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CLEAN ENERGY A COMPETITIVE ALTERNATIVE FOR MICROENTERPRISES DESPITE INVESTMENT UNCERTAINTY IN MEXICO

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Microenterprises with high electricity consumption in Mexico have a life expectancy of no more than seven years (INEGI) and are very vulnerable to changes in fiscal policies, high fixed costs and few financing opportunities. The study aims to understand the economic-environmental sustainability of these companies. A survey of 150 companies with high electricity consumption in Region III of Michoacán was carried out using fuzzy cognitive maps (MCD) with four variables: the availability of investing in photovoltaic (PV) cells for economic growth; public policy management; competitiveness associated with sustainability; and economic-environmental culture for regional development. The MCD model makes it possible to emulate the variables to establish new economic-environmental strategies in the companies, allowing them to extend their useful life and strengthen their competitiveness, in addition to promoting a culture of solidarity with the environment. The results obtained indicate that these companies have a positive impact on photovoltaic investment. The economic savings of more than 70% and a return on investment in photovoltaics of between seven and nine years stand out. Despite public policies, they are contrary to business growth and development.

Keywords: *development, clean energy, diffuse cognitive maps, competitive, sustainability*

JEL Classification: D14, G41, R13

1. INTRODUCTION

The objective of this work is to present the main challenges in public policies to face the energy demand of micro-enterprises in Morelia and to propose

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insufficient knowledge regarding the competitive behavior of these units and their competitive environment, these companies manage to survive longer than expected (Osorio *et al.*, 2018). The arguments are based on meeting the challenges of competitiveness based on innovation, given their majority participation in the productive fabric, which should be strengthened to enhance their adaptability (Valdés and Sánchez, 2012). Dynamic capacity adaptation mechanisms are important in remaining in the market (Kathleen and Jeffrey, 2000). Thus, new technologies such as photovoltaic (PV) cells not only offer an energy-saving alternative but also contribute to paradigm shifts in the technological association and the environment in air quality, as well as other direct and indirect benefits to social and economic development (Tylecote and Ramírez, 2004; Secretaría de Energía, 2009; Arivilca and Orbegozo, 2010). In Mexico, through the National Electricity System Development Program (PRODESEN), the National Commission for the Efficient Use of Energy (CONUEE) and the Ministry of Energy (SENER) estimate that clean energies produced to supply EC need at the national level will be equivalent to 490,047 GWh in 2033. Where the participation of clean energies will gradually increase from 26.60% in 2019 to 39.9% of the national total generated in 2033, this percentage represents the generation of 195,316 GWh with the various clean energies (Pizarro-Alonso *et al.*, 2019). The aforementioned, associated with MSMEs are forced to invest in PV to be competitive and increase the useful life of the business. However, MSMEs have a disadvantage. According to Gómez Martínez *et al.*, 2009, companies recognized in the market are more likely to be approved for credit; additionally, it is important to have a financially solvent guarantor and audited financial statements to gain access to financing. The current Mexican government does not promote sources of financing in clean energies, nor does it promote investment in clean energies, which causes uncertainty in the population's investment in PV.

The federal government's defence of the Federal Electricity Commission (CFE) as the sole energy supplier in the country, preventing free competition associated with the opening up to new clean energy technologies. Nevertheless, the dynamics of PV users have been increasing over the last four years, according to Ramos *et al.* (2019). The average price per PV unit is $45500 (Mexican currency), and recently, with increased participation of PV suppliers - the price per PV unit has decreased by about 2/3 - which offers a very attractive alternative, especially for Mexican micro-enterprises (Romero, 2022). Environmental culture - companies, by nature, are obliged to be efficient and competitive due to the increasingly demanding market confrontation associated with environmental care (Saavedra and Hernández, 2008). Companies linked to renewable energies allow them to take care of the environment and are an economic alternative for their consumers (Arivilca and Orbegozo, 2010). The evolution of photovoltaic technology has significantly improved efficiency and decreased manufacturing costs (Hernández, 2017).

In much of the world, governments show solidarity with companies to invest in new clean technologies to reduce environmental impacts. In this sense, the study

investment in PV allows companies to be more competitive and consequently there is satisfaction with the technology.

The association algorithm is applied in question 16, with the purpose of knowing to what extent public policies promote environmental economic development with PV investment with respect to confidence, support and lift indices.

The business community expresses sensitivity and uncertainty due to public policy stances that are averse to investment in clean technologies, development, and growth and due to the environmental impact caused by the combustion of fossil fuels and the generation of CO2 electricity.

By applying the DCM model, it allows a transversal diagnosis at the moment and the interaction of all the indicators (items) that directly impact environmental economic sustainability. From this diagnosis, new change strategies can be formulated in the negative indicator-variables (Figure 5): J, L, M, O, P, Q and R to make changes in the assignment matrix and thus improve the results of economic sustainability.

MSMEs are of utmost importance for the economic development of Mexico, of which 4,800,157 belong to this segment; that is, 76% of the total (INEGI, 2020). Through PV, costs can be reduced and thus extend the useful life of business units, which are usually between 5 to 7 years on average (INEGI, 2020).

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is focused on the appreciation that users and experts have in economic-environmental sustainability derived from four factors: economic growth promoted by investment in PV, Regional development by reducing costs and viability in PV investment, public policies that promote the availability of financing and sustainability through competitiveness (Figure 1):

