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Challenges for Energy Transition in Poverty-Ridden Regions—The Case of Rural Mixteca, Mexico

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Abstract: This paper presents distinct scenario pathways and their storylines resulting from an analysis of interdependencies. We identified the main drivers of a proposed renewable energy transition in rural Mixteca-Puebla, Mexico. By analyzing the main factors involved in alleviating impoverished communities in the rural region, we show the varying degrees to which these drivers influence, support, or hinder a promising energy transition. A Cross-Impact Balance Analysis was conducted to explore the multiple inter-relationships among a set of conditions. This methodology allowed us to evaluate the relationships between social, political, cultural, and environmental variables. The main drivers were identified as clusters of several elements, in which the *uncertainties in governance* and the *legal system* trigger the inter-relationship of forces in the area. The focus of this paper is to show how the societal aspects affect the structural energy transformation and its capacity for adaptation in future trends envisioned for the area. This research contributes to the use of technological transformation as a means to alleviate poverty in a rural area. These outcomes give insights regarding the conditions to be considered, in respect to possible–encouraging, but also pessimistic pathways for the region in coming decades.

Keywords: scenario analysis; cross-impact balance; energy transition; rural areas; socio-technical system; renewable energy; transformation pathways; poverty alleviation

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1. Introduction

The imminent threat of climate change and its impact on the human habitat demands an energy system transition from fossil fuels toward renewable sources. Many countries, cities, and regions have envisioned how to become low carbon communities, but still lack a defined framework including potential unintended outcomes, e.g., new forms of property and digital knowledge [1]. The energy transition can frame the shift in a way that inadvertently downplays the profound economic, social, political, and cultural disruptions that such energy changes entail. Moreover, a sustainable energy system transition involves multiple factors besides the technological transformation [2]. Literature on sustainability transitions addresses the deployment of specific technologies [3,4], or focuses on financial aspects [5] or environmental concerns [6]. Social factors are usually taken as a constant in the analysis [7], and the complex multidisciplinary processes that sustain or hinder social features [8] are rarely analyzed. Thus, there is a need to explore energy transition processes through the shifts between the dynamics of networks, communities, and governance contexts in which the different types of actors interact [9].

While the concept of "energy transition" has a connotation related to security, efficiency and sustainability among the high-income economies [10,11], in low-income countries the "energy transition" deals with the dilemma of gaining access to affordable energy services, without becoming trapped in a fossil fuel-intensive future [12]. Low-income economies face the challenge of sustainable development to promote energy justice and equity, economic development and poverty alleviation, whilst contributing to curbing climate change [13]. A renewable energy transition in rural areas of low-income countries, where the affordability of electricity provides limited energy availability to its population, could offer an opportunity to mitigate poverty. Nevertheless, in many cases around the world, large energy projects are carried out without paying attention to the potential adverse impacts on poor people [14–16]. The provision of clean energy, as Burke [17] suggests, may also provide an improvement not only to basic services, but in job opportunities, additional sources of income, value added to renewable energy sources, and reductions in climate change impacts, among others.

Extensive research has established and measured energy transition success through its choice and promotion of a specific technology [3–5,11,12,17–21]. However, the suitable integration of societal needs has not been sufficiently considered [22]. Research on energy transitions in low-income economies has mainly been focused on choosing the appropriate (renewable) energy technology and its expansion, aiming mostly to tackle energy poverty [23]. However, access to energy does not necessarily alleviate income poverty or any other dimensions of it [24,25] when discussing low-income economies. Hence, identifying context-specific factors critical to the success of poverty alleviation research is vital. Sovacool recognized that when the energy technology system considers the societal context, renewable energy systems can be effective [20]. Recent research suggests that the energy transition should not be seen as a transfer of technologies, but rather as a transformation of the entire system [26]. Miller calls a system that delivers social value [27] and incorporates the social dynamics of diverse communities into its design a “socio-energy system” [28]. The Poor People’s Energy Outlook argues that it becomes possible to escape the vicious cycle of poverty when people living in poverty have the sustainable energy access they need to grow enterprise activities, both small and large [22]. Multiple strategies have been designed in the aim to reduce poverty: social assistance payments [29] as a temporary alleviation of vulnerability; development of synergies in value-chain sectors as agriculture [30]; and supporting income-generating activities through the access of microfinance activities [31]. However, the drawback of these programs is that although they tackle the specific dimensions of poverty for which the program has been designed, they do not reflect on cultural or any social aspects. Moreover, there is no conclusive evidence regarding an improvement in other dimensions of poverty, such as health, education, or livelihood [32].

The evaluation of future systems analysis includes scenario simulation, because this offers a systematic approach about the future. Some studies have analyzed the energy transformation through the economic lens, while other uncertainties have been set aside, i.e., political or cultural concerns [18,33]. In this sense, methods such as scenario analysis can help to deal with uncertainty in societies. Model-based scenario analyses are practical tools concerning possible alternative futures [34]. Different types of scenario techniques have been used to evaluate future developments [35], most of them based on intuitive logic. An approach that describes the context in a more systematic way through the analysis of its interdependent factors is the Cross-Impact Balance (CIB) analysis [36]. An argument in favor of CIB includes the coupling of storylines in the model as a means to improve analysis and facilitate communication among parties [37]. Storylines are the qualitative narratives that describe the main trends in socio-economic, political, technological, and environmental drivers of change and their inter-relationships [38].

Despite the importance of societal needs, a thorough understanding of how to integrate these into the technological transformation is still necessary [17]. Literature is scarce, particularly with regard to the emerging role of the paradigm shift, in which technology is not the end of the transformation [35] but the means of the transition. Frequently, energy transformation is seen primarily as a change of the required energy technologies without considering that energy systems are embedded in societal dynamics, i.e., the transformation should be understood as a socio-technical challenge [39]. The presented research considers the energy transition as the means of a major social reconfiguration to contribute to economic development and poverty alleviation in rural regions. The novelty of this research is the shift of this perspective, which is the result of an intensive discussion in the European and North American literature [40], to the challenges of a poverty-ridden region in the Global South. By taking the case of rural Mixteca, we sought to understand the energy transformation as the means to improve living conditions and pursue the alleviation of poverty. This paper explores the possibility of taking advantage of the energy transition to contribute to social and economic development in rural regions.

The overarching aims of this paper are threefold: (1) to analyze the challenges of transforming a poverty-ridden area through a renewable energy transition, considering societal aspects as variables; (2) to show a series of plausible future outcomes (scenarios) derived from the inter-relationship of impacts between the drivers of change (descriptors); and (3) to analyze the different scenario pathways and storylines resulting from these interdependencies. The focus of the paper is how societal aspects affect the structural energy transformation and its capacity of adaptation in the future trends envisioned for the area. To this end, we used scenario analysis through the Cross-Impact Balance method, because it offers accountability for future uncertainties regarding how the impact factors evolve over time. This approach integrates the analysis of the complex interactions of the political, economic, technological, and social correspondent factors of the energy system.

Section 2 of this paper introduces Mixteca and the current situation. Section 3 discusses the methodology used: Cross-Impact Balance, the descriptors obtained, and the different scenarios resulting for our case. Section 4 describes the two clusters and the two storylines behind the scenarios obtained in Section 3. Section 5 provides a discussion of the findings where the main drivers and a hypothesis of the contrasting outcomes are addressed. To conclude, some final comments are provided in Section 6.

2. Mixteca-Puebla: Characterization of the Area

The Mixteca region includes parts of the Mexican states Guerrero, Oaxaca, and Puebla. This research focuses solely on the Mixteca region in the state Puebla. Mixteca in Puebla is located in the southwest of the state (see Figure 1). The region covers an area of 11,025 km^2, representing 32.5% of the state's territory, with 45 municipalities conforming the region. Its population of 254,100 inhabitants is scattered across 472 locations, representing 4.5% of the total state population; Mixteca is essentially considered a rural region [41].

Figure 1. Location of Mixteca region in the state of Puebla, Mexico.

The landscape is arid, semi dry, and hot, with a steady temperature of 25 °C. The average solar radiation index for the whole state of Puebla is 5.5 kWh/m^2 [42], while in the Mixteca region values as high as 6.4 kWh/m^2 have been reported [43].

The main economic activities are limited to subsistence farming, goat breeding, and palm weaving.

The region is poverty-ridden. About 79% of the population lives below the income poverty line [44]. Furthermore, they are deprived in at least one of the social dimensions which constitute the multidimensional concept of poverty [24,45]. These social dimensions are income, education, health services, social security, food, housing and quality space, basic services, social cohesion, and accessibility to paved roads [46]. About 30% of the population under the income poverty line live under extreme poverty conditions. Their income is below the cost of the basic food basket (extreme income poverty line) and is accompanied by three or more social deprivations. A chart showing the trend in poverty and vulnerability over the past decade is presented in Figure 2.

