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**Authors**
Itzel Osorio
Aubin Dronsart
Alexa Preinfalk
Sebastián Arcos
Erika Ortiz
Marco Jano

**Coordination**
Anda David

# Analysis of the Social Impacts and Vulnerabilities Linked to the Just Dimension of an Energy Transition in Mexico's Power Sector

IDEA Instituto de Desarrollo Energía y Ambiente
ICM Iniciativa Climática de México
Union Européenne
ÉDITIONS AFD AGENCE FRANÇAISE DE DÉVELOPPEMENT

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**Itzel Osorio**
**Aubin Dronsart**
**Alexa Preinfalk**
**Sebastián Arcos**
**Erika Ortiz**
**Marco Jano**
Instituto de Desarrollo, Energía y Ambiente (IDEA)

**Abstract**

Mexico's just energy transition (JET) requires addressing both decarbonization and deep social inequalities. This study analyzes four high-impact measures: the retirement of fossil-fuel plants, the expansion of large-scale solar and wind, and residential distributed generation. From 80 proposed strategies, four were selected using multicriteria analysis. Methods included a literature review, construction of a state-level vulnerability index (exposure, sensitivity, adaptive capacity), and 18 expert interviews across government, academia, civil society, and international institutions. Results show heterogeneous vulnerabilities: Guerrero is highly exposed to fossil plant retirement; Puebla's high indigenous population heightens risks from solar expansion; Tamaulipas, Coahuila, and Nuevo León face medium vulnerability in wind; while Sonora and Sinaloa are especially sensitive to residential distributed generation. Policy recommendations emphasize labor reconversion and unemployment insurance, fair land-use compensation and community energy cooperatives, environmental safeguards for panel and battery disposal, and gender-sensitive health and training programs. Together, these measures anchor governance, equity, and sustainability in Mexico's energy transition.

**Keywords:**
Just Energy Transition, Vulnerability, Energy, Equity, Mexico

**JEL codes:**
Q42, Q56

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**Résumé**

La transition énergétique juste (TEJ) du Mexique exige de relever simultanément les défis de la décarbonation et des profondes inégalités sociales. Cette étude analyse quatre mesures à fort impact : le retrait des centrales fossiles, l'expansion de la capacité solaire et éolienne à grande échelle, ainsi que la génération distribuée résidentielle. Parmi 80 stratégies proposées, quatre ont été retenues à l'aide d'une analyse multicritère. La méthodologie combine une revue de la littérature, la construction d'un indice de vulnérabilité au niveau des États (exposition, sensibilité, capacité adaptative) et 18 entretiens avec des experts issus du gouvernement, du monde académique, de la société civile et d'institutions internationales. Les résultats révèlent des vulnérabilités hétérogènes : le Guerrero est particulièrement exposé au retrait des centrales fossiles ; la forte population autochtone de Puebla accroît les risques liés à l'expansion solaire ; le Tamaulipas, le Coahuila et le Nuevo León présentent une vulnérabilité moyenne pour l'éolien ; tandis que Sonora et Sinaloa sont particulièrement sensibles à la génération distribuée résidentielle. Les recommandations portent sur la reconversion professionnelle et l'assurance chômage, une compensation équitable de l'usage des terres et les coopératives énergétiques communautaires, des garanties environnementales pour l'élimination des panneaux et batteries, ainsi que des programmes de santé et de formation sensibles au genre. Ensemble, ces mesures fondent la gouvernance, l'équité et la durabilité de la transition énergétique au Mexique.

**Mots-clés :**
Transition énergétique juste, Vulnérabilité, Énergie, Équité, Mexique

# 1 Introduction

Climate change alters productive, social, and natural systems, affecting the livelihoods of communities and aggravating the situation of poverty and inequality (Intergovernmental Panel on Climate Change (IPCC), 2023). Mexico ranks thirteenth among the main greenhouse gas emitters globally (Climate Watch, n.d.). According to the National Inventory of Greenhouse Gas and Compound Emissions, in Mexico in 2022 a total of 777 $MtCO_2e$ were emitted. The sectors that contribute most to this figure are transportation, electricity generation, and agriculture and livestock, with 191.6 MtCO2e, 136.3 $MtCO_2e$, and 139.1 MtCO2e, respectively (INECC, 2024).

Likewise, Mexico is one of the 194 countries that signed the Paris Agreement in 2016, a binding international treaty on climate change. The Agreement seeks to establish a commitment to reduce emissions and to create a relationship of collaboration among the parties, with the aim of promoting adaptation to climate change and increasing mitigation commitments over the years. Therefore, it is expected that every five years, the countries submit an updated national climate action plan, known as the Nationally Determined Contribution (NDC, for its acronym in English), in which the actions that will be promoted to achieve the climate goals are described (United Nations, n.d.). Within this framework, the Energy Transition, understood as the structural change of energy production and consumption systems toward renewable and sustainable sources, is crucial for the fulfillment of these objectives.

Now then, for this energy transformation to be sustainable and socially legitimate, it must be undertaken under the approach of a Just Energy Transition (JET). This is not limited to the substitution of fossil sources with renewables, but rather constitutes a broader process that integrates social and environmental justice, as well as the active participation of communities. This change also requires guaranteeing inclusion and social equity at the local and national level, through spaces that allow the population to define development alternatives in accordance with their needs and specific cultural and social characteristics. In this sense, the JET seeks to ensure that the energy transformation benefits all sectors of society, including workers and regions traditionally dependent on the fossil industry.

In line with this approach, the current administration in Mexico has placed the energy transition as a strategic priority, integrating the perspective of energy justice in its national plans and policies. Under this approach, various announcements, plans, and strategies promoted since the arrival to power of the administration of Claudia Sheinbaum stand out.

At the strategic level, from the National Development Plan (NDP 2025–2030) objectives related to the energy transition are set out, the same that are taken up in other planning instruments. For example, in the National Strategy for the Electricity Sector, published in November 2024, an increase is proposed in the participation of clean energies for electricity generation to

38%, maintaining the stewardship of the Mexican State with a participation of 54% in the annual average of the energy injected into the grid (Article 12 of the Electricity System Law). This is added to the fact that in the NDP, it is indicated that "Energy Justice" must become a pillar of national development, which implies expanding coverage and access to energy in marginalized communities, ensuring that all regions of the country have sources of clean and sustainable energies (Presidency of the Republic, 2025b). In that sense, two priority programs stand out that attempt to materialize the notion of energy justice in the territories. On the one hand, the project "Sol del Norte" was promoted to install 5,500 photovoltaic panels in Mexicali, Baja California with the objective of bringing electricity to homes that do not have it (1.1 million people in 2023 according to INEGI). In parallel, the program "Efficient Firewood Stoves for Well-being" (Presidency of the Republic, 2024) is being promoted, which focuses on the 28 million users of firewood for cooking in Mexico (according to CONAHCYT).

At the normative level, the new Law of Planning and Energy Transition (LPTE) is published, derived from the Energy Reform of 2024, which becomes the reference for the other norms on the issues of ET. In this law, the introduction of the concept of Energy Justice in Mexican legislation is formalized, which is defined as the "Actions or Strategies aimed at reducing Energy Poverty, social and gender inequalities in the use of energy, and promoting regional development and shared prosperity through access to reliable, affordable, safe, and clean energy and energy infrastructure for the satisfaction of basic needs, the reduction of impacts on health and the environment. It also includes the expansion of spaces for inclusive participation, principally of Indigenous peoples, in the local productive chains of energy projects" (Law of Planning and Energy Transition, 2025). It should be mentioned that the Energy Reform also expands the scope of the funds dedicated to fighting energy poverty, modifies the coordination of the energy sector, and fosters private investment with the objective of establishing a clearer and more favorable regulatory framework to drive the acceleration of the ET.