- Economic growth. Through economic development to enable investment in environmentally friendly technologies (Bitar and Chamas, 2017). In MSMEs, regardless of the line of business, the energy cost comprises one of the three main problems that limit growth and survival, surpassed by public insecurity and unfair competition due to the informal economy (INEGI, 2018). INEGI (2020), in its 2019 economic census, reports that 6,373,169 economic units operated in the country, of which 4,800,157 belong to the MSMEs segment, same that employed 27,132,927 out of a total of 36,038,272 employed people.
- Development Region. Cultural regions express the spatial distribution of features and patterns created by human groups in a certain era. Economists regionalize a country by dividing it into spaces distinguished by forms of organization of resources and population; since the economic aspect is fundamental in the organization in time and space (Boisier, 2001; Burnes, 2008; López and Ramírez, 2012). Society perceives development by the social, economic, political, technological, environmental, quality of life, etc. Coinciding all variables in common, the transition from a specific economic standard of living to a higher one (Valcárcel, 2006; Rosales, 2016). From an integrated systemic approach, regional development is the interaction of sets of individual and singular processes, each of which constitutes the sustainable development of the social individual and its environment (Alejandre and Pineda, 2011).
- Public policies. Since the arrival of the current government in Mexico, which has closed the opening of clean energy to the country in order to preserve the CFE monopoly, the reaction of businessmen has been moderate. However, protests have been isolated for fear of fiscal reprisals. According to Mujica and Rincón (2010) the controversies between the government and the market should be oriented towards the search for solutions by deepening the approach and application of uniform policies on the most relevant issues.
- Sustainability. The discrepancies and uncertainty between the different positions on the environment and economic growth, there is a strong current of optimism in contributing to environmental economics. This current maintains that, with economic growth, the environmental problems generated by development can be corrected (Mujica and Rincón, 2010). ECLAC in 1991 stated that sustainable development requires a systemic effort, which encompasses the conduct of economic policy, management of natural resources, technological innovation, and influential participation of population strata, education, and consolidation of institutions, investment, and research. In the search for a balance between economic growth and environmental conservation, considering the costs involved in economic

However, there are businesses with high consumption domestic tariffs (DAC) and more than 5 HECE compromising the profitability of the productive unit. The algorithm produces 94 rules (Table 4), of which the last ones (88 to 94) are taken as an approximation to the common denominator of the HECE case study. Where the frequency or support is between 0.56 to 0.6; while the confidence in the rule is between 0.76 and 1.0; the leverage measures the difference between the support with which they appear in the set of HECE contained in a rule and the expected frequency, if they were independent, with values from 0.57 to 0.73; and the lift > 1, which represents the probability of the consequent rhs increase because the antecedent lhs happened, Table 4. On the other hand, in Figure 4, there are all rules and their nodes, where the support is symbolized by the size of the circle (size), and the lift by the color intensity. The higher the intensity, the higher the value of the lift (Figure 4).

17. Both groups agree on having financing for PV.
18. Both groups are undecided whether the government (CFE) has a benefit from the use of PV.
19. Both groups disagree with public policies on supporting competitiveness.
20. Both groups disagree with public policies on environmental protection.
21. The PV users agree with the savings obtained

Stage II. Diffuse cognitive maps

The survey results (Table 2) are divided equally for companies (groups) without PV and with PV. From these, two concept vectors are derived; C_t according to the means of the items: $A, B, \ldots, X$

$$C_t = [A\ B\ C\ D\ E\ F\ G\ H\ I\ J\ K\ L\ M\ N\ O\ P\ Q\ R\ S\ T\ U\ V\ W\ X]$$

The concept vector C_1 of the companies without PV cells is composed of the mean values (Table 3) of all factors (items) involved and described ($A, B, C, \ldots, X$, Table 2):

$$C_1 = [0\ .53\ .73\ .08\ .38\ -.24\ .39\ .35\ .53\ .55\ .55\ .57\ .08\ -.4\ -.35\ -.38\ -.49\ -.36\ 0\ 0\ 0\ 0\ 0\ 0]$$

Similarly, the corresponding values for emissivity with PV cells, C_2:

$$C_2 = [0\ .72\ .83\ .49\ .67\ .21\ .55\ .65\ .74\ .61\ .83\ .63\ -.17\ -.49\ -.43\ -.43\ -.57\ -.57\ 0\ 0\ 0\ 0\ 0\ 0]$$

Both concept vectors C_1 and C_2 are initiators in the iterative process to obtain $R = C_t * \varphi_k$, either can be used.

From the survey of the 150 entrepreneurs, the experts take these survey results as a reference (Table 1) and according to their experience assign the weights w_{ij} corresponding to the causal relationship in row indicator i on effect indicator j to

5. Both groups are looking for the benefit of energy-economic savings.
6. PV companies estimate a return on investment between 4 and 7 years.
7. The enterprises with PV average number of cells per company is between 15 and 25.
8. The companies with PV savings of 70 to 90%.
9. PV users expect to pay the investment between 5 and 10 years, which is different from the return on investment in question 6.
10. There is no financing from banks or government support, companies have used their own resources, which decreases the competitiveness capacity.
11. Both groups agree that having photovoltaic cells will promote economic growth and benefit the environment.
12. Both groups agree that they have lowered the cost of photovoltaic cells.
13. Both groups agree on the positive image that using PV generates in society.
14. Both groups agree with the benefits of PV.
15. Both groups agree that PV takes care of the environment.
16. Both groups recommend the use of photovoltaic cells, if the company has high energy consumptions above 800kwh/day, which agrees with the model recommendation apriori in the lift ratios in refrigerators: Coca-Cola, Pepsi-Cola, Aga, beer, ice, dairy, etc. (Figure 4 and Table 4). The question 16 is argued too by association rules applying RStudio version 4.3.0 $(2023-04-21-ucrt)$, which allows establishing the rules based on support, confidence and elevation. Those businesses with more than six devices with high electrical consumption $(>800kwh/day)$ in groceries representing 70% of companies with PV and 63% in companies without PV (Figure 3). Therefore, those that do not yet have PV are highly candidates for installing a set of cells according to their energy needs so as not to compromise economic sustainability. In Figure 3, you can see the density of high-consumption equipment based on the support, confidence, and elevation calculations in RStudio. Freezers with high electrical consumption $(>1000W)$ such as Coca-Cola Company, Pepsi-Cola, and Sidral Aga have larger circles due to their frequency in groceries and to a lesser extent there are freezers for beer, ice, sausages, dairy products, televisions, etc. The nodes are joined to other circles of different sizes, these unions represent conditional probabilities (Bayesian Theory), that is, it is the support or support, while the intensity of the color represents the value of the confidence.