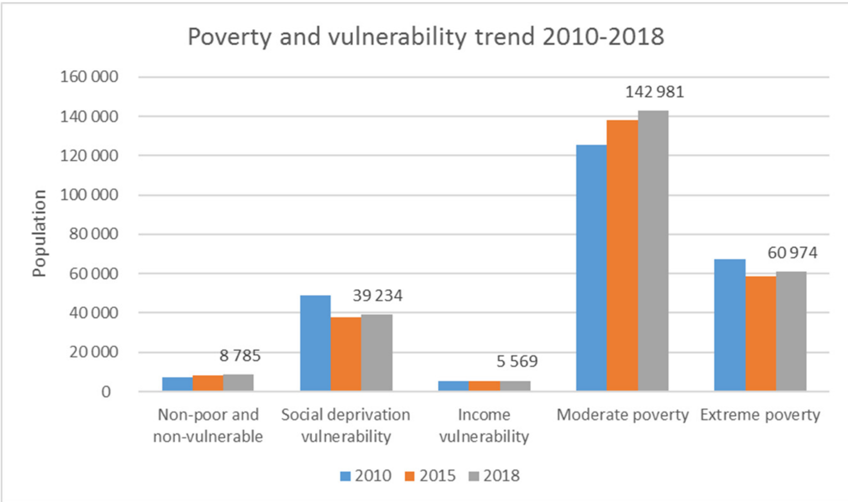

Figure 2. Poverty and vulnerability trend in Mixteca-Puebla state; authors own calculations based on data from [44].

Characteristics of the poverty in Mixteca are highly relevant to structural deficiencies related to the precariousness of housing, its materials, and lack of basic services. Basic services refers to basic sanitation—to which 77% of the population has access, water supply near to their homes 76%, and electricity access 93% [47]. Only 54% of the inhabitants are covered by all three basic services. In addition to the low access to basic infrastructure, the quality of the provided services is meagre. The water service quality is under intermittent conditions; electricity, currently supplied through fossil fuel generation, is delivered under a poor technical and commercial efficiency [48], which makes it unviable to use for productive purposes. Lack of access to electricity is acknowledged as a sign of marginalization and vulnerability [24,49].

The lack or inadequate provision of basic services, in particular of energy, has a major impact on women, who are typically responsible for collecting and managing traditional sources of fuel(biomass). Additionally, because most men, husbands and brothers, emigrate, women are becoming in charge of households and communities, partly impeding the required empowerment of women. Alleviating time spent on activities that could be avoided with modern technology could relieve the burden and women could engage in more productive activities.

Mexico's education system is relatively weak, despite significant public investment in the sector. Children in Mixteca face unequal education opportunities, and the quality of education services that reach these communities remains low. Consequently, the average level of education in the area is less than 6 years. The vast majority of schools lack facilities such as laboratories, libraries, or sport areas; more strikingly, they lack basic services. Figures for Mixteca are not available, but those for the entire state of Puebla show that 18.5% of public schools do not have toilet facilities, 28.2% do not have electricity, and 27.8% do not have running water [50]. Given the deprived conditions of Mixteca, the percentages for the area should be higher, because 80% of the community primary schools are located in populations with a high or very high degree of marginalization [51].

Mixteca inhabitants have emigrated over several decades in search of work and a source of secure income. The preferred destination is north, mainly the United States, where growing demand for unskilled labor, mainly in agriculture, started a trend several decades ago. Mixteca emigrants are more likely to be males of working age, from 18 to 64 years old, which is the reason why the proportion of women living in Mixteca is on average 20% higher than men; reaching 25% in the range from 25 to 30 years old. The share of females under 18 years old is 49% [52]. Emigrants usually leave women behind who then become responsible for household and community decisions; therefore, women can gain a non-intended partial empowerment.

As a result of emigration, remittances are an important income source, manifesting a high degree of economic dependence not only for families, but also for the whole of rural Mixteca. Remittances have increased over the past years, providing support for private consumption, particularly of low-income families (Figure 3). In 2018, Mixteca contributed 13% of the total received remittances in the state of Puebla, although only 4.5% of the entire population of the state lives in Mixteca. Remittances predominantly are used as part of an income generation strategy for households rather than to stimulate a reduction in labor supply. The typical role of emigrants is capital delivery to their communities of origin.

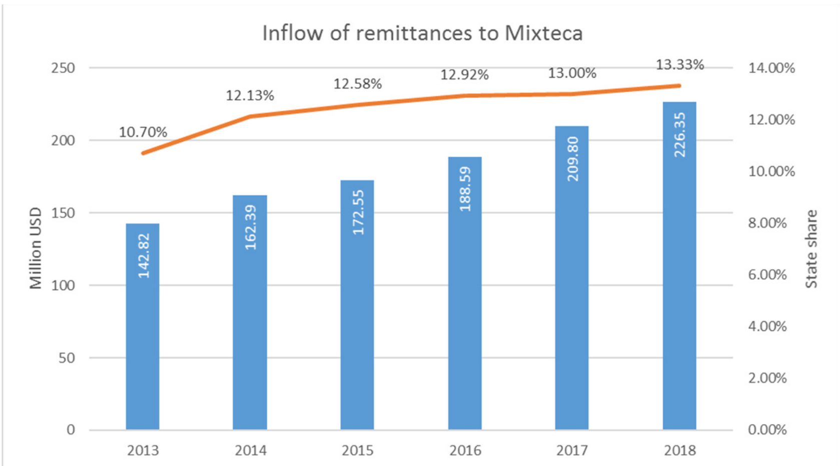

Figure 3. Inflow of remittances to Mixteca and share of state participation, authors own calculations based on data from [53].

According to the Organisation for Economic Co-operation and Development (OECD) data, Mexico has the lowest financial inclusion among its members [54]; only one-third of the population has access to a savings account in the country, not to mention credit. According to estimates, only 6% of the population in Mixteca has knowledge or access to financial services [55]. The lack of financial education in rural areas is another aspect to consider, because people still believe that they do not need to learn to manage their limited budgets [56]. Thus, inhabitants tend to favor informal ways of financing, because community financial societies, cooperative loan societies, and popular financial societies lack rigorous standards. Moreover, there are no official banking institutions in the area, except for one bank located in the most developed community.

The weak rule of law is present in Mixteca. For example, electoral manipulation and vote-buying are ubiquitous, in exchange for future benefits such as federal social programs. One in two people in Mexico was offered a bribe for their vote, and one in four was threatened with retaliation [57]. The issue is exacerbated in Mixteca by factors such as the population's financial dependence and the association with low levels of schooling [58], which are well-known and widespread. In transgressions related to corruption, impunity reached 98% [59]; simple acts such as requests for public services, among other interactions with the government, are actions that involve corruption and which are also experienced among the poorest communities [60].

As mentioned above, the region shows a high solar radiation, and thus good conditions for solar power plants. However, currently, the Mexican state has decided to support fossil fuel infrastructure at the expense of current and future renewable energy investment [61,62]. This includes the construction of a new oil refinery and a new budget allocation to the modernization of coal, diesel, gas, and oil-fueled power plants. The decision to favor fossil fuel generation over renewable energy now positions Mexico on a path that hinders renewable energy generation, risking projects under development. This decision, limiting Mixteca's future plans on supporting renewable energy projects, could restrict its future development of clean energy [63].

3. Methodology: Cross-Impact Balance Analysis

The overall idea of the Cross-Impact Balance (CIB) analysis is to generate plausible context energy scenarios; in our case, of the energy system in rural Mixteca, which address not only techno-economic variables, but also societal non-quantitative variables, such as culture, politics, or the environment (i.e., the overall socio-economic, political, cultural, and environmental context in which energy systems are embedded) [36].

The selected CIB approach offers useful advantages for our purposes. Its qualitative orientation with respect to judgments and evaluation procedures meets the typology of data we face in this research; it balances logic with a theoretical basis of the system. The approach has been successfully applied in diverse and multiple research fields such as waste [64], water [65], politics [66], education [67], health [68], mobility and transport [69], and energy [70] among others; for further comparisons, please refer to Weimer-Jehle [71].

The CIB approach is implemented in four steps [34,37]:

(1) Defining the context. A selection of descriptors, which characterize the energy system of Mixteca, needed to be defined and understood as a socio-technical system. The selected descriptors represent social and cultural aspects, i.e., on emigration, ethnic identification, education, community organization, and women's empowerment, and political features, such as governance and uncertainties, policies, and the legal system. Furthermore, economic facets consisting of income, wealth distribution, and financial markets are addressed. Environmental factors such as climate change and its impacts on the population are also included under the model input data (Table 1).

This was achieved through interviews with fourteen experts in Mixteca and in three other Federal States of Mexico, as well as through a literature search. The experts had solid experience in rural development, sociology, energy research, technology assessment and policy, and the panel was formed by members of recognized affiliations such as CONACYT (Consejo Nacional de Ciencia y Tecnología—Mexican Council of Science and Technology), Mexican scientific thematic networks, Non-Governmental Organisations (NGOs) with a local presence in Mixteca (seven persons), and governmental institution members (five persons). In addition, five communities in Mixteca were visited, where nineteen families were interviewed. The detailed definition of each descriptor and its states can be found under the Supplementary Material, Table S1: Descriptors and states.

(2) Identifying the future system-states. To address possible trends and uncertainties, a set of two to four alternative future states were defined and assigned to each descriptor. These future states were selected through the group of experts involved. The selected descriptors and their alternative futures for the region under review are summarized in Table 1.