Finally, at the operational level, derived from the Energy Reform, five instruments were established for a "binding planning" of the energy sector and that seek the strengthening of the ET. The five instruments are: the National Energy Balance, the National Strategy of Energy Transition, the Plan for the Energy Transition and the Sustainable Use of Energy (PLATEASE), the Development Plan of the Electricity Sector (PLADESE), and the Development Plan of the Hydrocarbons Sector (PLADESHI). These tools support the development of the electricity sector, with the exception of the PLADESHI, in line with the principles of "energy justice, energy transition, and decarbonization" (art. 12 of the LESE). Additionally, and in line with these instruments, in the Plan for Strengthening and Expansion of the National Electricity System 2025–2030, published at the beginning of 2025, 51 projects are contemplated that aim to generate 22,674 additional MW (including 7,143 MW of renewable capacity and 2,216 of battery electric storage) by the Federal Electricity Commission, and 6,400 additional MW by the private sector. With this, the goal is to comply with the national clean energy targets and to comply with international commitments in the fight against climate change (Presidency of the Republic, 2025c).

Both the definition of JET and that of energy justice describe the crucial challenge faced by those responsible for materializing ET policies, which is to contemplate in an integral manner the possible specific and differentiated impacts in different regions and sectors that this transition will have. Implementing strategies that drive the energy transition in Mexico is an enormous challenge that requires understanding and studying the pattern of energy consumption in the country, as well as the main challenges that exist due to the high dependence of the Mexican economy on hydrocarbons, among which oil and natural gas stand out. In addition, the opportunities and limits of renewable sources that seek to effectively substitute fossil fuels in the country's energy matrix must be analyzed. Mexico has several alternatives of renewable sources (which are not only solar photovoltaic and wind), such as the thermal applications of solar energy, hydraulic resources, bioenergy, and geothermal, for which it is necessary to carry out deeper research on the technical criteria necessary for their use and implementation in the country. Finally, the concrete public policy actions that must be carried out to achieve a just and sustainable energy transition must be studied (Ferrari et al., 2023).

Based on this context, in this research document two objectives are set out. The first is to identify the vulnerabilities of the actors impacted by the energy transition strategies in Mexico that could be implemented in order to respond to the fight against climate change in the energy sector. The second corresponds to the formulation of public policy recommendations aimed at reducing the impacts from a just energy transition perspective, taking into account the findings of the first objective so that these strategies are inclusive and beneficial for all.

It is important to mention that, although the actions of Energy Transition (ET) can have positive or negative impacts, the purpose of this study is not to offer a weighting of them, but rather the study of the negative impacts that may accentuate social vulnerabilities, and the formulation of recommendations to mitigate them. In this sense, the questions that guide this analysis are:

a) What are the negative impacts and social, economic, and environmental vulnerabilities that may occur after the implementation of a transition pathway in the Mexican energy sector?
b) Which economic actors (communities, households, workers, private companies, public companies and institutions) will be affected by the implementation of these actions focused on the energy transition, and which are the most vulnerable?
c) What public policy recommendations can help reduce vulnerabilities from a justice perspective?

To carry out this analysis, the ET actions described in the documents "*NDC from Civil Society: A proposal from civil society to increase ambition through a climate justice approach*", hereinafter *NDC from Civil Society* (ICM, 2022a), and "*Sectoral pathways* *for the national net zero emissions scenario*", hereinafter *Sectoral Pathways* (ICM, 2023e), both from the Iniciativa Climática de México (ICM), will be taken as a basis. In accordance with the actions proposed in these documents, the following four ET actions were chosen[1]:

1. Just and planned retirement of conventional thermoelectric power plants that have exceeded their useful life (hereinafter "Retirement of fossil plants").
2. Increase the current large-scale solar photovoltaic capacity from 6 GW to 63.2 GW by 2060 (hereinafter "Addition of solar photovoltaic capacity"). The focus is centered on the installation, grid connection, operation, and maintenance of the plants.
3. Increase the current onshore wind capacity from 6.5 GW to 73.3 GW by 2060 (hereinafter "Addition of onshore wind capacity"). The focus is centered on the installation, grid connection, operation, and maintenance of the plants.
4. Promotion of residential distributed solar generation (hereinafter "Residential Distributed Generation"). The focus is centered on the installation and operation of residential solar panels.

Thus, the central contribution of this document is to provide information on the vulnerabilities associated with the four ET actions mentioned above, which have a high decarbonization potential[2] and whose implementation is feasible, according to the scenarios provided in the ICM documents. This makes it possible to identify the federal entities that could be more prone to facing the impacts of the energy transition actions, and, consequently, could require public policies focused on the mitigation of these.

The rest of the document is structured as follows. Section 2 summarizes the methodology that was used for the identification of the actors, the vulnerabilities, as well as the interviews. Section 3 presents a brief description of each of the ET actions, as well as their outlook in Mexico, followed by a summary of the impacts associated with their implementation. Section 4 shows the results of the vulnerability analysis for three states for each action. Finally, Sections 5 and 6 describe the results of the interviews, and present the public policy recommendations.

[1] The selection of key actions for the energy transition in Mexico was based on a multi-criteria analysis of 80 strategies coming from two decarbonization pathways, one to 2030 and another to 2060. This analysis was carried out in two phases: the first evaluated technical and economic criteria, and the second incorporated social impacts, economic impacts, and priorities of the current administration, in order to identify the most viable and priority strategies. For more detail see Annex 9.9.1.

[2] It should be mentioned that all the actions indicated in the "Net Zero Emissions Pathway" contribute together to the reduction of emissions; nevertheless, the electricity sector is one of the largest emitters of polluting gases. In the period 2024 to 2060, in the ICM scenarios, 742 Mt CO2eq were calculated for the retirement of thermoelectric plants; 244.8 Mt CO2 for coal-fired plants; 1312.54 Mt CO2eq for solar plants; 1255.32 Mt CO2eq for wind plants; and 401 Mt CO2eq for Distributed Generation (ICM, 2022a).

# 2 Summary of the methodology

After the selection of the four actions mentioned above, the analysis of the impacts and vulnerabilities associated with their implementation, as well as the public policy recommendations from a justice approach, was carried out in three additional stages that are described below.

## 2.1 Identification of the impacted stakeholders

For this stage of the study, a delimitation of the value chains of each action analyzed was carried out, and a determination of the direct and indirect impacts. Thus, the scope of the action of retirement of fossil plants considers the impacts that take place during the closure of the plants, which includes the cessation of operations and the dismantling of the facilities. With regard to the actions of installation of large-scale solar and onshore wind generation, the impacts that occur during the phases of installation and operation and maintenance of the plants are studied. In the case of the action of residential distributed generation, the stage of installation and operation of the solar panels in the households is considered.

A review of national and international literature was carried out to identify the stakeholder impacted and the way in which this occurs. Section 3 presents in a summarized way the impacts for each type of stakeholder, while Annex 9.2[3] contains the detailed version in the form of a literature review.

## 2.2 Identification of the level of exposure, sensitivity, and resilience

For this purpose, a vulnerability index is proposed that allows the federal entities to be compared in terms of their level of vulnerability according to the dimensions of exposure, sensitivity, and adaptive capacity. This classification was made according to the Vulnerability Scoping Diagram (Polsky et al., 2007), which makes it possible to assign a numerical value to the different components of the vulnerability dimensions, according to the magnitude of the study variables. Thus, the resulting index is the sum of the different scores of the state for each of the dimensions. The detail of the calculation is found in Annex 9.9.3.

The information used comes from national public sources with state-level disaggregation, which allows its replicability. For this document only three states were analyzed for each ET action, and future studies could extend to the rest of the federal entities in which the respective ET actions take place. The selected states are analyzed in depth in Section 4 of this study. Additionally, the scope is limited to the states that will be directly affected by the energy transition actions, that is, the state where the fossil plant to be retired is located or the states with the greatest integration of renewable generation resources in 2060, according to the document "*Sectoral Pathways*" (ICM, 2023c).