800 Kw-h/day, reducing the number of productive units for the sample size. The objective is to know the impact of public policies (PP) on the availability of investment, energy efficiency, socio-environmental culture, regional development, competitiveness, and satisfaction in economic-environmental sustainability.

Stage I

The first objective is to obtain information about energy consumption, PV management, environmental appreciation, etc., that will provide sufficient elements to make decisions to experts. Table 1 provides the general survey for PV users and non-users, cross-sectional in the period May-September 2022.

Table 1. General data survey

1.	How much were you paying before PV?
2.	What is the rate per kWh you are paying?
3.	How many high-consumption appliances do you have in your business?
4.	How often do you maintain your electrical equipment?
5.	Does solar and PV energy care for the environment?
6.	What is the return on investment in PV?
7.	How many PV units do you have?
8.	How much do you save on average every two months?
9.	How long do you expect your PV investment to pay for itself?
10.	Does your PV investment have any type of financing?
11.	With the use of PV can there be economic growth of the company?
12.	Do you agree with the costs of PV investment for your business?
13.	Does the investment in PV have a positive impact on the image of your company?
14.	Is there any benefit over risk in PV investment?
15.	Does the investment in PV favor the protection and care of the environment?
16.	Would you recommend the use of clean energies?
17.	Would you agree to acquire PV, if there were governmental financing?
18.	With solar energy, could the government have any type of benefit?
19.	Are Mexico's public policies oriented to promote the commercial competitiveness of PV?
20.	Are Mexico's public policies oriented to improve the environment?
21.	Do you agree with the cost of PV and the savings achieved in electricity payments?

Stage II

From the survey in Table 1, the experts analyzed this to respond to the Table 2 survey. That is, the response to the survey Table 2 is conditioned by the results of the survey in Table 1. Then, the responses of the Likert scale Table 2 survey are adjusted to a decade scale in the interval $[0, 1]$. Where 0 means that there is no relationship, while 1 represents the maximum possible relationship (Table 3), (Kaufmann and Gil, 1988, Kaufmann *et al.*, 1994). In the research, impacts on economic and environmental aspects of 24 parameters are contemplated among themselves (by experts) (Table 2).

The function $f(R)$, is the product between the concept vector and the assignment matrix φ:

$$R = C_t * \varphi_k \quad (9)$$

The resulting elements of the vector R, all those ≥ 0 are taken as ones and those < 0 are taken as zeros to form the new Boolean vector, C_{t+1}, as an iterative process until $C_{t-1} = C_{t+1}$. The identity function allows to visualize the oscillations until equilibrium with the possibility of modifying the elements of the matrix φ, (Curia and Lavalle, 2011).

5. METHODOLOGY

The research focuses on electricity-intensive production units (PUs) with and without photovoltaic energy. Specifically, these PUs are grocery stores, butcher shops, ice cream parlors, video game stores, recreational centers, mechanical workshops, furniture stores, etc. One of the patterns to highlight in these companies is the high operating costs caused mainly by coolers, freezers, or other industrial equipment, compromising economic sustainability (Ramos *et al.*, 2021). The survey applies to 150 microenterprises in Region III, known as Region Cuitzeo, located in the northeast of the state of Michoacán, formed by 13 municipalities, one of which is the municipality of Morelia (Figure 2).

I. Lerma-Chapala
II. Bajío
III. Cuitzeo
IV. Oriente
V. Tepalcatepec
VI. Purépecha
VII. Pátzcuaro
VIII. Tierra Caliente
IX. Costa
X. Infiernillo

Figure 2. The regions of Michoacan

Source: Development by DENUE, 2022

The sample has considered companies from 0 to 5 people. As a result, 405 microenterprises have been considered, from which 298 are located in Morelia (DENUE, 2022). In addition, the microenterprises have high electricity consumption with various equipment with electricity consumption greater than

activities and consumption patterns related to biodiversity. In this sense, the intervention of clean energies makes a non-extractive use of natural resources, and their benefits are positive (Ortiz and Arévalo, 2014). Natural resources that generate a benefit are considered assets. Although their price is very low, economic agents can limit their consumption (Escalante and Catalán, 2005).

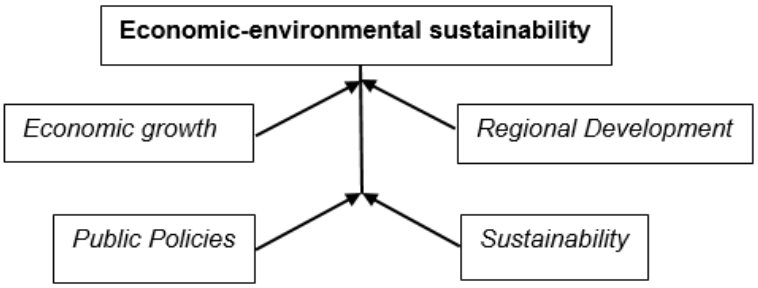

Figure 1. Variable structure

Source: Development by authors

Public policies that encourage investment in photovoltaic power generation cells will allow for sustainable development, both economically and environmentally, impacting those regions with the highest energy demand in productive units (microenterprise). Bearing in mind that, environmental economic development and intergenerational equity must consolidate a balance between the goals of environmental conservation and economic growth (Kolstad, 2001; Goodstein, 2002; Escalante and Catalán, 2005). Thus, the research is oriented in two ways, first, the extraction of knowledge regarding significant patterns and rules, association model (section 3), and second, the level of diffuse incidence of cause and effect of events related to energy consumption and their impact on the environmental-economy, fuzzy cognitive maps model (section 4). Both sections are integrated into the methodology (section 5).

3. ASSOCIATION MODEL FOR HIGH-ENERGY EVENTS

The general way of interpreting and performing tasks in data mining is by classification, which can be supervised, semi-supervised, or unsupervised (Han *et al.*, 2006; Witter *et al.*, 2011). Patterns are identified with statistical tests or relationships between variables under study and techniques that regularly involve rules, decision trees, cluster groups, etc. (Han *et al.*, 2006). The patterns or labels of the data are conjugated to obtain characteristics of the behaviour of the object that can be converted into information, (Agrawal *et al.*, 1993; 1994; Han *et al.*, 2006; Zhu *et al.*, 2009) can be characterized, data can be predicted or grouping

Stage III

The fuzzy assignment matrix is constructed, indicating the cause-effect incidents, as well as equations (6) and (7) for the DCM model.