(3) Identifying the interdependencies and building up the cross-impact matrix (CIM). The inter-relationships between descriptors were valued using an integer, ranging, in our case, from −3 to +3, with −3 indicating a strong trade-off relationship, whereas +3 indicated a strong supporting relationship. The quantification of the interdependencies was performed with the assistance of the experts. An example of this evaluation is shown in Figure 4.

The outcome of the quantification of all interdependencies between system states is a CIM, which is shown in Appendix A, Figure A1.

(4) Identification and analysis of the scenarios. Using ScenarioWizard v4.31 (it can be downloaded from: www.cross-impact.org), consistent combinations of descriptor-states were identified. Each consistent combination of all descriptors described a scenario (Figure 5). The scenarios were analyzed to identify relevant driving forces and the political, societal, economic, and technological conditions of possible future developments (see Section 4).

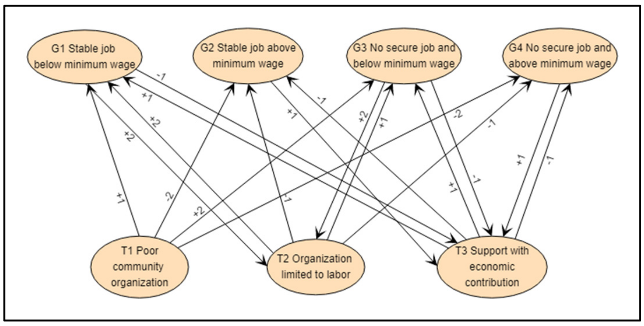

Figure 4. Exemplary network inter-relationship between two descriptors and its states. It shows the influence (promotes: + or hinders: − and its degree (here: −2 . . . 2). Descriptor G can exert influence on descriptor T (active), and at the same time descriptor G can be influenced by descriptor T (passive).

Table 1. Descriptors and states.

Descriptor	State 1	State 2	State 3	State 4
A. Emigration	A1 Return emigration	A2 Permanent emigration with bond	A3 Permanent emigration without bond	
B. Ethnic identification	B1 Low ethnic identification	B2 High ethnic identification	B3 Pluricultural	
C. Education	C1 Less than 5 years	C2 From 5 to 9 years	C3 More than 9 years	
D. Source of income	D1 Labor	D2 Remittances	D3 Remittances plus labor	
E. Basic services access (water, electricity, drainage)	E1 No access to any service	E2 Partial access to services including water	E3 Partial access to services including electricity	E4 Access to all services
F. Population acceptance of renewable energy plans and participation	F1 Poor community organization	F2 Limited to labor	F3 Support includes economic contribution	
G. Job and earning	G1 Stable job and min. or below min. wage	G2 Stable job above minimum wage	G3 No secure job and below minimum wage	G4 No secure job and above minimum wage
H. Governance uncertainties	H1 Low uncertainties	H2 Strong uncertainties with growth	H3 Strong uncertainties without growth	
I. Governmental policies for integrated energy system	I1 Restrictive policies on new energy systems	I2 Supportive policies on new energy systems		
J. Investments on energy research	J1 Low investment or none	J2 High level of investment		
M. Cooperation between government, private investors, NGOs	M1 Inexistent or low	M2 Existent or good	M3 Excellent	
N. Added Value creation from the renewable energy sector	N1 Inexistent or very low	N2 Existent or good		

Table 1. *Cont.*

Descriptor	State 1	State 2	State 3	State 4
O. Financial market in rural economy	O1 Limited access to formal financial market	O2 Access to informal financial market	O3 No access to formal or informal market	
P. Legal System	P1 Law enforcement	P2 Aggravate	P3 Not effectively enforced	
Q. Climate change	Q1 High impact	Q2 Low impact		
R. Environmental effects on population	R1 High impact	R2 Low impact		
S. Women's empowerment	S1 Limited or no empowerment	S2 Full attained	S3 Partial	
T. Community organization	T1 Poor community organization	T2 Limited to labor	T3 Support includes economic contribution	

<table>
<tr><th>Scenario No. 1</th><th>Scenario No. 2</th><th>Scenario No. 3</th><th>Scenario No. 5</th><th>Scenario No. 4</th><th>Scenario No. 6</th><th>Scenario No. 7</th><th>Scenario No. 8</th></tr>
<tr><td>A. Emigration:
A2 Perm w/bond</td><td colspan="3">A. Emigration:
A3 Permanent emigration without bond</td><td colspan="4">A. Emigration:
A1 Return emigration</td></tr>
<tr><td>B. Ethnic identity:
B2 High</td><td colspan="3">B. Ethnic identity:
B3 Pluricultural</td><td colspan="4">B. Ethnic identity:
B2 High ethnic identification</td></tr>
<tr><td colspan="4">C. Education:
C1 Less than 5 years</td><td colspan="4">C. Education:
C2 From 5 to 9 years</td></tr>
<tr><td colspan="2">D. Source income:
D2 Remittances</td><td colspan="2">D. Source income:
D3 Remittances plus labor</td><td colspan="4">D. Source income:
D1 Labor</td></tr>
<tr><td colspan="4">E. Basic services access (water, electricity, drainage):
E1 No access to any service</td><td colspan="3">E. Basic Services:
E3 Partial access to services including electricity</td><td>E. Basic Services:
E4 All</td></tr>
<tr><td colspan="4" rowspan="2">F. Population acceptance of renw energy plans and participation:
F2 Limited to labor</td><td colspan="4">F. Population acceptance of renw energy plans and participation:</td></tr>
<tr><td>F3 Econ.contrib.</td><td>F2 Ltd to labor</td><td colspan="2">F3 Economic contribution</td></tr>
<tr><td colspan="4">G. Job and earning:
G3 No secure job and below minimum wage</td><td colspan="4">G. Job and earning:
G2 Stable job above minimum wage</td></tr>
<tr><td colspan="4">H. Governance uncertainties:
H3 Strong uncertainties without growth</td><td colspan="4">H. Governance uncertainties:
H1 Low uncertainties</td></tr>
<tr><td colspan="4">I. Governmental policies for integrated energy system:
I1 Restrictive policies on new energy systems</td><td colspan="4">I. Governmental policies for integrated energy system:
I2 Supportive policies on new energy systems</td></tr>
<tr><td colspan="4">J. Investments on energy research:
J1 Low investment or none</td><td colspan="4">J. Investments on energy research:
J2 High level of investment</td></tr>
<tr><td colspan="4">M. Cooperation between government, private investors, NGOs :
M1 Inexistent or low</td><td colspan="4">M. Cooperation between government, private investors, NGOs :
M3 Excellent</td></tr>
<tr><td colspan="4">N. Added Value creation from the renewable energy sector:
N1 Inexistent or very low</td><td colspan="4">N. Added Value creation from the renewable energy sector:
N2 Existent or good</td></tr>
<tr><td colspan="3">O. Financial market in rural economy:
O3 No access to formal or informal market</td><td colspan="5">O. Financial market in rural economy:
O2 Access to informal financial market</td></tr>
<tr><td colspan="4">P. Legal System:
P2 Aggravate</td><td colspan="4">P. Legal System:
P1 Law enforcement</td></tr>
<tr><td colspan="4">Q. Climate change:
Q1 High impact</td><td colspan="4">Q. Climate change:
Q2 Low impact</td></tr>
<tr><td colspan="4">R. Environmental effects on population:
R1 High impact</td><td colspan="4">R. Environmental effects on population:
R2 Low impact</td></tr>
<tr><td colspan="3">S. Women's empowerment:
S1 Limited or no empowerment</td><td>S. Women empow:
S3 Partial</td><td>S. Women empow:
S2 Full attained</td><td colspan="2">S. Women's empowerment:
S3 Partial</td><td>S. Women empow:
S2 Full attained</td></tr>
<tr><td colspan="7">T. Community organization:
T2 Limited to labor</td><td>T. Comm. organiz:
T3 Econ.contrib.</td></tr>
</table>

Figure 5. Consistent scenarios identified via CIB.

4. Storylines

4.1. Driving Forces

In order to select the role of the descriptors in our system, an evaluation of their impacts is a helpful way to consider the driving forces. Once we plotted all impact values, whether active (y-coordinate) or passive (x-coordinate), in a chart, we obtained the system grid shown in Figure 6. Active sum accounts for the number of descriptors, which are influenced by another descriptor. Passive sum shows the number of descriptors, which affect another selected descriptor. A high active sum and a comparable low passive sum indicates a driving force; in Figure 6, they are situated at the top-left of the chart. Descriptors with a low active but high passive sum are those which are more reactive to changes of the system than actively influencing it. They are mostly situated in the lower-left part of the chart. A third category represents those descriptors with no large discrepancies between active and passive sum; they influence a considerable part of the system under review, but they are also very much influenced by other descriptors. Weimer-Jehle refers to this type of descriptors as usually connected with the potential emergence of complex system behavior [71].