This vulnerability analysis only considers the negative impacts since, as the definition indicates, this concept refers to the social, economic, and environmental conditions that increase the susceptibility

[3] Note that the Annexes are in a separate document that can be downloaded on the same page as the working paper.

of a community to the impact of threats, and therefore, considering the positive impacts of the energy transition action is beyond the scope of the analysis. However, it must be recognized that although the actions also have positive impacts, including them in the analysis could lead to erroneous conclusions, and indicate as less vulnerable, states that are highly vulnerable, because in appearance the positive impacts could dominate the negative ones. Nevertheless, it must be kept in mind that the positive and negative impacts are distributed in different ways and it is possible that not all stakeholders are affected by both. This is precisely what the just energy transition seeks: that the benefits do not remain with only a few and that the negative impacts can be mitigated through public policies that improve the well-being of the impacted population.

## 2.3 Public policy recommendations

In this stage, eighteen semi-structured interviews were conducted, between March and April of 2025, with experts from the Mexican energy sector to learn their opinion on the vulnerabilities linked to the four ET actions, as well as the public policy recommendations to mitigate them. The participants in these interviews come from various sectors, such as public institutions (for example, the Ministry of Energy or the Federal Electricity Commission), subnational-level organizations, civil society organizations, consulting firms in public policies or independent consultants, international financing organizations (such as the IDB), as well as universities and academic research departments (for example, UNAM). This qualitative component of the study made it possible to identify perceptions, experiences, and proposals directly related to the implementation of the four energy transition actions that are analyzed throughout the document.

The analysis of the responses used a text mining methodology, as well as manual review and identification of the following six public policy Axes and specific recommendations for each one. The interrelation between the different recommendations to mitigate the same vulnerability stands out, which highlights the importance of joint work and coordination between the Ministries and other institutions of the federal government to make public policy proposals that can effectively mitigate the vulnerabilities.

# 3 Analysis of the Energy Transition actions and their vulnerabilities

In this section, the details and the negative social, economic, and environmental impacts associated with the implementation of each ET action analyzed are summarized, according to what has been identified in the literature.

## 3.1 Retirement of thermoelectric and coal-fired power plants

The just, participatory, and planned retirement of coal-fired and conventional thermoelectric power plants and other thermal plants that have exceeded their useful life is a crucial action to reach the goal of zero emissions. This action consists of scheduling the dismantling of coal-fired and thermoelectric plants, having considered the conditions of the electrical system so as not to affect its quality, reliability, continuity, or safety. Within the framework of the value chain, this action refers to the final stage of the useful life of the plants. The negative impacts associated with the retirement of coal-fired and thermoelectric plants are summarized in the loss of jobs in mining, oil, or operation and maintenance activities of this type of plants and, consequently, the reduction in the income of these households and private actors; potential contamination of rivers, oceans, and natural areas due to the disposal of hazardous waste; and the reduction in fiscal revenues related to fossil fuels. In this sense, it is important to plan remediation actions for the population, workers, communities, and nearby ecosystems, in order to reduce or eliminate the economic and social impact of the retirement of the plant, which represents a source of income for the families of the workers and the nearby community. On the other hand, the environmental impact that the power plant may have caused during its years of operation to nearby ecosystems must be addressed (ICM, 2023d).

According to the Program for the Expansion and Modernization of the National Transmission Network (PAMRNT) 2024–2038, in 2023 the capacity of conventional thermal generation was 11,300 MW, while that of coal-fired generation was 5,463 MW (CENACE, 2024). The average life of thermal and coal-fired plants exceeds 30 years, on average, which indicates that they have exceeded their useful life. In Mexico, there are still only 3 coal-fired power plants: Plutarco Elías Calles in Guerrero, Carbón II, and José López Portillo in Coahuila, the latter having been in operation for more than 41 years. In this sense, based on the Net Zero Emissions Pathway for Mexico 2060, the just and planned retirement of conventional thermoelectric plants represents a reduction of 17 GW installed, equivalent to 155.02 $MtCO_2e$, with the retirement of 98 plants located in 23 states up to 2036 (ICM, 2023a). The states with the greatest installed fossil capacity, from highest to lowest, are Coahuila, Guerrero, and Veracruz (see Figure 1).

**Figura 11. Fossil generation capacity (thermoelectric and coal-fired) retired (MW) up to 2060.**
Source: Own elaboration with data from ICM (2023a)

The annual retirement plan of the plants proposed in said document focuses on the plants that will exceed their useful life up to 2036 (ICM, 2023a), as described in Table 1. The retirement plan suggests the gradual closure of the different units that make up the plants, not an immediate disconnection of all the capacity, which allows the addition of new generation resources to the system.

**Table 1. Retirement plan of thermoelectric and coal-fired plants, ICM proposal**
Source: Own elaboration with data from ICM (2023a)

| Year | 2027 | 2028 | 2029 | 2030 | 2031 |
|---|---|---|---|---|---|
| **Retired cap (MW)** | **2 716** | **2 677** | **3 207** | **2 781** | **1 632** |
| **States** | Baja California | Campeche | Sinaloa | Puebla | Baja California Sur |
| | Chihuahua | Coahuila | Chihuahua | Campeche | Colima |
| | Coahuila | Durango | Coahuila | Coahuila | Durango |
| | Colima | Guerrero | Colima | Estado de México | Hidalgo |
| | Guerrero | San Luis Potosí | Guanajuato | Guanajuato | San Luis Potosí |
| | Hidalgo | Sonora | Guerrero | Guerrero | Sonora |
| | Sinaloa | Tamaulipas | Hidalgo | Sinaloa | Veracruz |
| | Sonora | Veracruz | San Luis Potosí | Sonora | |
| | Tamaulipas | | Sonora | Tamaulipas | |
| | | | Tamaulipas | Veracruz | |
| | | | Veracruz | | |

| Year | 2032 | 2033 | 2034 | 2035 | 2036 |
|---|---|---|---|---|---|
| **Retired cap. (MW)** | **1 318** | **1 365** | **753** | **505** | **69** |
| **States** | Sinaloa | Baja California Sur | Chihuahua | Chihuahua | Guadalajara |
| | Campeche | Colima | Coahuila | Baja California Sur | México |
| | Estado de México | Hidalgo | Estado de México | Hidalgo | Querétaro |
| | Nuevo León | Sinaloa | Guanajuato | Oaxaca | Tamaulipas |
| | Sonora | Sonora | Yucatán | Veracruz | |
| | Tamaulipas | Tamaulipas | | | |
| | Veracruz | Veracruz | | | |

It is important to highlight that on May 31, 2024, the National Electric System Development Program (PRODESEN) 2024–2038 was published. This indicative planning instrument is the means by which the Ministry of Energy (SENER) establishes the policy for the electricity sector and in which the development of the National Electric System (SEN) is projected for a period of 15 years. PRODESEN includes the Indicative Program for the Installation and Retirement of Power Plants (PIIRCE), and identifies the additions and retirements of electricity generation resources considering a margin of 14 years. For this year, PIIRCE 2024–2038 indicates the modernization of approximately 11,182 MW of installed conventional capacity, which will make it possible to have greater flexibility to allow the gradual incorporation of clean energy sources (Ministry of Energy, 2024). Despite having an indicative plan, no other official documents have been published that detail the plan to follow to achieve this objective, or that mention an aspect of just retirement. However, in January 2025, the reconversion of the Tula thermoelectric plant to natural gas was announced, as well as the remediation of the Tula River (Presidency of the Republic, 2025a). The new guidelines in this matter of retirement of thermoelectric plants will presumably be incorporated in the Electric Sector Development Plan (PLADESE), the publication of which is expected in September 2025, with retirement and modernization objectives that form part of the binding planning (Presidency of the Republic, 2025).

The impacts that are associated with the retirement of thermoelectric and coal-fired plants are summarized in part 3.5, according to what has been identified in the literature. The details of the review are presented in Annex 9.2.1.