Fuzzification: the type Likert survey to users and non-users of the PV with the options: (1) totally disagree, (2) disagree, (3) undecided, (4) agree and (5) strongly agree, are adjusted in infinitesimal values in an interval [-1, 1] to apply the weights w_{ij} in the FCM matrix (Kosko, 1986; Peláez *et al.* (1995); Hiliera and Martínez, 2000), where -1 is the inverse causal relationship between one variable and another; the value of 1 represents the directly proportional causal relationship between one variable and another; and the value of zero, is the neutral part:

The matrix is constructed with causal weights from origin i to destination j for each element w_{ij} of the matrix φ. Moreover, patterns of the independent variables and their impact on the dependent variable sustainability of high electricity consumption companies and their possible strategies to increase sustainability are sought. Thus, the information in the first part provides complementary information for the assignment of weights of the φ matrix through the following survey of causal relationships between variables:

The matrix is structured with the dependent variable: economic-environmental sustainability (EES) $\in \{item: X\}$, which, is composed of five independent variables: willingness to invest (DI) $\in \{items: A, B, H, S, T, U\}$ to decrease costs due to high electricity consumption; energy efficiency (EE) $\in \{items: V, W\}$ in the use of technology influencing the structure and installed capacity; similarly socio-environmental culture (CSA) $\in \{items: G, I, J, K\}$ with the use of clean technologies and the culture of environmental care; regional development (RD) $\in \{items: C, D\}$ manifested in economic returns and, contribution to the environment with the use of technology; competitiveness and satisfaction (CS) $\in \{items: E, F\}$ facilitating investment and improving productive processes for higher performance and permanence in the market; public policies (PP) $\in \{items: L, M, N, O, P, Q, R\}$ in opening to investment in renewable technologies for competitive through investment financing.

6. RESULTS AND DISCUSSION

Stage I

Of the 150 microenterprises surveyed, half have PVs in Region III of Michoacán, the composition according to the number of surveys applied per municipality from highest to lowest: in Morelia, 57%; in Tarímbaro, 10%; in Zinapécuaro, Charo and Huandacareo with 5%; in Acuitzio, Álvaro Obregón, Indaparapeo and Cuitzeo with 3%; in Copándaro, Queréndaro and Santa Ana Maya with 2%; in Chucándiro, 1% of the total.

$$leverange = (\{X\} \rightarrow \{B\}) = support\ (\{X\} \rightarrow \{Y\}) - support\{A\} * support\{Y\} \quad (4)$$

Conviction-allows to determine the direction of the rule. It is not always the same $\{X\} \rightarrow \{Y\}$ as $\{Y\} \rightarrow \{X\}$. So that conviction allows to determine the direction of the rule. It is not always the same $\{X\} \rightarrow \{Y\}$ as $\{Y\} \rightarrow \{X\}$. So that

$$conviction = \frac{1-support\{Y\}}{1-confidence(\{X\}\rightarrow\{Y\})} \quad (5)$$

4. FUZZY RELATIONSHIPS

The elements of the matrix φ are obtained from the opinions of the p homogeneously weighted experts (λ), using the generalized mean (Kaufmann *et al.*, 1994):

$$w_{ij} = \sum_{s=1}^{S}(\lambda_s w_{ij,s}^{p})^{\frac{1}{p}} \quad (6)$$

Where w_{ij} is the generalized average, λ_s is the expert weighting ($\sum_{s=1}^{S}\lambda_s = 1$, $\lambda_s \in [0,1]$), $w_{ij,s}^{p}$ is the element cause i minus the effect i of the matrix by consensus of s experts, p is the order of the mean ($p \in Z$) and s is the number of experts.

The elements express the relationship between the causal factors of the origin item i and the destiny of item j. Thus, due to its assignment characteristics by a set of experts, this matrix becomes a fuzzy matrix φ in elements with interval $[-1, 1]$. That is, those elements between -1 to 0 are causal weights from origin to destination that impact inversely, while the elements with interval 0 to 1 are causal weights from origin to destination that impact positively. Thus, it is constructed with elements with weights (positive and negative), w_{ij}:

$$\varphi = \begin{bmatrix} w_{11} & w_{12} \dots & w_{1h} \\ w_{21} & w_{22} \dots & w_{2h} \\ \dots & \dots \dots & \dots \\ w_{n1} & w_{n2} \dots & w_{nh} \end{bmatrix} \quad (7)$$

The fuzzy cognitive map (FCM) model regularly starts from a database or information extracted by surveys, observation, and routine incidences of experts. In this sense, expert opinion forms the fuzzy incidence matrix, which is flexible to manipulate to simulate and control possible future scenarios and establish strategy planning (Kosko, 1986; Carlsson, 1996; Hiliera and Martinez, 2000). The assignment matrix is composed of the consensus among experts, which is conjugated with the concept vector, C_t (vector of zeros and ones) to form a new vector, C_{t+1}:

$$C_{t+1} = f(C_t, \varphi) = f(R) \quad (8)$$

construct the weighting or assignment matrix, φ_k (Table 5). As there are two initiating concept vectors, one group without PV and another with PV, the average of both is taken to make the matrix product (Equation 9) and thus obtain Table 6.