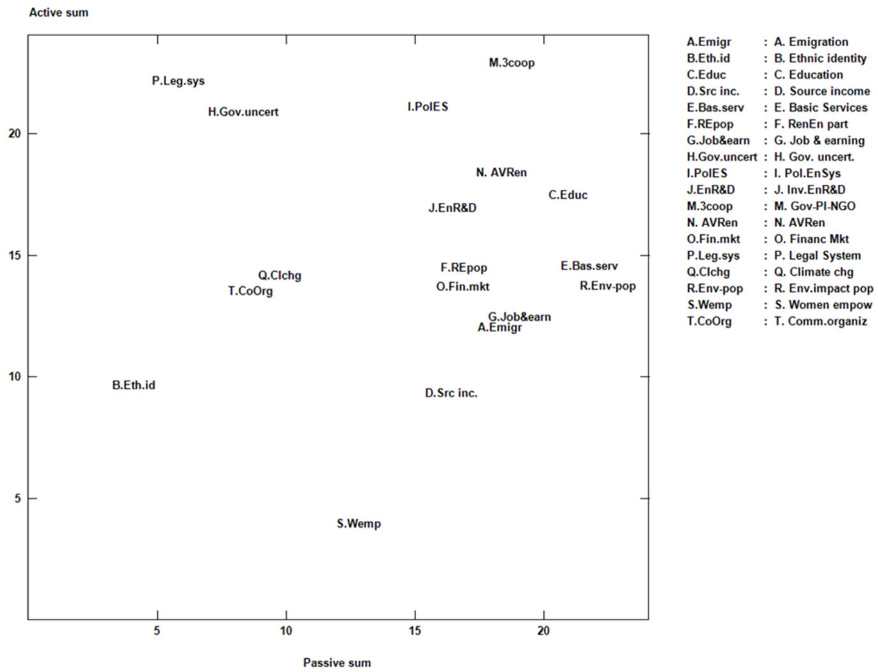

Figure 6. Active–passive positions of the descriptors.

Considering this structuring of the descriptors, the main driving forces are *P. Legal system* and *H. Governance uncertainties*, which exert more control than those at the right or bottom. In addition, as a third driving force, we identified *Q. Climate change*. This last descriptor has a special position in the system because, on the one hand, it is influenced by the behavior of the system; on the other hand, the development of the descriptor is also determined by factors outside of the system under review.

Highly connected descriptors are M. Cooperation between government, private investors, NGOs; I. Governmental policies for integrated energy system; N. Added Value creation from the renewable energy sector; C. Education; and J. Investments on energy research.

The rest of the descriptors show generally rather low active sums, but comparable high passive sums. The tight inter-relationship among all the descriptors is an intricate web, as shown in Figure 7, depicting the general complexity of the system under review. The following Sections 4.3–4.5 present an in-depth analysis of this complexity.

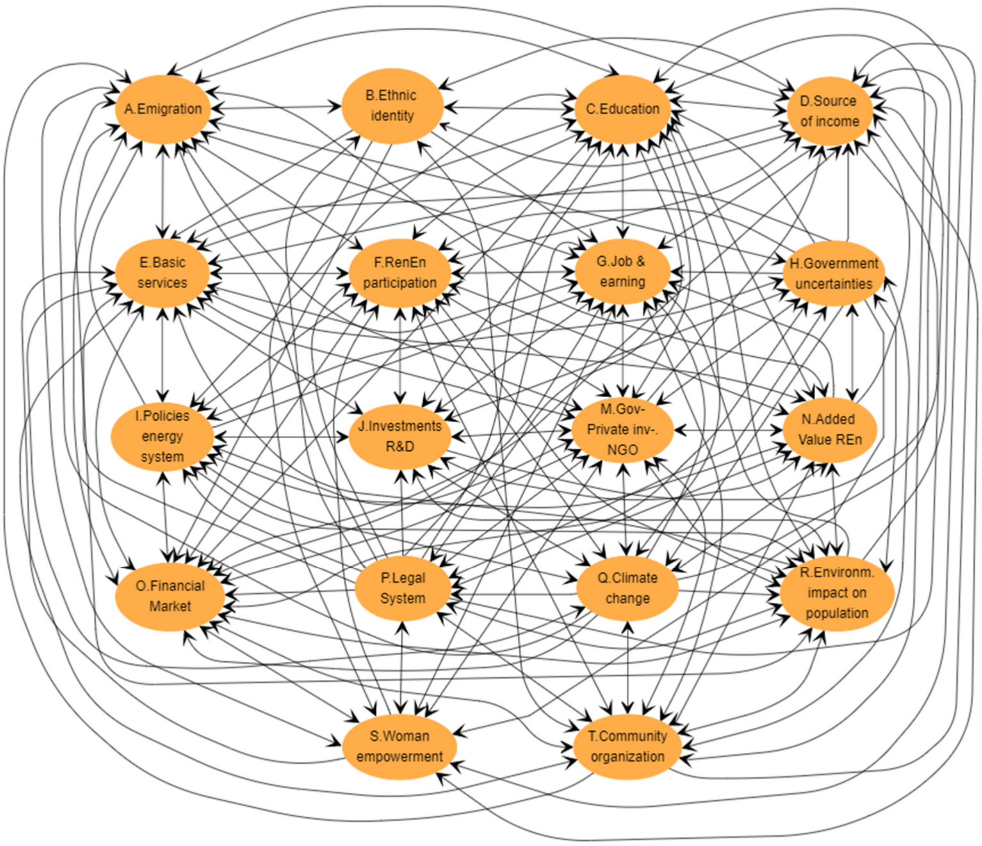

Figure 7. Interdependencies among descriptors. The arrows indicate the direction of the influences.

4.2. Characterization of Clusters

As mentioned above, a total of eight consistent scenarios were identified (Figure 5). These eight scenarios have been arranged into two clusters, because they shape very different outcomes/future developments.

The synopsis under cluster 1 consists of scenarios 1, 2, 3 and 5, whose storyline "Back to the XIX century" explores the worsening of social, economic, and political conditions in Mixteca. The cluster describes a situation which is characterized by an aggravated legal system with a strong uncertainty regarding governance and no economic growth perspectives. Additionally, the region is highly affected by climate change. The combination of these driving forces depresses the economic situation of the population, reducing the incentives to invest in education and decent jobs in the region, and promotes emigration as unskilled workers. A lack of access to formal financial markets also hinders investment in decent jobs. The bad economic situation also impedes investment in basic services, further deteriorating living standards and the prospects of remaining in the region. With respect to the energy system, the traditional orientation of the energy policies prevails, thus discouraging investments in renewable energy sources, as well as in the participation of civil society.

These conditions are comparable to those experienced by past generations during the early 19th century, where the country started its transition as an independent society, characterized by widespread poverty and lack of opportunities in rural areas.

Synopsis 2 consists of the cluster of scenarios 4, 6, 7 and 8, whose storyline "Hope for a better future" contrasts with synopsis 1. It envisions a future with an improvement of social, economic, and political conditions, where the low uncertainties in governance combined with law enforcement in the legal system provide an improved framework, with stable sources of employment and income generation in the region. The support of renewable energy policies for the energy transition increases the potential of investment in these projects, not only from cooperation with entities outside the region, but from the population itself, who will be supportive and willing to self-finance its projects, aiming for self-sufficiency in the energy supply. Therefore, contrasting with synopsis 1, the self-generation of jobs and income within the communities will be a milestone aspired for and achieved, thus avoiding emigration, improving the chance of education, and increasing the possibility of lower impacts from climate change with lower impact on the population. Hence, a likely improvement in the quality of life would reduce poverty in the hope for a better future.

The overall appreciation is that cluster 1 differs from cluster 2 in a divergent pathway; the main drivers such as legal system and governance uncertainties produce opposite outcomes that lead to either hindering or promoting appropriate development conditions in the area.

4.3. Cluster 1, Synopsis: "Back to the XIX Century"

Synopsis 1 is characterized by the aggravation of the legal system, whose ineffective judicial system (descriptor P) will affect the region. Corruption and impunity will undermine the rule of law, a situation comparable to the status quo in Mixteca. Using Mexican data, because specific data for Mixteca are not available, on a scale of 0 (high corruption) to 100 (no corruption), Mexico achieves just 29, i.e., it ranks 130 out of 198 analyzed countries [72]. In the context of rampant corruption, impunity and the weak rule of law, the security crisis, and the aggravation of the legal system (state P2), development in Mixteca will be a tough challenge. Another dominant driver in this synopsis is the strong uncertainty in governance (descriptor H). Conflicting policies, programs, and communication between national and regional levels will contribute to increased uncertainties. Insufficient state capacities, both geographically and across policy sectors, will presumably undermine the effective and coherent implementation of policies. As a result, the energy sector will be exposed to hazards; the transition from a fossil fuel economy to the use of renewable energy sources is a tough future under synopsis 1. The future under this scenario challenges economic growth, affecting the weak economy in Mixteca.

The worsening of the legal system, combined with strong governance uncertainties, would exert a powerful negative influence on adopting local policies to support renewable energy systems in the region (descriptor I). It will reverse the renewable path the country had envisioned and to which they had committed in 2012, significantly hindering the integration of local renewable energy projects and restricting its future development (state I1). Therefore, scarce investment in research into renewable and clean energy will be the future trend, and Mixteca will not be able to profit (descriptor J). Under these circumstances, investments in research and development of renewable energy will not be a priority (state J1); on the contrary, Mixteca will depend on fossil fuels in future.