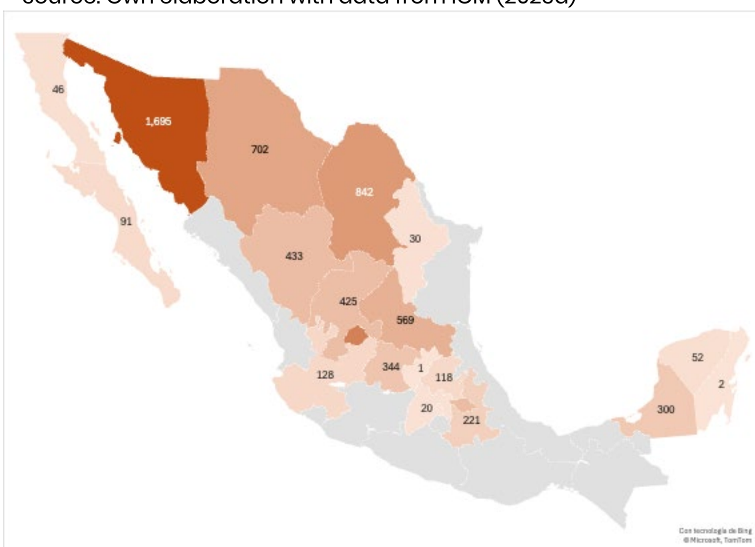
## 3.2 Addition of large-scale solar capacity

Large-scale solar photovoltaic energy is configured as one of the fundamental pillars to transform the electricity sector in Mexico, offering a path toward decarbonization and energy security. The current plans point to one objective: to raise the installed solar capacity to 63.2 GW by the year 2060

(ICM, 2023b). To reach this goal, various mechanisms are being considered that include the design of strategic policies, promotion programs, refinement of regulatory frameworks, and activation of financial instruments to reactivate existing projects and trigger new developments. This substantial increase of more than 950% will not only strengthen the country's position in the global energy transition, but will also contribute a significant mitigation potential of greenhouse gases, with estimates close to 51.17 million tons of $CO_2$ equivalent ($MtCO_2e$) for the same time horizon.

In 2023, the solar generation capacity in Mexico reached 7,577 MW, according to information on the permits granted by the CRE. This capacity corresponds to a total of 101 plants that operate in the country, whose distribution by federal entity is presented in Figure 2. In this regard, the three states with the greatest installed capacity are Sonora with 1,695 MW, Coahuila with 842 MW, and Chihuahua with 702 MW.

**Figura 2. Installed solar generation capacity in 2023**
Source: Own elaboration with data from ICM (2023a)




Approximately 55% of the total capacity comes from the projects of the Long-Term Auctions carried out between 2015 and 2017, while less than 10% is the CFE's own capacity[4]. In this regard, the Indicative Program for the Installation and Retirement of Power Plants (PIIRCE) indicates that between 2024 and 2038 an interconnected solar generation capacity[5] equivalent to 12,729 MW is expected to be incorporated, which is equivalent to 1.68 times the capacity in 2023 (SENER, 2024). Thus, according to the planning scenario of the PIIRCE, it would be expected that in 2038 the solar generation capacity would be equivalent to 20,306 MW. In contrast, according to the estimates of the document *Sectoral Pathways*, for the same period the pathway proposes a capacity of 42,537 MW, which is a little more than twice the capacity proposed in the PIIRCE (ICM, 2023d). Finally, and in the short term, it should be

[4] As of December 2024 and according to the data from the Plan for Strengthening and Expansion of the National Electric System 2025–2030, the CFE has 433 MW of its own PV-solar generation capacity.
[5] The Plan for Strengthening and Expansion of the National Electric System 2025–2030 indicates that between 2027 and 2030 the following photovoltaic capacity addition projects are expected to be developed: CFV Puerto Peñasco Sequence III and IV, CFV Carbón II, CFV Río Escondido, CFV Altamira, and CFV Laguna, which together add up to 1,673 MW of capacity.

noted that it is expected that CFE's installed photovoltaic solar capacity will be multiplied by ten by 2030 (up to 4,673 MW), according to the forecasts of the Plan for Strengthening and Expansion of the National Electric System 2025–2030 (Presidency of the Republic, n.d.).

The impacts related to the installation of large-scale solar projects are summarized in part 3.5, according to the literature review. The details of the review are presented in Annex 9.2.

## 3.3 Addition of onshore wind capacity

The addition of large-scale wind capacity, like solar, is positioned as a key pillar for the transformation of the electricity sector in Mexico, by providing an effective route toward decarbonization and energy security. To achieve this objective, it is fundamental to establish clear goals, design strategic policies, implement development programs, optimize regulatory frameworks, and activate financial instruments that facilitate the reactivation of existing projects and the promotion of new initiatives in the wind sector. This integrated development pursues an ambitious objective: to increase the installed capacity from approximately 6.5 GW to 73.3 GW by 2060 (ICM, 2023, p. 38). This increase in installed capacity will not only consolidate Mexico's position in the global energy transition, but will also contribute significantly to the mitigation of greenhouse gases, with an estimated reduction potential of 51.2 million tons of $CO_2$ equivalent ($MtCO_2e$) for that same period.

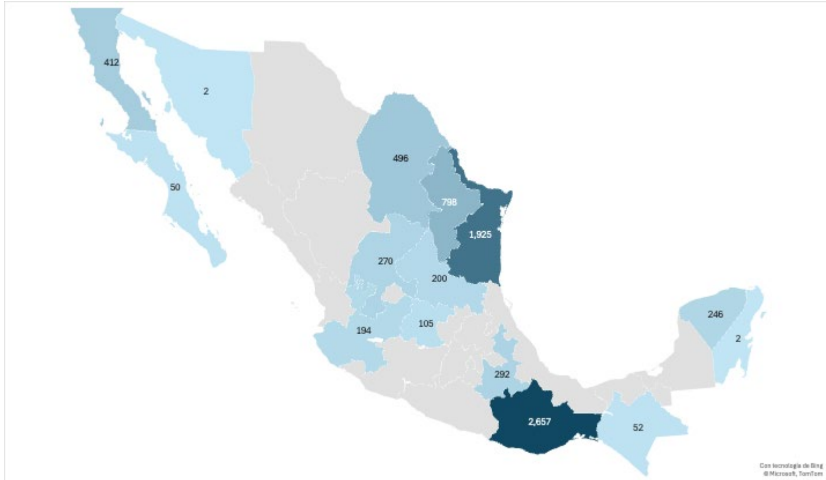
Due to its clean, renewable nature and the notable reduction in costs in recent years, wind energy has been consolidated as a viable alternative for the massive generation of electricity. Nevertheless, its success depends on the selection of sites with constant wind and adequate speeds. In Mexico, the geography offers various terrestrial and maritime areas ideal for harnessing this source of energy. The regions with the greatest potential include the Isthmus of Tehuantepec, Tamaulipas, Baja California, the Gulf of Mexico, and the Yucatán Peninsula, although many other zones also have favorable conditions for its development.

However, the fact that these areas have generation potential does not mean that the social conditions also exist for the installation of a wind project. For example, the Isthmus of Tehuantepec has one of the greatest generation potentials in Mexico. Nevertheless, it is also a region in which there has been strong social opposition to the projects due to the lack of social vision in their design, one that would allow the redistribution of benefits among all the members of the community, instead of weakening the social fabric and benefiting only a few. In this sense, it is necessary that projects be integral, considering not only the geography of the site but also a social approach in their design.

According to the information on the permits granted, the Energy Regulatory Commission reported for 2023 an onshore wind generation capacity in Mexico equal to 7,700 MW. This capacity corresponds to a total of 68 plants that operate in the country, whose distribution by federal entity is presented in Figure 3. In this regard, the three states with the greatest installed capacity are Oaxaca with 2,657 MW, Tamaulipas with 1,925 MW, and Nuevo León with 798 MW.