Table 5. Weighting matrix

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
A	1	0.7	1	1	0.8	0.8	1	0.6	1	-0.8	0.8	0.8	0	0.5	0.4	1	1	1	1	1	0	0	0	1
B	0.7	1	0	0.3	0.7	0.8	0	0	0	0	0.8	0	0	0	0	0	0	0	0.7	0.7	1	0.7	0	0.7
C	1	0.7	1	0	0.7	0.8	0.7	0	0	0	0.7	0	0	0	0	0	0	0	0.7	0.7	0	0.7	0	0
D	0.8	0.6	0.7	1	0.8	0.6	0	0.3	0.8	-1	0.7	0	0	0	0	0	0	0	0.7	0.7	1	0.7	0	0.7
E	1	1	0.8	1	1	0.9	0.7	0.7	1	-1	0.7	0	0	0	0	0	0	0	0	0.7	0	0	0	1
F	0.7	0.7	0.7	0.7	0.7	1	0.8	0.7	1	-0.8	0.7	0	0	0	0	0	0	0	0.7	0.7	0.7	0.7	0	1
G	0	0	0	0	0	0	1	0	0	0	0.7	0	0	0	0	0	0	0	0	0	0	0	0	1
H	0	0	0.3	0.3	0	0	0	1	0	0.7	0.7	0	0	0	0	0	0	0	0	0	0	0	0	0
I	0	0	0	0	0	0	0	0	1	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
J	1	-1	-1	0.7	-0.5	0	-1	1	-1	1	0	0	0	0	0	0	0	0	-1	-0.5	0	0	0	1
K	0.7	0.7	0.7	0.7	0.7	0.8	1	0	1	0	1	0	0	0	0	0	0	0	0.7	0.7	0.7	0.7	0.7	1
L	0.1	0	0	0	0	0	0	0	0	0	0	1	-0.8	-0.5	0	0	-1	-1	0	0.7	0	0	0	-0.7
M	-0.7	-0.7	0	0	0	-1	-0.7	0	-0.7	-0.7	-0.7	-0.7	1	-0.7	-0.7	-0.7	-0.7	-0.7	0	0	0	0	0	-0.7
N	-1	-1	0	0	-0.7	-0.7	-0.7	0	-0.7	-0.2	0	-0.8	-1	1	-0.8	-0.7	-0.7	-0.7	0	0	0	0	0	-0.7
O	-1	-1	0	0	-0.7	-0.7	-0.7	0	-0.7	-0.2	0	-0.8	-1	1	1	-0.7	-0.7	-0.7	0	0	0	0	0	-0.7
P	-1	-1	0	0	-0.7	-0.7	-0.7	0	-0.7	-0.2	0	-0.8	-1	1	-1	1	-0.7	-0.7	0	0	0	0	0	-0.7
Q	-1	-1	0	0	-0.7	-0.7	-0.7	0	-0.7	-0.2	0	-0.8	-1	1	-1	-0.7	1	-0.7	0	0	0	0	0	-0.7
R	-1	-1	0	0	-0.7	-0.7	-0.7	0	-0.7	-0.2	0	-0.8	-1	1	-1	-0.7	-0.5	1	0	0	0	0	0	-0.7
S	1	1	0.7	0.7	0.7	0.7	0.8	0.5	0.9	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.7
T	1	1	0.7	0.7	0.7	0.7	0.8	0.5	0.9	0	0	0	0	0	0	0	0	0	0.9	1	0	0	0	0.7
U	1	1	0.7	0.7	0.7	0.7	0.8	0.5	0.9	0	0	0	0	0	0	0	0	0	0.9	1	1	1	1	0.7
V	1	1	0.7	0.7	0.7	0.7	0.8	0.5	0.9	0	0	0	0	0	0	0	0	0	0.5	0.5	1	1	1	0
W	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
X	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1

From these parameters, a square and reflexive matrix is generated (assignment matrix, Equation 8), in in which the main diagonal should be composed by ones (Kauffmann and Gil, 1988). The concept vector C_{t+1} (Equation 9) by the assignment matrix φ_k generates the vector R in Table 6. That table shows the different iterations performed.

Table 6. The diagnosis of the companies

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
1	6.4	5.0	2.0	2.7	4.3	4.9	3.9	2.0	4.1	-0.4	4.7	2.9	1.8	-2.7	1.7	1.1	0.2	0.3	1.6	2.8	1.9	2.2	0.6	5.9
2	5.3	4.7	8.0	7.8	5.4	4.7	4.9	5.4	5.9	-5.4	7.1	-2.1	-3.8	3.3	-2.3	-0.8	-1.6	-1.8	7.8	8.4	5.4	6.5	3.7	6.3
3	8.9	8.4	8.0	7.8	7.5	7.8	7.7	5.4	8.7	-4.1	7.8	0.0	-1.0	1.5	-0.4	0.3	0.3	0.3	7.8	7.7	5.4	6.5	3.7	9.8
4	6.0	5.4	8.0	7.8	5.4	5.7	5.6	5.4	6.6	-4.7	7.8	-1.4	-4.8	4.0	-3.4	-0.1	-0.9	-1.1	7.8	8.4	5.4	6.5	3.7	7.0
5	8.9	8.4	8.0	7.8	7.5	7.8	7.7	5.4	8.7	-4.1	7.8	0.0	-1.0	1.5	-0.4	0.3	0.3	0.3	7.8	7.7	5.4	6.5	3.7	9.8
6	6.0	5.4	8.0	7.8	5.4	5.7	5.6	5.4	6.6	-4.7	7.8	-1.4	-4.8	4.0	-3.4	-0.1	-0.9	-1.1	7.8	8.4	5.4	6.5	3.7	7.0

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derived from rules or objects that do not comply with normal behaviour. Understood as the extraction of knowledge regarding significant patterns and rules, which are regularly found where there is a large amount of data; with the application of these techniques, there is the possibility of understanding and characterizing the phenomenon, at least in its first approximation (Zhang and Zhang, 2007).

In the intervention of mutually inclusive events, the association rules allow conjugating relationships between their elements where apparently there is no visible information. An association rule (unsupervised) is the conditional probability of the form $X \rightarrow Y$ where X: an event where data exists, antecedent, and Y: an event that combined with the antecedent, called consequent. The rule reflects how much the presence of the antecedent influences the consequent and, according to the frequency in the number of units. Through these could calculate the lift.