Due to the stagnation of renewable energy policies, the future value added of solar energy (descriptor N) will be not considered (state N1) under this future trend. Notwithstanding the high radiation levels in the region, the lack of support for renewable energy policies would provide unequal conditions to add value with clean energy projects. This situation would lead to low interest and participation from the population (descriptor F), limited to providing a work force (state F2) in the rural area to contribute to renewable energy aspects. Thus, societal and economic conditions could inhibit the technological transition in the territory.

Prioritizing fossil fuels will also undermine the cooperation (descriptor M) between government, private investors, and NGOs on renewable energy projects, discouraging investments due to the meager value added (state M1). The decision to favor fossil fuel generation over renewable energy will also put Mixteca on a path that is even more inconsistent with mitigation measures to avoid strong impacts of climate change. Under the conditions shown in synopsis 1, Mixteca will be highly vulnerable to the impacts of climate change (state Q1), in the form of more extreme weather patterns such as rising temperature, heat waves, unusual rain seasons, and acute and longer droughts [73], which will unavoidably aggravate existing social and economic inequalities.

These adverse conditions from climate change will severely affect the low productivity from agricultural jobs, tending livestock, hauling water and processing agricultural products. It will also promote a high impact on population (descriptor R, state R1) who would seek to leave the area, mainly outside of the country, as a way to overcome the intensified poverty in Mixteca. Under these circumstances, the trend G3 "no secure job and below minimum wage" is a consequential outcome. The uneven distribution of income is highlighted in low-skilled and rural Mixteca, which is one of the affected regions with a history of unequal job opportunities [45].

Due to the scarcity of resources and opportunities to make a living, rural Mixteca will experience persistent inequity in education under our synopsis 1. The marginalized population will have no choice but to give up on education and devote their time to seeking an income to sustain themselves, or to emigrate. As a result, the level of schooling under synopsis 1 is expected to be low, under five years (state C1), which is not enough to complete basic education.

Migratory flows will be a pressing issue reflecting the lack of economic growth, and thus, low prospects for decent jobs. However, cluster 1 allows for two different situations: emigrants will either have a strong bond to their region (state A2; scenario 1) or not (state A3, scenarios 2, 3 and 5). The latter describes the current situation, where there is a strong partial dependence of remittances in the region. Even with no bond to Mixteca, remittances will be an important income source in the region. However, the relevance differs between scenarios 1 and 2, and 3 and 5. The first two scenarios, 1 and 2, see financial transfers as the main income source (state D2); the other two scenarios, 3 and 5, show a combination of remittances with labor income to compensate the minimum wage and support domestic consumption (state D3). The dependence on the remittances is also a reflection of low job earnings (state G3) in the region.

The region will also have higher percentages of deprivation in terms of access to basic services (state E1) such as water, electricity, and drainage that encompass the fulfillment of their social rights. This outcome is also a consequence of the lack of an adequate level of education, which prevents the inhabitants from having the knowledge to exert their rights of access to the basic services coverage.

Given the worsening conditions in the area, formal financial services will be not provided, because the security demands for loans by the formal sectors are too high for the local population, and thus the establishment of a formal banking sector is not profitable. The population may have access to informal financial markets (state O2; scenario 5) or no access to any financial markets (state O3; scenarios 1–3). This depends on the economic situation in the region, which could differ between the scenarios.

The depressed economic and social situation with (mainly male) emigrants leaves no (State S1; scenarios 1–3) or limited human and financial resources (State S3; scenario 5) to empower women, although the necessity is obvious. Women are more likely to be engaged in low-productivity activities and work in the informal sector or in unpaid family jobs, and less likely to move to the formal sector compared to men; therefore, empowerment among women will be highly limited. Scenario 5 in this cluster is the only one which envisions a partial empowerment and women's participation in decision-making processes (state S3), probably related to an attempt to move to a higher level of full empowerment.

In synopsis 1, most scenarios are inclined to the pluricultural identity (state B3) obtained through the interaction of two or more communities inside the national territory, or outside of it as a consequence of the migratory flow [74]. The pluricultural identity is also promoted by the interaction of communities in the vicinity during the early years of children's education. Only one scenario, scenario 1, reflects the high ethnic identification bond that permeates through returning emigrants, as well as through those who keep a permanent bond with their ethnicity (state B2). This sense of belonging to an ethnic group promotes community support, mostly on the labor force. Ethnic identity is very much linked to emigration patterns, but it also maintains a relationship with income sources; while the pluricultural status in two scenarios (3 and 5) generates income from remittances and labor, the other two scenarios depend mostly on remittances due to meager job opportunities and low earnings.

In summary, cluster 1 envisions a path of increased poverty, lack of opportunity for development, persistent emigration, and a society's lack of hope regarding its own future. An energy transition is expected to bring neither success nor better quality of life in Mixteca under this synopsis.

4.4. Cluster 2, Synopsis: "Hope for a Better Future"

A future with low uncertainty regarding governance (state H1) describes a situation in which the government will have developed the capacity to exert effective and efficient decisions, ensuring a proper and informed process as well as stakeholder involvement, hence decreasing the risk of uncertainty among the population. Policies will be open and transparently handled, offering the communities in Mixteca an understanding of the local decisions taken. It will also maintain their focus and address issues in an effort to avoid stagnation and provide certainty regarding the local government commitments, regardless of political administration change. Therefore, low uncertainty (state H1) about future government decisions and potential for economic growth would lead the way to a better future in the region.

A priority of the government will be to eradicate or diminish corruption through an enforced legal system (state P1). To accomplish this objective, on all governmental scales, authorities will address effective transparency and accountability procedures to reach a convincing law enforcement.

In this cluster of scenarios, the energy transition plays a structural role compared to cluster 1, in achieving Mixteca region's potential. To make use of the principally good conditions of high irradiation levels for installing photovoltaic systems (PVs), the energy policy will provide a system of supportive schemes, such as allowing clean energy preferred access to the national grid, subsidizing investments of PV infrastructure, guaranteeing selling prices, capacity building regarding the generation, controlling, maintaining, and marketing of renewable energy, and reinstating energy auctions (state I2). The encouraging legal and economic conditions promote the investment in PVs, leading to lower energy costs and better availability of electricity. Its generation capacity will be more competitive than gas and coal by a significant margin, which will increase its attractiveness as energy storage solutions become prevalent. The good conditions will attract two types of investors with different aims. The primary aim of one type of investor is to provide affordable electricity to the industry clusters in Puebla states and beyond, with less interest in supplying to the region. With the transition of the Mexican economy and a globally shrinking oil demand for Mexican crude oil [75], the new solar-harvesting alternative would provide support as an alternative source of revenue. The second group of investors are locals. Due to trust in the government and good general economic conditions, the inhabitants will start to invest in PVs, with the aim of improving their own supply of electricity, and potentially the competitiveness of their local industry. Supply to nearby communities with larger populations will be possible, although not in the focus of these investors. The momentum of the second group of investors depends largely on the acceptance of the population regarding renewable energy plans and participation (descriptor F). This ranges from a willingness to contribute economically (state F3) to providing "only" labor support (state F2). The good conditions will also lead to a high level of investment in renewable energy development (state J2).

The development of the electricity system will be accompanied by a positive value added (state N2). Due to the high radiation levels combined with a supportive economic environment, investments in PV technology will provide value added to the region, which will impact positively on innovation efforts or education [76]. A high share of the investors are local; therefore, the value added will stay in the region, fostering local economic growth [77].

The regional energy system in Mixteca would most likely exert a positive contribution on the national and global effort to mitigate climate change (state Q2). The magnitude could lead to a noteworthy decline in greenhouse gas emissions (GHG) beyond the national target of 25% that studies forecast for 2030 [78,79]. Nevertheless, the situation of the climate in the region will be dominated by efforts outside the region. Consequently, the environmental influence is expected to be handled without greater impact on the population (state R2), and the communities will be better prepared to implement mitigation measures, such as adaptations in agricultural practices, or the construction of houses in secured areas away from riverbanks or cliffs.

The positive impacts of the transformation on the region will also promote considerable partnerships between private investors, government, and NGOs, who would support development projects in renewable transition (state M3).

The broad positive economic circumstances, fueled by the energy transformation, will affect the labor markets, i.e., decent jobs with wage rates above the minimum (state G2). This would lead to an increasing relevance of labor income to total income, through which purchasing power is promoted over time; better working conditions will be provided along with stable jobs (state D1). Under better working conditions, it is likely that emigrants will decide to stay in the region, or even return from abroad (state A1). For some of them, working outside the country has provided the capital and skills to start small businesses, reflected in higher rates of self-employment upon their return to Mexico, compared to those with no migration history. Better working conditions in Mexico would bring an opportunity where emigrants do not return to the United States, reincorporating them into the economically active population. This development enforces the relevance of labor income as the main income source.