**Figure 33. Installed onshore wind generation capacity in 2023**

Source: Own elaboration with data from ICM (2023a)




Approximately 20% of the total capacity comes from the projects of the Long-Term Auctions carried out between 2015 and 2017, while less than 2% is CFE's own capacity. In this regard, the PIIRCE indicates that between 2024 and 2038 an interconnected wind generation capacity equivalent to 27,687 MW is expected to be incorporated, which is equivalent to almost 3.6 times the capacity in 2023 (SENER, 2024). Thus, according to the planning scenario of the PIIRCE, it would be expected that in 2038 the wind generation capacity would be equivalent to 35,387 MW. In contrast, according to the estimates of the document *Sectoral Pathways*, for the same period the pathway proposes a capacity of 29,334 MW, which is about 82% of the capacity proposed in the PIIRCE (ICM, 2023d). (Presidency of the Republic, n.d.).

The impacts related to the installation of large-scale wind projects are summarized in part 3.5, according to the literature review. The details of the review are presented in Annex 9.2.1.

## 3.4 Residential Distributed Generation

Distributed Generation (DG) is the scheme of participation in the National Electric System (SEN) that allows a user to become a small-scale generator (installed capacity less than 700 kW), under the figure of Exempt Generator, which does not require a generation permit to produce electricity (ICM, 2022a). According to the Energy Regulatory Commission (2025), at the end of 2024, the installed capacity in DG was 4.44 GW, of which 99.4% of this capacity corresponds to solar generation. The map in Figure 4 shows the distribution of the installed DG capacity in the country. In this regard, Jalisco is the state with the greatest capacity (658.04 MW), followed by Nuevo León (468.77 MW), Chihuahua (317.74 MW), Guanajuato (290.06 MW), and the State of Mexico (230.2 MW).

**Figure 4. Installed capacity of residential DG**
Source: Own elaboration with data from Energy Regulatory Commission (2025)

PRODESEN 2024–2038 indicates that residential DG has the potential to benefit about 743,695 inhabitants who do not have access to electricity. Among the additional benefits is the improvement in quality of life associated with access to health, education, and housing services, which are linked to the provision of electricity (Electric Sector Law, 2025).

The impacts related to the installation of DG projects are summarized in part 3.5, according to the literature review. The details of the review are presented in Annex 9.2.1.

## 3.5 Impacts of the four actions

The energy transition in Mexico entails a series of significant impacts in various social, economic, and environmental dimensions. In terms of employment, the retirement of fossil technologies can generate structural job losses, while renewable energies (solar and wind) offer jobs, but which require skills different from those developed in fossil technologies. However, in terms of health and the environment, exposure to fossil fuel-based technologies generates risks due to exposure to pollutants, toxic waste, and alterations in local ecosystems.

Below, the impacts, the associated actions, and the vulnerabilities identified are summarized in the following table:

| IMPACT | ET ACTION | IDENTIFIED VULNERABILITIES |
|---|---|---|
| EMPLOYMENT | FOSSIL RETIREMENT | Loss of jobs linked to fossil power plants and mining activities. Potential consequence of forced migrations in territories with more economic opportunities. |
| | | Difficulty in transferring the skills of fossil plant workers to renewable energy plants. |
| | | Reduction in household income and risk of falling into poverty. |
| | | Reduction in the demand for fossil fuels, such as the purchase of coal from local communities. |
| | | Codependence with companies in the regional value chain. |
| | | Loss of local economic activities. |
| | | Emotional costs linked to job loss. |
| | | Loss of identity linked to productive activities (coal extraction and electricity generation). |
| | SOLAR & WIND | Temporary jobs linked to the construction works of the plant. |
| | | Limited job opportunities after the construction phase. |
| | | Short-term economic dependence and subsequent collapse of economic activity. |
| | | Income inequality that is accentuated with pre-existing inequalities. |
| | | Displacement of less competitive local actors. |
| | | Lack of linkage of projects with local economies. |
| | | Lack of training and development of local resources. |
| | | Social tensions associated with competition for basic services. |
| HEALTH | FOSSIL RETIREMENT | Long-term health damage linked to exposure to pollutants, as well as respiratory and cardiac diseases associated with mining and electricity generation activities. |
| | | Limited access to health care for women in the informal sector. |
| ENVIRONMENT | FOSSIL RETIREMENT | Disposal of hazardous waste. |
| | | Inadequate final disposal of the plant. |
| | | Soil contamination linked to pollutant emissions and contamination of local agricultural/fishing products. |
| | SOLAR & WIND | Pollution due to dust or noise and spillage of chemical substances. |
| | | Absence of comprehensive environmental planning that may affect natural resources in the long term. |
| | | Uncontrolled expansion in ecologically sensitive areas. |
| | | Alteration of land use, fragmentation of natural ecosystems. |
| | | Loss of balance of the landscape and of the communities' identity with their environment. |
| | | Destruction of natural sites. |

| | | |
|---|---|---|
| | | Damage to soil, aquifers, and health due to the use of chemicals to eliminate grass. |
| | | Increase in temperature in nearby areas associated with tree felling and soil erosion. |
| | **WIND** | Noise pollution that causes stress in local fauna and affects livestock activities. |
| | | Reduction of biodiversity during the plant's operation: risk to birds and bats. |
| | **SOLAR & DG** | Replacement of solar panels whose useful life has not ended by more efficient ones. |
| | | Plan for the final disposal of panels in the medium term. |
| | | Environmental contamination due to improper waste management. |
| | **DG** | Batteries to back up DG systems, so it is important to think about their final disposal. |
| **ENERGY POVERTY** | **FOSSIL RETIREMENT** | Reduction in the supply of electricity generation in the region. |
| | **DG** | Indebtedness derived from excessive installation costs. |
| | | Lack of access to cheap credit. |
| | | Subsidy in low-consumption areas makes investment in solar DG panels less attractive. |
| | | Lack of certifications for companies installing residential panels. |
| | | Problems with the quality of installations. |
| | | Absence of certified providers for residential panel installation. |
| | | Lack of adequate infrastructure in homes to install panels safely. |
| | | Need for home ownership to install solar panels. |
| **GOVERNANCE, PARTICIPATION & COMMUNITY INCLUSION** | **FOSSIL RETIREMENT** | Reduction in fiscal revenues related to fossil fuels. |
| | | Dependence of state budgets on oil revenues. |
| | | Vulnerability of PEMEX due to its financial situation. |
| | | Loss of asset value, stranded assets, and economic impact. |
| | **SOLAR & WIND** | Tensions and distrust toward public institutions due to lack of transparency and inclusiveness. |
| | | Absence of a communication and community participation strategy, which can trigger protests and social conflicts, as well as perceptions of social injustice in areas with strong cultural identity or a history of economic exclusion. |
| | | Social conflicts associated with community acceptance of the project. |
| | | Displacement of populations associated with the destruction of cultural heritage. |
| | | Disconnect between the worldview of communities and energy projects. |
| | | Unequal distribution of benefits. |
| | | Scarce sharing of benefits in local communities. |
| | | Lack of continuous evaluation of social impacts and payment of co-benefits. |

| | | |
|---|---|---|
| | | Absence of a policy of oversight and compliance with obligations toward communities. |
| | | Prioritization of economic activity over the rights of communities, turning territories into "green sacrifice zones.[6]" |
| | | Rent-seeking by municipal and state authorities, corrupt practices. |
| | | Appropriation of energy infrastructure for illicit activities (regions with weak state presence). |
| | | Excessive administrative burden associated with project oversight. |
| | | Subsidies to electricity and fuel tariffs capture a considerable part of public resources. |
| | | Instability of the electric grid due to saturation. |
| | | Cumulative impact in territories where projects are already installed and need for greater infrastructure for the installation and transport of energy. |
| | **DG** | Perception of injustice due to unequal distribution of subsidies. |
| | | Perception of injustice and lack of transparency in the allocation of zones or subsidies. |
| | | Loss of trust associated with non-fulfillment of project expectations. |
| **TERRITORIAL MANAGEMENT & SOCIAL BALANCE** | **SOLAR & WIND** | Speculation and increase in land prices, which raises the cost of locally produced food. |
| | | Breakdown of communal and shared-use land management models. |
| **GENDER** | **SOLAR & WIND** | Increase in prostitution and human trafficking associated with the arrival of workers from outside the community. |
| | | Exclusion of women from decision-making in projects and from the benefits. |
| | **ALL** | Reduction of their participation in economic activities to the provision of food and care services. |

[6] Sacrifice zones are usually "frontline communities" inhabited by low-income people and/or racialized communities, or else "hot spots" of chemical pollution, where the population resides in the vicinity of highly polluting industries or military bases (Lerner, 2010). The concept of green sacrifice zones can be broadened to encompass spaces and populations affected by the stages of supply, transport, installation, operation, and final waste management of the solutions intended for low-carbon transitions (Zografos & Robbins, 2020).