In the association rules, the set of elements is identified, let $I = \{i_1, i_2, i_3, \ldots, i_n\}$ for a set p, and $T = \{t_1, t_2, t_3, \ldots, t_n\}$ in a set of n transactions. Each element $t_i \subseteq I$. Therefore, a subset of I, is equivalent $t_i \subseteq I$.

The support is the relative frequency of a rule with respect to the total number of transactions (T). The support, $S\ (X \rightarrow Y)$ represents the portion of the database for which $X \cup Y$ is true. In which the set $X \subseteq I$.

$$S(\{X\} \rightarrow \{Y\}) = \frac{\sigma(\{X\} \rightarrow \{Y\})}{T} = \frac{\sigma(\{X \cup Y\})}{T} = \frac{\sigma(\{X,Y\})}{T} \quad (1)$$

Confidence-measures as the name implies how reliable the rule is. Expressions for confidence ($X \Rightarrow Y$) represents the portion of records containing Y within those containing X.

$$C(\{X\} \rightarrow \{Y\}) = \frac{\sigma(\{X\} \rightarrow \{Y\})}{\sigma(\{X\})} \quad (2)$$

Lift helps to detect whether the product that, in the consequent, right-hand side (rhs), is because it gave the product combination that appears in the antecedent, left-hand side (lhs).

$$lift = \frac{C(\{X\} \rightarrow \{Y\})}{S(\{Y\})} = \frac{confidence\ (X \Rightarrow Y)}{sopport\ Y} \quad (3)$$

If $lift > 1$, it is equivalent to the probability of the consequent (rhs) increasing because the antecedent (lhs) happened. When $lift = 1$, it is not affected by the antecedent. And $lift < 1$, the probability of the consequent decreases due to the antecedent.

Leverange-calculates the difference between the frequency with which the products contained in a rule appear and the frequency expected if they were independent:

Table 2. Incident survey

1. The relationship of **investment in PV (A)** with respect to...is?
2. The relationship of **economic growth in enterprises (B)** with respect to ...is?
3. The relationship of **PV viability (C)** to ... is?
4. The ratio of **current cost per unit of PV (D)** to ... is?
5. The relationship to **PV usage and competitiveness (E)** relative to...is?
6. The relationship of **PV satisfaction to what you currently pay in energy (F)** relative to ... is?
7. The relationship in the use of **clean energy and image (G)** with respect to ...?
8. Ratio of **PV investment risk (H)** to ... is?
9 The relationship of **environmental care with PV (I)** with respect to ...is?
10. The relationship of **excessive electricity consumption with PV (J)** with respect to ... is?
11. The relationship of **recommending PV to companies (K)** with high electricity consumption with respect to ... is?
12. The relationship of obtaining **financing to acquire PV (L)** with respect to ... is?
13. The relationship on the **benefit of clean energy for CFE (M)** with respect to ... is?
14. The relationship in **public policies (PP) to promote competitiveness (N)** with PV with respect to ... is?
15. The relationship of **PP oriented to improve the environment with PV (O)** with respect to ...is?
16. The relationship in **PP that promote environmental economic development with PV (P)** with respect to...is?
17. The relationship of the **current mexican government gives facilities to invest in PV (Q)** with respect to...es?
18. The relationship of the **PP oriented to promote the culture of clean energy (R)** with respect to ...is?
19. The relation of **profitability with PV (S)** with respect to ... is?
20. The ratio of **energy savings with PV (T)** to ...is?
21. The ratio of **savings achieved with PV (U)** to ...is?
22. The ratio of **energy efficiency security with PV (V)** to ...is?
23. The ratio of **energy with PV is accessible to maintenance (W)** with respect to ...is?
24. The ratio of **economic-environmental sustainability (X)** with PV with respect to ...is?

A = investment in PV
B = economic growth in enterprises
C = PV viability
D = current cost per unit of PV
E = PV usage and competitiveness
F = PV satisfaction to what you currently pay in energy
G = the use of clean energy and image
H = PV investment risk
I = environmental care with PV
J = excessive electricity consumption with PV
K = recommending PV to companies
L = obtaining financing to acquire PV
M = the benefit of clean energy for CFE
N = competitiveness
O = environment with PV
P = promote environmental economic development with PV
Q = facilities to invest in PV
R = culture of clean energy
S = profitability with PV
T = energy savings with PV
U = savings achieved with PV
V = energy efficiency security with PV
W = energy with PV is accessible to maintenance
X = economic-environmental sustainability

Table 3. Fuzzification: adjustment of Likert scale values and fuzzy interval

Likert scale	1	2	3	4	5
Fuzzy Interval [-1,1]	-1	-0.5	0	0.5	1

2. Regional development is formed by items {C: PV viability, D: current cost per unit of PV}, where both items have no oscillation. Then, regional development has a positive impact on economic development.
3. Sustainability:
   - Competitiveness and Satisfaction consist of on items {E: PV usage and competitiveness, F: PV satisfaction to what you currently pay in energy}, where both items have positive cyclical oscillations. Therefore, Competitiveness and Satisfaction has a positive impact on economic development.
   - Socio-Environmental Culture consist on items {G: clean energy and image, I: environmental care, J: excessive electricity consumption, K: recommending PV to companies with high electricity consumption}, where items $\{G, I\}$ have positive cyclical oscillation $(G, I > 0)$ and $\{K\}$ have no oscillation $(K = 7.8)$, while $\{J\}$ is the critical negative item has negative cyclical oscillation $(J < 0)$, which negatively impacts on economic development.
4. Public Policies consist on items {L: obtaining financing to acquire PV, M: benefit of clean energy for CFE, N: PP to promote competitiveness, O: PP oriented to improve the environment with PV, P: PP that promote environmental economic development with PV, Q: current Mexican government gives facilities to invest in PV, R: PP oriented to promote the culture of clean energy}, where the item $\{N\}$ has positive cyclical oscillations $(N > 0)$, while $\{L, P, R\}$ has positive oscillations close to zero and negative also close to zero generating a minimal impact on economic development, while the set $\{M, O\}$ has positive cyclical oscillations and negative cyclical oscillations and $\{Q\}$ negative and positive cyclical oscillations, the latter items generating a partially negative impact on the economic development.