With a higher and more reliable income, investments in schooling and infrastructure will gain importance. A longer schooling time (state C2) will not only mean building a skilled workforce, but also training future generations in raising awareness of sustainable development, as well as changing the population's attitudes in everyday life. In particular, investments in PVs by local investors will increase the availability of electricity, which will also be used for productive purposes, in contrast to the current situation in Mixteca. According to the statistics [47], most of rural Mixteca is connected to the grid, but availability for productive uses is rather limited. This will be accompanied by more investment in other basic infrastructures, because the financial situation of the communities, as well as the organization of the communities, is improving. However, it is only in scenario 8 that all basic services are available (state E4), and the population is willing and able to support community building with financial resources (state T3). In scenarios 4, 6 and 7, the access to infrastructure is limited (state E3), and the contribution of the inhabitants to community building focuses on labor (state T2). The difference between both types of participation could lie in the degree of income. As long as the population is able to satisfy its basic needs, people will likely provide financing for the area.

Despite the positive economic situation, this will not overturn the impediments to accessing formal financial markets; informal organized credit suppliers will dominate the local financial market. The financial market in Mixteca will still be based on informal banking (state O2). Unlike cluster 1, where loans were mainly used to cover very basic needs, in cluster 2, a switch in the application of the loans to more productive uses to improve the standard of living is likely. Savings will be used to buy assets: farm animals, land, or build an additional room or an improvement to an existing part of the house, such as the roof or a wall. Financial inclusion will remain a challenge for rural communities in the future.

The strong commitment of women and the creation of women-to-women networks along the value chain and decision-making process are vital for the integration of Mixteca's new energy technology at the community level, and ensuring the long-term use of these technologies [80]. These findings reflect women's essential roles as decision-makers, not only in the household but also in their communities. Women use their social network of relatives and friends to introduce products into their communities; thus, they have become trusted advisors, as with household energy. This empowerment reveals the need to involve women in energy projects and the need to incorporate gender into policies on energy transition [80–82]. Although empowerment is foreseen in all scenarios of this cluster, the intensity differs between scenarios 4 and 8, and scenarios 6 and 7. Scenarios 6 and 7 see a partial empowerment (state S3); scenarios 4 and 8 a full achievement (state S2).

All four scenarios of cluster 2 present a future with high ethnic identity (state B2). Ethnicity will be an important quality of the future communities in Mixteca. Returning emigrants will have a sense of belonging to their communities of origin through it. Community organization is inter-related through labor, which, in turn, is promoted by the ethnic bond of the community itself.

In summary, cluster 2 envisions a path of a higher degree of economic development and better quality of life in Mixteca, because of a renewable energy transition. A sense of prosperity in the area derived from stable jobs and earnings, as well as a perception of security regarding the energy transformation, leads to the construction of a better and sustainable future. However, of the derived scenarios, scenario 8 differs from the other scenarios, in particular regarding basic services, women's empowerment, and community organization.

4.5. Comparative Summary

Both clusters show rather divergent developments, and thus distinct future situations. The reason lies in the different state of the main drivers, i.e., those with a large active or otherwise relevant position, and those which are highly interwoven. The main drivers are *P. Legal system* (P2 vs. P1), *H. Governance uncertainties* (H3 vs. H1), and *Q. Climate change* (Q1 vs. Q2). The highly interwoven descriptors are *I. Governmental policies for integrated energy system* (I1 vs. I2), *N. Added Value creation from the renewable energy sector* (N1 vs. N2), *C. Education* (C1 vs. C2), *J. Investments in energy research* (J1 vs. J2), and *M. Cooperation between government, private investors, NGOs* (M1 vs. M3).

The clear separation between both clusters is partly broken up by five of the descriptor-states, which overlap both clusters. These relate to the descriptors *B. Ethnic identification* (state B2), *F. Population acceptance of renewable energy plans and participation* (state F2), *O. Financial market in rural economy* (state O2), *S. Women's empowerment* (state S3), and *T. Community organization* (state T2). However, these descriptors show passive positions in the system or low active positions (Figure 6). Their impacts on development do not exert a compelling influence; rather, they mostly receive the effects from the other descriptors. The changes to these passive descriptors may not necessarily reflect a change in the trend; the change is reflected within the cluster but stays under the same pathway.

5. Discussion

The divergent patterns of both clusters indicate the complexity required to set the transformation process of the region in motion—in both directions. A combination of multiple (relevant) descriptors is necessary for change. The picture may be explained through the concept of transformability brought by Walker et al. [83], as one of the attributes of social–ecological systems (SESs). Walker states that a new system will be established when ecological, economic, political, or social conditions make the existing system implausible. Societal groups may find themselves trapped in an undesirable situation or development process, i.e., in a "basin of attraction", which is wide and deep. Small movements into a new configuration within the same basin are possible, but the outcome of the reconfiguration is not seen by the society as an improvement. An improvement which leads to a new basin would require a large reconfiguration of the descriptors, which would define a new system with new states. Assuming, for the sake of argument, the situation described by cluster

1 as the starting point of an undesirable situation. Only a complete change of the most relevant descriptors would lead to the situation of cluster 2.

Some SESs persist in states where the society cannot meet the basic needs of human well-being or when the societal, environmental, and political factors are degraded to an imminent loss of well-being; Folke refers to them as "dysfunctional states" [84]. In our case, Mixteca seems to move from a current poverty situation to a worsening state in cluster 1, where extreme poverty has persisted for extended periods. These systems may lack the adaptive capacity to reorganize. To escape from the poverty trap, Folke suggests financial and/or political support, external supporting organizations (NGOs), and local developments of innovation. These supporting components are present in cluster 2 in the following states: *G2 stable job above minimum wage*, *H1 low uncertainties in governance*, *I2 supportive policies on new energy systems, M3 excellent cooperation between government, private investors and NGOs, P1 law enforcement*; hence, the future of this cluster seems to alleviate poverty. As Folke points out [84], transformational change involves shifts in perception and meaning, societal network configurations, patterns of interactions among different actors, power relations—not only political—and organizational and institutional arrangements. Transformations make use of crises as windows of opportunity and navigate societal transition from a regime in one stability landscape to another. Transformation involves novelty and innovation [85]. It is this window of opportunity of which Folke speaks, in which the energy transformation, as our results suggest for Mixteca, could serve as the means of a major social reconfiguration [19] to improve well-being in the area [17].

Although Walker's concept is used for a static view of possible futures, principally, the concept of basins of attraction could also be useful to explain possible developments of states over time within each cluster, i.e., to derive possible trajectories. A trajectory would describe possible switches from one state to another, and in the longer term to a possible final state. For example, with an improving economic situation over time, the opportunities to participate in installing a local community-based energy system—descriptor *F. Population acceptance of renewable energy plans and participation*—could change. As long the economic situation is comparably bad, interested inhabitants would participate by offering their labor skills (state F2; scenario 6). If the income situation is enhanced, the inhabitants will provide financial resources (state F3; scenarios 4, 7–8). Such perturbations could occur continuously, thus leading to different complex trajectories. However, because the system evolves over time, the system could shift from the domain of influence of one basin of attraction to another, until it reaches a stable landscape [85].

The present study focused on the situation in Mixteca. Thus, an unconditional transfer of the findings to other region is not recommendable, because the social–cultural–economic setting, as well as the climatic conditions, could be different, potentially influencing the findings. However, the presented approach should provide insights as to which descriptors could be relevant for scrutinizing comparable regions, i.e., poverty-ridden areas.

In the center of the analysis was the modelling of the inter-relationship between the descriptor-states, which was based on extended literature research and experts' judgements. The perceptions and knowledge of the experts had some impact on the construction of the Cross-Impact Matrix, and thus on the modelled driving forces of the system. This challenge of potentially, but unintended or even not detected, biased findings is inherent in the CIB method. To reduce the relevance of this challenge the CIB approach builds on the widely accepted criteria for scenario-building, fulfilling plausibility, consistency, traceability, and transparency [7].

6. Conclusions

The transition from fossil fuel-driven energy systems to renewables-based systems brings a suitable opportunity not only for migrating technologies per se, but to reposition political and social dynamics through the configuration of the socio-technical system. New technology implementation as a driver of the creative destruction of old regimes, as pointed out by Geels [19], is necessary to create opportunities for the more widespread dissemination of renewable systems. This new perspective would bring the opportunity to better understand how to enhance the potential for a successful transition by including civil society in the initiatives of transformation, using social interactions in the new configuration. This perspective should also include the analysis of weaknesses and inter-relationships among the actors of the previous regime, which contribute to retaining it as a dominant actor. The shift to the new model of innovation promotes social interaction in the energy system, despite resistance to adopting and disseminating the new and promising configuration. The adoption of this model could be useful in the attempt to establish the pathway to energy transition as the means to alleviate poverty in rural Mixteca. The restructuring of the energy system could provide the opportunity to a just transition among sectors and institutions.

To achieve the transition, small-scale technological innovations should be available for those rural communities where consumers could become producers with their own power installations [86]. This could foster the development of a social network related to energy, from the individual to the community level [87,88]. The potential of the effectiveness and impacts of these motivations in the creation of a sustainable local energy community could lead to de-carbonization, decreasing emigration, self-employment [89], and self-sufficiency of energy supply [88], creating a sustainable environment in the area and a promising energy transition, while attempting to instill less invasive power dynamics among actors.