# 4 State-level vulnerability analysis

As described throughout Section 3, the selected Energy Transition actions have the potential to generate differentiated impacts depending on the territorial, sociodemographic, and governance conditions in which they occur. Thus, although these actions are necessary to move toward a more sustainable energy system, they bring with them social, economic, and environmental vulnerabilities that manifest with different intensities depending on the territory where they are implemented.

To identify the states most vulnerable to the negative impacts, a composite vulnerability index was developed at the state level, which considers three dimensions: exposure, sensitivity, and adaptive capacity. Based on the literature review on the impacts linked to each of the actions, socioeconomic and demographic variables were identified that were related to the impact and that had public availability at the state level. Subsequently, the variables were classified into one of the three dimensions of exposure, in order to create an index that integrated the occurrence of all measurable negative impacts.

This index makes it possible to compare the relative vulnerability of the states where each action takes place and serves as an input to identify the states that could be more vulnerable, exposed, sensitive, or with less adaptive capacity to any of the actions, in order to identify those that would require more urgent public policy interventions compared to others that could have more characteristics that made them less vulnerable.

In the following sections the selected territories and their characteristics for each action are presented. The last part of this section is dedicated to a comparison and general review of the vulnerability scores of the four actions. The methodology of the vulnerability index is described in Annex 9.3, highlighting the states that are used as an example to calculate the index, the variables that compose it, and a proposal for interpreting it.

## 4.1 Retirement of fossil plants

The state-level vulnerability index associated with the just and planned retirement of fossil coal-fired and conventional thermoelectric plants focuses on the three states with the greatest installed capacity to be retired by 2036, according to the ICM study[7]: Guerrero with an installed capacity of 2,616 MW; Coahuila with 2,388 MW; and Veracruz with 2,000 MW (ICM, 2023). Thus, for this analysis the retirement of the three coal-fired plants in the country located in Coahuila and Guerrero, and one thermoelectric plant in Veracruz, will be considered, which are listed below.:

a. Carbón II Thermoelectric Plant, located in Coahuila.
b. José López Portillo Thermoelectric Plant, located in Coahuila.

[7] The plants identified in the ICM study use coal, natural gas, and fuel oil, with a steam cycle (boiler) process. Regarding the selection criteria, it is indicated that these plants were chosen according to their useful life, operating costs, level of emissions, and inefficiency.

c. President Adolfo López Mateos Thermoelectric Plant, located in Veracruz.
d. President Plutarco Elías Calles Thermoelectric Plant, located in Guerrero.

Annex 9.3.1 presents a description of the components of vulnerability (exposure, sensitivity, and adaptive capacity) according to the values for the state variables of Coahuila, Guerrero, and Veracruz, and shows the detail of the scores obtained in each component.

## 4.2 Addition of solar photovoltaic capacity

To construct the vulnerability index of this action, the three states with the greatest installed capacity projected to 2060 were considered, according to the pathway proposed by ICM. The map in Figure 5 shows the estimates of solar generation capacity. In this regard, Sonora is the state that projects the greatest capacity with 6,240 MW, followed by Chihuahua with 4,160 MW, and finally Puebla, which has an expected 3,890 MW. These three states have the highest outlook for solar capacity and, consequently, will occupy a greater proportion of their territories, which is why they are more likely to receive the negative impacts of this action.

**Figure 55. Proposed solar generation capacity 2060**
Source: Own elaboration with data from ICM (2023a)

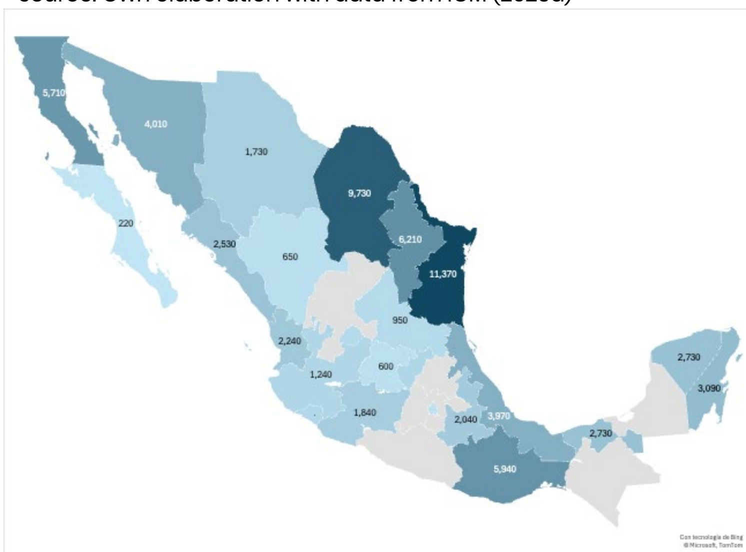
Annex 9.3.2 shows the detail of the scores obtained in each component and the descriptive table of the variables and presents a description of the components of vulnerability (exposure, sensitivity, and adaptive capacity) according to the values for the state variables of Sonora, Chihuahua, and Puebla.

## 4.3 Addition of onshore wind capacity

For this action, the calculation of the vulnerability index focuses on the three states with the greatest installed capacity in 2060, according to the pathway proposed by ICM. The map in Figure shows the projection of installed solar generation capacity in 2060. In this regard, Tamaulipas is the state that projects the greatest capacity with 11,370 MW, followed by Coahuila with 9,730 MW, and finally Nuevo

León, which has an expected 6,210 MW. These three states have the highest outlook for onshore wind generation capacity and, consequently, will occupy a greater proportion of their territories, which is why they are more likely to receive the negative impacts of this action.

**Figure 66. Proposed solar generation capacity 2060**
Source: Own elaboration with data from ICM (2023a)



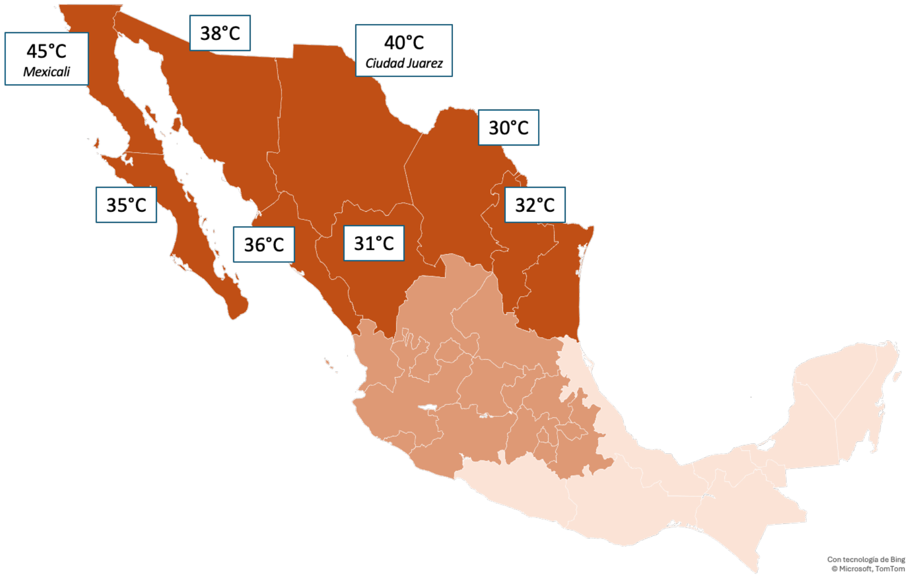

Annex 9.3.3 offers greater detail of the results of the index for each one of its vulnerability components by state, including the variables considered in the calculation.