In summary, although PPs are not oriented towards promoting initiatives to revive the dynamic economy, let alone environmental aspects, the result shows positive values in the Economic-environment sustainability. Although it has positive cyclical oscillatory behaviour $[7, 8.9, 7]$, this is due to the uncertainty forces of the other variables that affect X developed in adaptive processes and the ways of survival of the companies (Kathleen and Jeffrey, 2000; Tylecote and Ramírez, 2004).

7. CONCLUSIONS

In general, entrepreneurs agree with energy efficiency using PV, since, on average, they have between eight and 10 pieces of equipment with consumptions higher than 800wh/day. If the average electrical costs before PV is around $12,000 for a Small Commercial Demand rate of CFE and if they have been able to decrease costs between 70 and 80%, then it can be affirmed that the

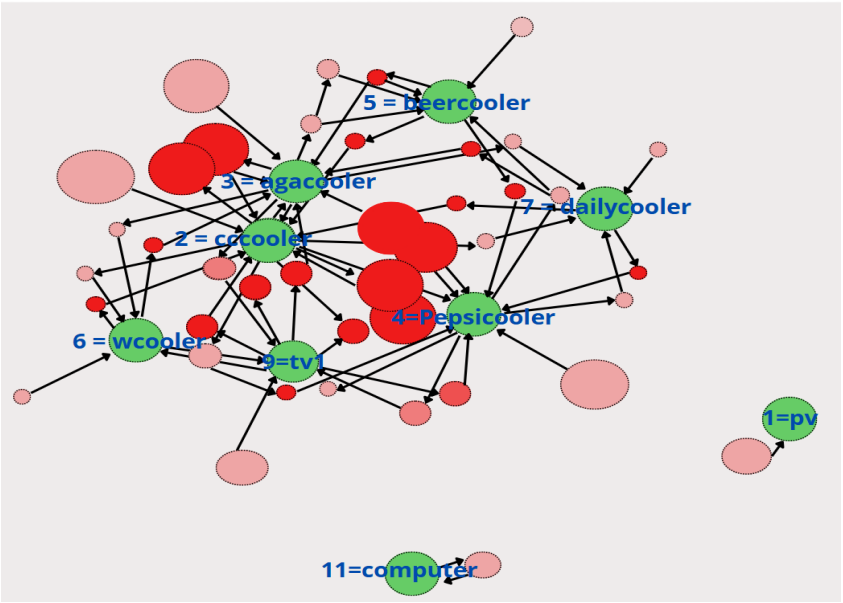

Figure 4a. Association Rules graph

Source: Development by the authors

Table 4. Association Rules[1]

Rule	{ihs}(1)	⇒	{rhs}(1)	support	confidense	leverange	shift
[86]	{2,3,4}		{7}	0.5555556	0.7608696	0.7301587	1.369565
[87]	{3,4,5}		{2}	0.5714286	1.0000000	0.5714286	1.312500
[88]	{2,3,5}		{4}	0.5714286	1.0000000	0.5714286	1.369565
[89]	{2,4,5}		{3}	0.5714286	1.0000000	0.5714286	1.369565
[90]	{2,3,4}		{5}	0.5714286	1.0000000	0.5714286	1.369565
[91]	{3,4,9}		{2}	0.6031746	1.0000000	0.6031746	1.312500
[92]	{2,3,9}		{4}	0.6031746	1.0000000	0.6031746	1.369565
[93]	{2,4,9}		{3}	0.6031746	1.0000000	0.6031746	1.369565
[94]	{2,3,4}		{9}	0.6031746	0.8260870	0.7301587	1.239130

(1) *2=cccooler, 3=agacooler, 4=pepsicooler, 5=beercooler, 7=dailycooler, 9=tv*

Source: Development by the authors

Following the general survey (Table 1), micro-enterprises with high electricity consumption equipment (HECE) have a PDBT tariff from CFE.

[1] Note: [86] is the applied rule number; {2=cccooler, 3=agacooler, 4=pepsicooler} is left-hand set (lhs) and {7=dailycooler} is right-hand set; the values 0.5555556, 0.7608696, 0.7301587 and 1.369596 are support, confidense, leverange and shift respectively.

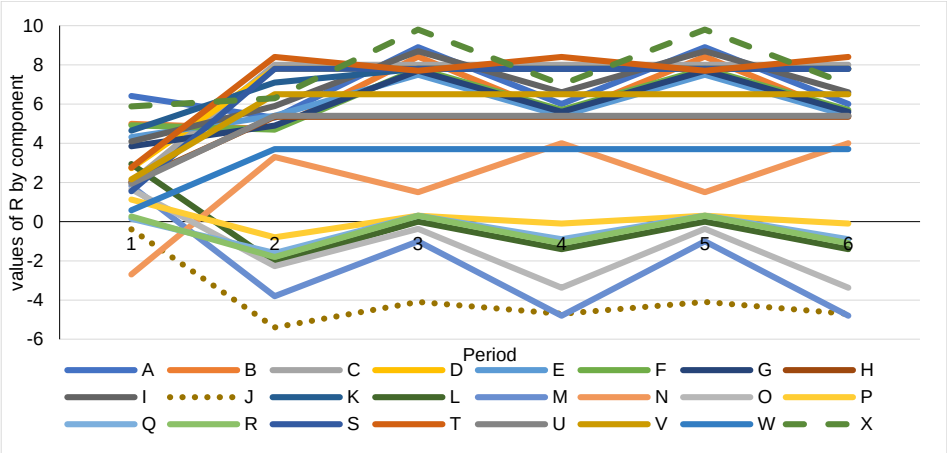

Figure 5. The oscillations of diagnostic

Source: Development by authors

Figure 5, represents the product: $R = C_{t+1}\varphi_k$, for the case study, and is the original diagnosis of the companies. In addition, four types of indicator behaviour can be identified:

i) Quickly reach stability, do not oscillate, and remain constant.

ii) Positive cyclical oscillations, those indicators that have values above zero.

iii) Negative cyclical oscillations, values below zero.

iv) Positive and negative cyclical oscillations.