The presented study emphasizes the relevance of analyzing the societal aspects affecting and being impacted in order to understand a renewable transition. This analysis is required to anticipate outcomes and adapt to undesirable consequences, as shown in cluster 1, by exploring possibilities to advance a desired just transformation to the benefit of the population, as reflected in cluster 2, with the aim of improving living conditions in Mixteca.

The use of the Cross-Impact Balance methodology proved useful in foreseeing several plausible scenarios and conditions under which an energy system in rural Mixteca could be developed. The outcomes of qualitative impacts, such as social, political, cultural, and environmental aspects, helped unfold the probable future storylines of the area. This approach seeks to introduce the contextual elements that make actors reshape their actions to promote a specific path. Our perspective highlights that pertaining actors' engagement in the practical context of the energy transition should be focused on systemic change [19,90]. The change is no longer questioned; rather, the overall direction of such change, as seen from the distinct results presented above.

Through the analysis of the main drivers, it was possible to envisage the relationships among the contextual conditions, and how each of the descriptors influences the multiple reciprocal interactions. The main drivers call for continuous change and adaptation; systematic transition and evaluation can help reflect on how deliberate actions interact in the societal transition dynamics [90]. These reflections, focused on dynamics and processes, can help re-orient interventions and identify new opportunities. CIB has also proved to be an operational tool to foresee the influence and direction of a renewable transition, and how socio-technical arrangements could be simulated. New pathways embodied in new practices or new technology can be envisioned, concretized by the specific conditions in Mixteca. This way, societal embedding in the energy transition and adoption of a new technology can be predicted.

This case has proven useful to show that the identified societal drivers allow the technological transformation to be triggered which, under suitable conditions, could improve living standards and decrease poverty in rural Mixteca. A challenge for the rural area is societal adaptability to the variable contextual conditions, and to the interdisciplinary exchange on the path to a transition. A critical reflexive evaluation of the outcome from the scenario evaluation could bridge the gap between transition dynamics and policies in the developing context. Providing energy access to alleviate poverty is more about understanding the roles that energy can play in the population's daily activities and supporting them to improve their well-being, rather than a shift of technology. If the transition can be kept open and remain focused on the goal of poverty alleviation, the innovation capacity could contribute to the societal upgrade. This is an opportunity to make a shift in rural communities.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/en14092596/s1, Table S1: Descriptors and states.