## 4.4 Residential Distributed Generation

For the study of the vulnerabilities associated with the installation of residential distributed generation, the focus will be on the states that have the highest temperatures during the summer (map in Figure 7), considering that the increase in temperature affects the population in terms of greater heat stress, outbreaks of diseases, malnutrition, in addition to having psychological effects associated with extreme weather (UNDP Global, 2023).

**Figure 77. Classification of the states according to their climate.**

Source: Own elaboration with data from (INEGI, 2025)




In accordance with the above, for the analysis of this action the states of Sonora and Sinaloa were chosen as they have the highest temperatures during the summer, with 38°C and 36°C on average, respectively. Additionally, Baja California was chosen which, despite not being among the states with the highest temperature, does have one of the municipalities with the most extreme weather conditions during the summer: Tijuana. INEGI indicates that this municipality can experience temperatures of up to 45°C, which is why it is also interesting to add the state of Baja California to the analysis (INEGI, 2025a). Additionally, in line with the National Strategy of the Electricity Sector recently presented by President Claudia Sheinbaum, which is part of the National Energy Plan, an ambitious project is contemplated for the installation of photovoltaic panels in households in the north of the country, starting in Mexicali, Baja California.

The general description of the results of the index for each of its vulnerability components by state, the description of the variables used to measure exposure, sensitivity, and vulnerability, as well as the vulnerability diagram are found in Annex 9.3.4.

## 4.5 Results of the vulnerability index for the four actions

Each energy transition action involves specific dynamics and contexts, which is why it is essential to observe their effects in a comparative manner to identify common patterns or relevant contrasts. This subsection presents a comparative synthesis of the results of the vulnerability index, according to the information described in the previous sections. In this regard, the results are illustrated in the maps of Figure 8.

For the retirement of fossil plants, Guerrero is the most vulnerable state with 4 points in the index (medium-high vulnerability), followed by Veracruz with 3 (medium vulnerability) and Coahuila with 2 (medium-low vulnerability). In this case, Guerrero is the state with the greatest capacity to retire and that has the socioeconomic variables with the worst performance, see Table 9 of Annex 9.3.1, which makes it more sensitive to the retirement of the coal-fired plants located in this territory. Although Veracruz and Coahuila are better positioned in terms of vulnerability, it is important to remember that the local economies are highly dependent on oil extraction and refining and on coal mining and sales to coal-fired plants. These activities were not considered in the index, which makes it very possible that both states have a higher level of vulnerability than what the index reflects. However, this could be determined by considering the information of the municipality where the plants and the mines are located, in order to offer a more precise response, which is lost when using state-level information.

With regard to the increase in large-scale solar photovoltaic generation capacity, it is observed that the three selected states, Sonora, Chihuahua, and Puebla, have a medium vulnerability index with a value of 3 points. Puebla has a higher score in exposure because it is the state with the greatest proportion of Indigenous population that could suffer the impacts linked to the installation of new projects. Additionally, as the state with the smallest area compared with Sonora and Chihuahua, a greater part of its territory would potentially be occupied by solar plants, which would reduce the surface available for forestry or agricultural activities. Nevertheless, it is the state with the greatest coverage of social programs and environmental monitoring, as well as lower perception of corruption, which contributes to its adaptive capacity and places it as the state with the best score in this category (medium), which offsets its high exposure.

In the case of the increase in onshore wind generation capacity, as in the previous action, the states have a medium vulnerability index, which is equivalent to 3 points. It should be noted that there are no drastic differences in the scores of each of the components of the index. This is due to the fact that the states have a similar performance in terms of the socioeconomic variables that were considered.

According to the results of the index for the other two actions, it is observed that there are notable differences in the magnitude of the index between the states of the north and those of the center-south. Although the indices for each action are not directly comparable because they do not incorporate the same variables, the socioeconomic variables for the northern states reflect their economic performance. In this sense, the need to have public policies that can mitigate these vulnerabilities by paying attention to the particular needs of the states becomes relevant.

With respect to the installation of residential distributed generation, it is observed that the states of Sonora and Sinaloa present a medium-high vulnerability (4 points) while Baja California is located at a medium level (3 points). It is noteworthy that Sonora and Sinaloa have a medium-low level of adaptive capacity due to the low return on investment of residential panels, owing to the subsidized electricity tariffs that benefit the majority of the population in these states (Hancevic et al., 2017).

The results presented throughout this section show that vulnerability is distributed differently among the states for which each of the actions is analyzed. Even though the states may have the same level of vulnerability, there are differences between the scores reached in each of the components. Each action analyzed—retirement of fossil plants, expansion of large-scale solar and onshore wind generation, and installation of residential distributed generation—entails specific patterns of exposure, sensitivity, and adaptive capacity, determined by the geographic, socioeconomic, and structural conditions of each state.

Although the index offers a general quantitative and territorialized perspective of vulnerability, it is necessary to complement it with a qualitative vision that captures perceptions, experiences, and proposals from the expert sector. The following section describes the public policy recommendations that emerged from the interviews with experts.

**Figure 8. Results of the vulnerability index for the selected states**
Source: Own elaboration

# 5 Qualitative analysis of expert interviews

In order to complement the quantitative analysis of vulnerabilities associated with the main actions of the energy transition in Mexico, semi-structured interviews were carried out with key actors in the energy sector. This qualitative component of the study made it possible to identify perceptions, experiences, and proposals directly related to the implementation of the four energy transition actions that are analyzed throughout the document.

Between March 11 and 19, 2025, 70 invitations (30 women and 40 men) were sent to participate in the interview, which were assembled based on suggestions from the IDEA and AFD teams. In these invitations, the objectives of the project and the interviews were generally described, as well as the questions that would be covered during the session, so that all potential participants would have the same prior information[8]. Table 2 shows the affiliation sectors of the potential participants and the interview participants. Initially, the invitations were addressed to experts from the public sector (federal or state government officials), private sector, NGOs, energy associations, researchers and independent consultants, and international organizations. The selection sought to ensure a diverse representation of perspectives, with emphasis both on the technical dimension and on the social and environmental aspects of the energy transition with a justice approach.

**Table 22. Affiliation sectors**

| | Public | NGO | Researcher, consultant | Association | Private | International |
|---|---|---|---|---|---|---|
| Potential participants | 19 | 20 | 19 | 5 | 5 | 2 |
| Participants | 8 | 5 | 6 | 0 | 0 | 1 |

Between March 18 and April 4, 2025, 18 interviews were conducted, with the participation of twenty people (9 women and 11 men); there were two double interviews with women participants. The profiles of the interviewees include officials from government institutions, civil society organizations, academic institutions, and a multilateral organization. The interviews considered three main aspects: (1) identification of social, economic, and environmental vulnerabilities associated with each energy transition action analyzed; (2) existing public policies for the mitigation of vulnerabilities; and (3) proposals for public policies to address the vulnerabilities, as well as examples of international experiences.

The information obtained was systematized and classified based on the main emerging themes, which made it possible to build a vulnerability matrix. From this analysis, six strategic axes were defined to guide public policies that contribute to a fairer and more inclusive energy transition;

[8] The information prior to the interview, including the questionnaire, is presented in Annex 9.5.

in turn, these axes group together various recommendations, that is, detailed policy measures designed to respond to the challenges and needs of the actors. In this sense, it stands out that the same vulnerability, or set of vulnerabilities, can be mitigated through different public policy axes, encompassing diverse solutions. The public policy axes considered for the set of actions are the following:

**Axis 1.** Strengthening of energy governance and planning

**Axis 2.** Mitigation of socioeconomic impacts and protection of vulnerable communities

**Axis 3.** Promotion of Distributed Generation

**Axis 4.** Capacity building and technology transfer

**Axis 5.** Mitigation of environmental impacts

**Axis 6.** Mitigation of gender impacts

The complete results of the text analysis, the methodology, the co-occurrence graphs, and thematic clusters are available in Annex 9.9.6**.**

# 6 Public policy recommendations

Below is a set of public policy recommendations to address the vulnerabilities linked to the ET actions analyzed in this document with the objective of promoting an equitable and inclusive transition. These recommendations summarize the findings from the interviews with experts, which were grouped into six public policy axes, and the results from the previous stages of analysis. In turn, they were organized according to different groups of identified vulnerabilities: employment, health, environment, social participation, gender, governance, and infrastructure.