Results of the four factors that impact economic-environmental sustainability in economic growth, public policies, sustainability and regional development are presented below:

1. Economic growth:

- Disposition to investment is composed by items {A: investment in PV, B: economic growth with PV, H: PV investment risk, S: profitability with PV, T: energy savings, U: savings achieved}, where the items $\{A, B, T\}$ have positive cyclical oscillations, and the set of items $\{H, S, U\}$ have no oscillations obtain rapid stability, which shows that the companies are satisfied with the implemented technology. Therefore, the willingness to invest in PV has a positive impact on environmental economic sustainability.

- Energy Efficiency comprise items {V: energy efficiency security, W: PV accessible to maintenance}, where both items have no oscillations. So, economic efficiency has a positive impact ($V, W > 0$, Table 4) on economic sustainability.

The surveyed enterprises are made up of small businesses such as: grocery stores, butcher's shops, food processing in general, stationery shops, etc. Most of them are family businesses. Throughout the different economic crises in Mexico, this type of business has had an important growth. However, this type of business has a life span of around five years INEGI (2020). We are convinced that as the fixed costs become smaller, this type of business will be able to prolong its useful life. In this sense, the cost of electricity consumption can be a factor that hinders economic development, especially in those businesses that have high energy consumption, such as grocery stores with more than six freezers or butcher shops with large cooling chambers, among others. The survey is targeted at micro-enterprises that have PV cells and those that do not (Figure 3).

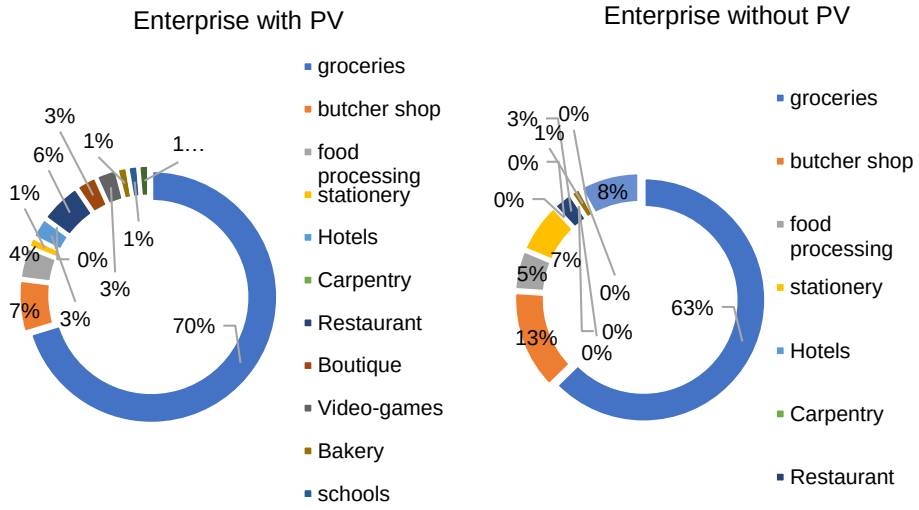

Figure 3. Micro-enterprises surveyed with PV and without PV

Source: Development by INEGI, 2020

Responses to the survey in Table 1:

1. Before PV, the electricity payments range from $6000.00 to $12000.00 for both groups.
2. All the companies have a Small Commercial Demand Tariff (PDBT) from the CFE, which is recommended according to their average energy consumption (CFE, 2020).
3. Without-PV companies have equipment with lower consumption, which may result in fewer chillers and their possible low competitiveness.
4. There is no permanent maintenance of the high-power consumption equipment in both groups.

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alternatives to help solar panel entrepreneurs in their decision making. In the National Development Plan (PND) 2019-2024, in Mexico, micro, small and medium-sized enterprises (MSMEs) generate about 70% of jobs and account for more than 50% of business income (Government of Mexico, 2019). Microenterprises are generally within the associated family with improvised actions and without well-structured business strategies. In many cases, it is due to the population's desperation to feel productive due to the lack of work (Aguilar *et al.*, 2011; Burgos, 2022). The income of the middle-class population needs to be increased to cover their basic needs. This sector of the population seeks self-employment due to the lack of sources of employment (Georgellis and Tsitsianis, 2005; Valdés and Sánchez, 2012; Ramírez *et al.*, 2013; Romero, 2022). In Michoacán, 95.6% of businesses are microenterprises, being in Region III, 94% of the total number of established economic units (Valenzo-Jiménez and González-Samaniego, 2021).

In emerging economies, the economic structure of nations contributes about 45% of jobs and 33% of the gross domestic product (Bartolacci *et al.*, 2020). According to Jiménez *et al.* (2017), in the last 25 years, the option of self-employment creating MSMEs has been increasing. Unfortunately, most of them are in informality representing 62.6%, while medium and small enterprises in formality represent 37.4%. Additionally, in small and medium enterprises (SMEs), there is apathy and distrust in the processes of change of economic stability. According to Zevallos (2003), this distrust in institutions is a generalized phenomenon in Latin America, and this is key to understanding the economic performance and competitiveness of local MSMEs. In the opposite case to the performance of industrialized countries, where institutions and economic performance have a high degree of independence. In addition, in Mexico, MSMEs do not have the best provisions for financial credits for investment since high-interest rates make investment difficult, considerably reducing competitiveness and permanence in the market. This puts in predicaments the sustainability of the companies and their productive lifespan, not having a government empathetic to society's energy problems.

Consequently, the research questions arise in the uncertainty generated by the current government with its public policies adverse to investment in clean technology. The questions arise: do current public policies affect investment in clean technologies for economic-environmental sustainability? To what extent do public policies affect the willingness to invest in PV, energy efficiency, socio-environmental culture, regional development, and competitiveness?

2. VARIABLES INVOLVED IN ECONOMIC - ENVIRONMENTAL SUSTAINABILITY

MSMEs in Mexico have their profits slightly above the break-even point, and any cost increase directly affects the financial sustainability of the business, preventing investment and competitiveness in the market. However, aware of the