", while in case two, it is completely "medium".

By adding more questions, the context to be evaluated becomes broader, and it is noted how certain questions have a unanimous answer, while in others there are different extremes. In case A, where there is a question, it helps us to know in a very general way the expert's perception of the resilience of the energy system of the country where it is evaluated, but when considering case B, which already has more questions, it helps to put in a more specific context the perception of the expert; in this case the questions were adapted to the context of Mexico; this does not mean that case one does not work, but rather it is a faster and more global evaluation that can help to know the perception of resilience without going into so many details.

Due to the restriction on the number of variables and values, doing it by dimensions according to the three subprinciples allowed us not only to have five variables, but fifteen in total, that is, one variable per question, and each dimension consists of five questions. In this way, the number of rules was not altered, the fuzzifier was simply used individually for each subprinciple, in addition, a second fuzzifier was used in which there are only 3 variables, which are the 3 subprinciples, efficiency, exposure, and diversity and redundancy and the Values are high, medium, and low. In this second fuzzifier, there is a total of 27 rules, as seen in Figure 4.

One of the limitations that this work has is the part where each person is asked to evaluate their knowledge of the question, since in the end it is the person's perspective of themselves, and this often hides the truth. Hence, the importance of using the tool with people who have a high degree of expertise and to avoid biases is normalized for better data consistency. As Canavese et al. (2014) mention, it is necessary to consider mixed methodologies (qualitative-quantitative) and the knowledge of experts to avoid greater uncertainty when obtaining data. We confirm that this type of method that uses expert opinion is very appropriate when the information on the variables alone is not sufficient, but there is a degree of inconsistency with the quality of life of the region to be evaluated.

Importantly, this model was not trained or validated using traditional machine learning techniques or statistical testing. Instead, validation was achieved through internal consistency: ensuring that the results were coherent and meaningful to the same group of experts who provided the data. The fuzzy results aligned with expected patterns and expert opinions, thereby reinforcing the credibility of the model despite the absence of statistical representativeness. As mentioned in Section 4, fuzzy logic does not calculate probabilities; therefore, the representativeness of the sample is not a factor to be considered, as in statistics. Instead, the focus is on membership.

This study lays the groundwork for future developments in the assessment of energy resilience using fuzzy logic. A logical next step would be to expand the number and diversity of expert participants, incorporating the perspectives of community leaders, technical operators, and decision-makers from different regions of Mexico, as well as adapting the model to local or regional contexts by including variables specific to each area. Another direction could involve the integration of hybrid methodologies, combining fuzzy logic with spatial analysis or scenario modelling. Similarly, the results could be translated into practical policy tools or dashboards to assist policymakers in visualising resilience gaps and devising strategies to mitigate them.

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Appendix A

This questionnaire is divided into two sections, the first asks the level of knowledge on a topic, and the second evaluates the question with high, medium or low with respect to the topic of section one.

Section 1

1. Risks, energy systems in the face of natural disasters
please rate from 1 to 10 how much you know the topic.
2. Financial aspects in energy infrastructure.
please rate from 1 to 10 how much you know the topic.
3. Natural gas market
please rate from 1 to 10 how much you know the topic.
4. Social and community aspects of energy systems.
please rate from 1 to 10 how much you know the topic.
5. Renewable energy
please rate from 1 to 10 how much you know the topic.

Section 2

Energy resilience is the capacity of energy sociotechnical systems to mitigate, minimize, recover and anticipate what is caused by a disturbance in economic, social, environmental and institutional terms.

How do you consider the level of energy resilience, in this case national, according to each question?

1. How robust are energy system risk analyses in the event of natural disasters?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply
2. How accessible are financial resources to rebuild energy infrastructure?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply
3. How risky is the import of natural gas in the region?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply
4. What is the level of preparedness of the community to face disturbances in the energy system?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply
5. What is the level of diversity of renewable energies in the energy mix?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply

Appendix B

This questionnaire is divided into three sections: efficiency, exposure and diversity and redundancy. All are answered with high, medium, low, not applicable. In each question, your level of knowledge is evaluated from 1 to 10, with 1 being I do not know the topic and 10 being I understand the topic and have experience.

Section 1

Efficiency describes the attempt to generate maximum value with minimal effort and thus to optimise functions and structures within the energy system.

1. How accessible are financial resources to rebuild energy infrastructure? (generation, transmission, distribution, etc.)
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

2. What is the level in which the infrastructure can solve the electrical interruption for more than 24 hours?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

3. How strongly are the reliability of the energy system protection mechanisms in case of a failure?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

4. How available is the information related to community energy needs for authorities?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

5. How strong is local infrastructure in terms of providing efficient energy consumption?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

Section 2

Exposure can be defined as the ability to reduce dependencies and negative predispositions towards a potential extent of damage.

1. How robust are the risk analysis of the energy system in case of natural disasters?
    a. High
    b. Medium
    c. Low
    d. Doesn’t apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

2. How high is the level of regulations in terms of promoting renewable energy?
    a. High
    b. Medium
    c. Low
    d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

3. What is the community response level to mitigate impacts/disturbances in the energy system?
    a. High
    b. Medium
    c. Low
    d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

4. How risky is the natural gas importation in the country?
    a. High
    b. Medium
    c. Low
    d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

5. How accessible are the resources for energy regulations in energy saving at different levels?
    a. High
    b. Medium
    c. Low
    d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

Section 3

Diversity can be interpreted as the implementation of mixed structures and functions on both, energy demand and supply. Redundancy seeks to create similar or the same components and structures with multiple use as the integration of decentralized utilities, e.g. for energy and food supply, is linked by redundant networks or power lines

1. How flexible and dynamic is the energy supply infrastructure?
    a. High
    b. Medium
    c. Low
    d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

2. What is the action plans level, risk management, human, physical and financial resources in case of emergencies?
    a. High
    b. Medium
    c. Low
    d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

3. What is the investment level that is made from the planning phase in the expansion of networks and transmission switching simultaneously?
    a. High
    b. Medium
    c. Low
    d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

4. How is the centralization level in institutional context?

   a. High
   b. Medium
   c. Low
   d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.

5. What is the consume/stakeholder awareness level of energy alternatives as well as the costs/benefits they offer and the requirements for their implementation?
   a. High
   b. Medium
   c. Low
   d. Doesn't apply

Based on the previous question, please rate from 1 to 10 how much you know the topic.