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Appendix A

	A.Emigr			B.Eth.id			C.Educ			D.Src inc.			E.Bas.serv				F.REpop			G.Job&earn				H.Gov.unce			I.PolES		J.EnR&D		M.3coop			N.AVRe		O.Fin.mkt			P.Leg.sys			Q.Clchg		R.Env-pop		S.Wemp			T.CoOrg		
	A1retmig	A2permw/b	A3permw/o	B1low	B2high	B3pluri	C1< 5yrs	C2-5-9	C3>9yrs	D1labour	D2remitt	D3lab+rem	E1none	E2prt-wtr	E3prt-elect	E4all	F1noself	F2wk	F3fin.res	G1stbel.min	G2stabv.min	G3nosec-bel	G4nosec+ab	H1low	H2strw/grw	H3strw/out	I1(-)	I2(+)	J1low	J2high	M1low	M2+	M3++	N1no	N2yes	O1ltd.form	O2acc.inf.	O3none	P1law enf.	P2aggrav	P3current	Q1high	Q2low	R1high	R2low	S1no	S2full	S3part	T1noself	T2wk	T3fin.res
A. Emigration																																																			
A1 return emigration				-1	2	2	-1	1	-1	1	-1	-1	0	0	0	0	0	1	1	1	1	1	1	-1	1	1	0	0	0	0	-1	1	1	1	-1	1	2	0	0	0	0	0	0	0	1	-1	1	1	0	0	0
A2 perm w/bond				-1	2	1	2	2	-2	0	2	2	-2	1	1	1	0	-1	2	1	-1	1	-1	-1	1	1	0	0	0	0	1	-1	-1	1	-1	0	1	0	0	0	0	0	0	-1	1	-2	2	1	0	0	0
A3 perm w/o bond				2	-1	2	-1	1	-2	0	-1	-1	0	0	0	0	0	-1	-1	1	-1	1	-1	-1	1	1	0	0	0	0	1	-1	-1	1	-1	0	0	0	0	0	0	0	0	-1	1	-2	2	2	0	0	0
B. Ethnic identity																																																			
B1 low	1	1	2				-1	1	1	1	1	1	-1	2	2	1	0	0	0	-1	1	-1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	0	0	0	0	0	0	0	1	0	-1	2	-2	0
B2 high	1	-1	-2				1	1	-1	2	-1	-1	1	1	1	-1	0	0	0	2	-2	1	-2	0	0	0	0	0	0	0	0	0	0	0	0	-2	-1	2	0	0	0	0	0	0	0	-2	0	2	-2	2	0
B3 pluricultural	2	1	2				-1	2	1	1	2	2	-1	1	1	2	0	0	0	-1	2	-1	2	0	0	0	0	0	0	0	0	0	0	0	0	1	1	-1	0	0	0	0	0	0	0	-1	0	1	-1	1	0
C. Education																																																			
C1 less than 5 years	1	2	2	0	0	0				1	2	1	2	1	1	-1	0	1	-1	2	-2	2	-1	0	0	0	1	-1	1	-1	0	0	0	2	-2	-3	0	2	-2	2	0	2	0	2	-2	1	-1	-1	0	0	0
C2 from 5 to 9 years	2	1	1	0	0	1				1	1	1	-1	2	2	0	0	1	1	1	0	1	0	0	0	0	1	-1	0	0	-1	1	2	-2	2	0	2	-2	1	0	1	0	0	-1	1	-1	-1	1	0	0	0
C3 more than 9 years	-1	2	2	2	-1	2				2	0	0	0	2	2	2	0	2	2	-1	2	-1	1	0	0	0	-1	1	-2	2	0	0	0	-3	3	2	2	-2	2	-2	0	0	0	-2	2	-1	2	1	-1	0	1
D. Source income																																																			
D1 labour	2	-1	1	-1	2	0	1	1	-3				-1	1	2	1	0	1	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	-2	0	0	0	0	0	0	0	-2	2	1	0	0	0
D2 remittances	1	2	2	0	0	1	1	1	-2				-1	1	2	1	0	1	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2	-2	0	0	0	0	0	0	0	-1	-1	1	0	0	0
D3 remittances+labour	1	-1	1	0	0	1	1	1	-1				-1	1	2	2	0	2	2	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	2	-2	0	0	0	0	0	0	0	-1	1	1	0	0	0
E. Basic services access (water, electricity, drainage)																																																			
E1 none	1	2	2	0	0	0	2	-1	-2	-2	0	0					0	1	-2	1	-1	2	-1	0	0	0	-2	2	-1	1	-1	1	1	-2	2	-3	-2	3	0	0	0	0	0	-1	1	-1	0	1	-2	2	0
E2 partial w/water	1	1	1	0	0	0	1	-1	-1	1	0	0					0	1	1	1	-1	1	-1	0	0	0	-2	2	-1	1	-1	1	1	-2	2	-1	1	-1	0	0	0	0	0	2	-2	0	0	0	-2	2	0
E3 partial w/electricity	1	1	1	0	0	0	1	1	-1	2	0	0					0	1	1	1	-1	1	-1	0	0	0	-2	2	-1	1	-1	1	1	-2	2	-1	1	-1	0	0	0	0	0	0	0	0	0	0	-2	2	0
E4 all services	-1	-1	-1	0	0	0	-2	2	1	2	0	0					0	0	2	-1	2	-1	2	0	0	0	1	-1	1	-1	1	-1	-1	1	-1	1	2	-2	0	0	0	1	0	1	-1	0	0	0	0	1	1
F. Population acceptance of renewable energy plans and participation																																																			
F1 poor participation	0	0	0	0	0	0	0	0	0	0	0	0	2	1	1	-2				0	0	0	0	0	0	0	0	0	0	0	2	-1	-2	2	-2	-1	-1	1	0	0	0	1	-1	3	-3	0	0	0	1	-1	-1
F2 limited to labour	-1	-1	-1	0	0	0	-1	1	2	1	-1	-1	-1	1	1	1				1	1	-1	1	0	0	0	-1	1	-1	1	-1	1	1	-2	2	0	1	-1	0	0	0	-1	1	-1	1	0	0	0	-1	1	0
F3 economic contribution	1	1	0	0	0	0	-1	2	1	1	1	1	-2	2	2	2				1	1	-1	1	0	0	0	-2	2	-2	2	-2	2	2	-2	2	1	1	-1	0	0	0	-1	1	-2	2	0	0	0	-1	0	1
G. Job & earnings																																																			
G1 stab job belw min	1	2	2	0	0	0	1	2	-1	2	2	2	1	1	1	-1	0	2	-2					0	0	0	0	0	-1	1	-1	1	1	0	0	-2	1	-1	0	0	0	0	0	0	0	2	-2	-2	0	2	-1
G2 stab job ab.min	-2	-2	-2	0	0	0	-1	2	2	2	-1	0	-1	1	1	1	0	1	1					0	0	0	0	0	0	0	1	-1	-1	0	0	2	1	-1	0	0	0	0	0	0	0	-2	2	1	0	0	1
G3 no sec.job&belw	3	3	3	0	0	0	2	-2	-3	0	2	2	2	-1	-1	-2	0	1	-2					0	0	0	0	0	-1	1	-1	1	1	0	0	-2	-1	2	0	0	0	0	0	0	0	2	-2	-2	0	2	-1
G4 no sec.job abv min	-1	2	2	0	0	0	1	2	-1	2	-2	0	-1	1	1	1	0	1	1					0	0	0	0	0	0	0	1	-1	-1	0	0	-1	1	-1	0	0	0	0	0	0	0	-1	2	1	0	0	1
H. Governance uncertainties																																																			
H1 low uncertainties	-1	-1	-1	0	0	0	-2	2	1	2	1	1	-1	1	1	1	-1	1	1	2	2	-1	1				-2	2	-1	1	-2	1	2	-2	2	1	1	-2	2	-2	1	0	0	-1	1	0	0	0	0	0	0
H2 strong uncert.w/grw	-1	1	1	0	0	0	-1	2	2	1	0	0	-1	1	2	1	1	1	-1	1	1	1	2				-1	1	1	-1	1	-1	-1	1	-1	-1	2	-1	1	-1	1	1	-1	1	-1	-2	2	2	-1	1	1
H3 strong unc. w/o grw	2	1	1	0	0	0	2	-1	-2	-2	2	2	1	-1	-1	-2	2	1	-2	-1	-2	2	-2				2	-2	2	-2	2	-1	-2	2	-2	-2	-1	2	-2	2	1	1	-1	2	-2	-2	2	2	-1	1	-1
I. Governmental policies for integrated energy system																																																			
I1 restrictive	1	2	2	0	0	0	1	2	-2	-1	0	0	2	-1	-1	-1	1	-1	-1	1	-1	1	-1	-2	1	1			3	-3	1	-1	-1	2	-2	-1	1	-1	0	0	0	2	-2	3	-3	0	0	0	0	0	0
I2 supportive	-1	-2	-2	0	0	0	-2	2	2	2	0	0	-2	2	2	2	-1	1	1	-1	1	-1	1	2	1	-1			-3	3	-1	1	1	-2	2	1	1	-2	0	0	0	-2	2	-3	3	0	0	0	0	0	0
J. Investments in energy research																																																			
J1 low invest. or none	0	0	0	0	0	0	1	1	-2	-1	1	1	2	1	1	-2	1	-1	-2	1	-1	1	-1	-1	0	-1	1	-1			2	-1	-2	2	-2	0	0	0	0	0	0	2	-2	3	-3	0	0	0	0	0	0
J2 high investment	0	0	0	0	0	0	-2	1	2	1	-2	0	-2	1	1	2	-1	1	2	-1	2	-1	1	1	-1	-1	-1	1			-2	1	2	-2	2	0	0	0	0	0	0	-2	2	-3	3	0	0	0	0	0	0
M. Cooperation between government, private investors, NGOs																																																			
M1 no/low	1	1	1	0	0	0	1	1	-1	-1	1	1	2	-1	-1	-2	2	-1	-1	1	-1	2	-1	-1	1	1	2	-2	2	-2				2	-2	-1	2	-1	-2	2	1	1	-1	2	-2	2	-2	-1	0	0	0
M2 good	-1	-1	-1	0	0	0	-1	1	1	1	-1	-1	-1	1	1	1	-1	1	1	-1	1	-1	1	1	1	-1	-2	2	-2	2				-1	1	1	1	-1	1	-1	-1	-1	1	-1	1	-1	1	1	-1	1	0
M3 excellent	-2	-2	-2	0	0	0	-2	2	2	2	-2	-1	-2	1	1	2	-2	1	2	-1	2	-2	1	2	1	-2	-3	3	-3	3				-2	2	2	-1	-2	2	-2	-1	-2	2	-2	2	-1	2	1	-1	0	1
N. Added Value creation from the renewable energy sector																																																			
N1 no/low	0	0	0	0	0	0	0	0	0	-1	0	0	1	-2	-2	-2	2	-2	-2	1	-1	1	-1	-1	0	0	2	-3	3	-3	2	-1	-2			0	0	0	0	0	0	1	-1	2	-2	0	0	0	0	0	0
N2 yes/good	-1	-1	-1	0	0	0	-2	2	2	2	0	0	-2	2	2	2	-2	2	2	-1	2	-1	1	1	0	0	-3	3	-3	3	-2	1	2			0	0	0	1	0	0	-1	1	-2	2	0	0	0	-1	1	1
O. Financial market in rural economy																																																			
O1 ltd access to formal	-1	-1	-1	0	0	0	0	1	-1	1	2	2	-1	1	1	1	1	1	1	1	1	-1	1	1	0	-1	-2	2	0	0	2	1	2	0	0				0	0	0	0	0	-1	1	-2	2	2	-1	0	1
O2 access to informal	0	0	0	0	0	0	1	1	-1	2	1	2	-1	1	1	-1	1	1	1	1	-1	1	-1	0	1	1	0	0	0	0	2	1	-1	0	0				0	0	0	0	0	0	0	-2	2	2	-1	1	1
O3 no access to any	1	2	2	0	0	0	2	1	-2	2	2	2	2	-1	-1	-1	-1	2	-2	1	-2	1	-1	0	0	0	1	-1	0	0	1	-1	-2	0	0				0	0	0	0	0	1	-1	2	-2	-2	-1	1	-2
P. Legal System																																																			
P1 law enforcement	-2	-1	-1	0	0	0	2	3	1	2	-1	-1	-2	2	2	2	-1	1	1	1	2	-2	2	2	-1	-2	-1	1	-1	1	-1	2	3	-2	2	2	1	-2				0	0	-2	2	-2	2	1	0	0	0
P2 aggravate	2	2	2	2	-1	0	3	2	-3	1	2	2	2	1	1	-2	1	1	-1	2	-3	3	-1	-2	-1	2	1	-1	2	-2	3	-2	-3	2	-2	-2	2	2				0	0	1	-1	2	-2	-1	-1	2	-1
P3 not effectively enforced	1	1	1	0	0	0	1	2	-2	1	1	2	1	1	2	-1	0	1	-1	1	-2	2	-1	-1	1	2	1	-1	1	-1	2	-1	-1	1	-1	-1	1	0				0	0	1	-1	1	-1	-1	-1	1	-1
Q. Climate change																																																			
Q1 high impact	1	2	2	0	0	0	1	1	1	2	0	0	2	2	2	-2	-2	2	1	1	-1	2	-2	0	0	0	-2	2	-2	2	-1	1	1	-2	2	-1	1	-1	-1	1	1			3	-3	0	0	0	-1	1	1
Q2 low impact	0	0	0	0	0	0	0	0	0	0	0	0	-1	1	1	1	0	0	0	-1	1	-2	2	0	0	0	0	0	0	0	2	-1	-1	0	0	0	0	0	0	0	0			-3	3	0	0	0	0	0	0
R. Environmental effects on population																																																			
R1 high impact	1	2	2	0	0	0	1	-1	-1	2	0	1	2	1	1	-2	-2	2	-1	0	0	2	-2	0	-1	1	-2	2	-2	2	-2	1	2	-2	2	-2	-1	2	-1	1	1	0	0			0	0	0	-2	2	-1
R2 low impact	0	0	0	0	0	0	-1	1	1	-2	0	-1	-2	-1	-1	2	1	-1	-1	0	1	0	1	1	0	-1	0	0	0	0	2	-1	-1	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0
S. Women's empowerment																																																			
S1 limited or none	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	-1	2	0	0	0	0	0	0	0				0	0	0
S2 full attained	-1	-1	0	0	0	0	-1	0	1	2	0	0	0	0	0	2	0	0	2	0	0	1	1	0	0	0	0	0	0	0	-1	1	2	0	0	1	2	-2	1	-1	-1	0	0	0	0				0	0	0
S3 partial	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	-1	1	1	0	0	1	1	-1	0	0	0	0	0	0	0				0	0	0
T. Community organization																																																			
T1 poor organization	1	1	1	2	-2	1	1	-1	0	-1	1	1	2	-1	-1	-2	2	-1	-1	1	-2	2	-2	-1	-1	1	0	0	0	0	2	-1	-1	0	0	0	0	0	0	0	0	2	-2	2	-2	0	0	0			
T2 limited to labour	-1	-1	-1	-1	2	1	-1	2	0	2	-1	-1	-1	1	1	0	-1	2	-1	2	-1	1	-1	1	1	-1	0	0	0	0	-1	1	1	0	0	0	0	0	0	0	0	-1	1	0	0	0	0	0			
T3 economic contribution	-2	-2	-2	0	0	0	-1	2	0	1	1	1	-2	2	2	2	-1	0	1	1	-1	1	-1	1	1	-1	0	0	0	0	-1	1	1	-1	1	0	1	-1	1	-1	-1	-1	1	-1	1	0	0	0			

Figure A1. Cross-Impact Matrix (CIM).

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