## 6.1 Protection of employment and economic reconversion

The closure of fossil plants is a key action for the energy transition. However, this process brings with it significant social and economic impacts in the territories that host the plants and those dedicated to coal mining. This closure represents the loss of jobs and the reduction in household income, thus becoming a threat to these households. Additionally, the skills of the workers in these sectors are not directly transferable to others, which increases the risk of poverty and mental illnesses linked to job loss.

Thus, to address these challenges, it is essential to develop job reconversion and training programs aimed at the workers affected by the closure of fossil plants, in order to facilitate their reinsertion in the renewable energy sector and others where their skills may be transferable. For this reason, specific training and workshops are required, designed to facilitate an effective labor transition, allowing the acquisition of new knowledge and insertion in an industry characterized by different techniques, problems, and expertise. The proposals point toward the development of federal programs and initiatives that foster new skills among workers affected by the closure of these plants. Currently, at the national level, there are initiatives such as the Distance Training Program (PROCADIST) of the Ministry of Labor, which offers online courses for skills development and to strengthen job performance. However, at the state level there are very few; for example, Training for Work (ICATI) in the State of Mexico and the Training Institute for Work of Mexico City (ICAT CDMX). In this sense, a national strategy is required that addresses the particular needs of each state and provides resources to the states to implement this type of initiative. These skills not only seek to facilitate labor reinsertion but also to support economic diversification in those communities whose economy traditionally depends on activities associated with fossil plants.

In situations in which difficulties arise in the processes of labor reconversion, or when the timing between the implementation of renewable energies and the closure of fossil plants is not properly coordinated, it is essential to have social protection mechanisms, such as unemployment insurance programs, training scholarships, and early retirement plans. In direct economic terms, it is considered crucial to design specific programs that provide financial assistance to the workers of fossil plants during their process of labor adaptation (Brown & Jeyakumar, 2022). These programs must ensure the stability of their income, foster the development of new skills through continuing education, and facilitate both labor mobility and reinsertion into the emerging labor market associated with the energy transition. International experience in regions such as Canada, with specific initiatives for labor transition, can serve as a reference for Mexico in structuring these programs.

The concertation among actors is a key element in the processes of transition toward new jobs and in the promotion of sustainable and community-based economic development. In this sense, the inclusion of trade unions in the planning of the energy transition constitutes an essential recommendation to foster a democratic and inclusive dialogue at the regional level. Likewise, direct interaction with the affected communities will make it possible to identify specific local priorities, enabling targeted attention through federal and local programs.

## 6.2 Public health and gender equality

The health of workers and populations in areas surrounding fossil plants is affected due to long-term exposure to pollutants, which causes various cardiac and respiratory diseases. In this sense, it is essential to guarantee access to health services that care both for those who already have some condition and for those who could develop them in the future, even once the plants are retired. This approach considers that the damage does not end once the plant is retired, but that the impacts persist beyond the closure of the facilities, which could accentuate the vulnerability of the population considering that they not only have health impacts, but also face the loss of their source of employment and income.

Likewise, a specific plan is required for addressing the health of women, especially those who do not participate in the formal labor market, since they have greater difficulty in accessing health services. This is accentuated because they are more prone to developing illnesses linked to stress and pollution. In this sense, it is important to study the differentiated health impacts on women, considering both physical and mental conditions, taking into account diverse factors such as exposure to pollutants or the care burdens associated with changes in the energy environment.

Finally, it is necessary to promote the participation of women in the consultation and evaluation processes of energy projects, avoiding reductionist approaches such as "token" or "checklist" that do not recognize the plurality of women's experiences and needs. Nevertheless, participation is not limited to these processes; it is also necessary to promote the specialized training of women in the use of energy systems at the domestic level, in order to foster their technical autonomy and strengthen their role in community energy management.

## 6.3 Mitigation of environmental impacts and land-use planning

The retirement of fossil plants brings with it the risk of inadequate disposal of hazardous waste, as well as soil and water contamination, affecting local fishing and agricultural activities. Thus, it is essential that there be governmental support in the dismantling processes of coal and thermoelectric plants, with the objective of guaranteeing controlled management, in accordance with current regulations, and minimizing as much as possible the generation of new sources of pollution (ElecAustro, 2010a).

Each plant must have a comprehensive plan that contemplates critical environmental aspects, such as the proper management of hazardous materials, occupational safety, and the rehabilitation of the sites intervened, including the soil and water resources (Távara Cieza et al., 2016a). These actions must be complemented with recycling and circular economy strategies.

Likewise, it is necessary to design land-use planning plans that promote a strategic management of the land, reduce conflicts, and balance environmental conservation, economic development, and community rights. In this sense, it is crucial to have clear legislation, since many conflicts arise from the absence of planning that considers local resources, the vocation of the territory, and the aspirations of its inhabitants.

It is also recommended to carry out comprehensive impact assessments that consider the set of energy projects in a region, instead of analyzing them in isolation. In this way, the cumulative and synergistic effects of megaprojects can be managed.

Finally, it is crucial to plan the final disposal of solar panels and batteries, with the objective of preventing the waste generated by this industry from becoming future environmental pollutants. This will prevent the waste of the renewable industry from becoming new sources of pollution and will allow the adoption of new circular economy practices.

## 6.4 Governance, participation, and community inclusion

Early consultations are key to fostering an environment of trust around energy projects. Even when the development of a project is not planned, it is important to keep the population informed about the energy and non-energy potential of their territory, in order to know their opinion and maintain an open channel of communication. For this reason, it is essential to inform communities in accessible language about their rights and the social, economic, and environmental impacts of the projects, from the pre-feasibility stage to their commissioning. Thus, the creation of effective communication channels helps prevent conflicts, improves public perception, and fosters the active cooperation of the community.

It is important to promote participatory governance models that allow communities to manage the income derived from renewable projects. In this case, energy cooperatives represent a viable model to link energy production with local needs and the community management of the resources generated.

Finally, it is necessary to establish fair compensation schemes for land use, ensuring that the developer companies make social investments in the territories where they operate and that they offer equitable conditions to the landowners. For example, in Oaxaca energy cooperatives have begun to be implemented, which allow the inhabitants of the area to be incorporated into the energy projects so that the community takes ownership of the projects and local capacities are developed through technical training.

## 6.5 Cross cutting recommendations

The energy transition requires a comprehensive approach that guarantees the equitable distribution of its benefits, particularly for the most vulnerable communities. The following recommendations strengthen governance, promote social equity, drive technological innovation, and encourage collaboration between the private sector and academia. Together, these recommendations establish the enabling conditions for the successful implementation of the energy transition actions that have been studied throughout this document.

With regard to the strengthening of governance and strategic planning, what stands out is the establishment of coordination mechanisms among federal, state, and municipal governments, as well as the strengthening of the regulatory and technical capacities of the public institutions involved in the transition. In this sense, a key recommendation is the creation of state energy agencies that help identify local energy priorities, in addition to promoting projects suited to the geographic and socioeconomic characteristics of the municipalities. It should be noted that, in Mexico, several states lack an institution in the energy field. In some cases, the energy issue is integrated within other departments of local governments (such as in Durango, Morelos, Quintana Roo, Sinaloa, Sonora, or Zacatecas). On the other hand, there are federal entities that do not have clearly identified agencies to address this area (for example, Chiapas, Colima, Michoacán, San Luis Potosí, Nayarit, Guerrero, Coahuila, and Tlaxcala). For this reason, it is necessary to study in detail the role that this type of institution can play in supporting the energy transition. The above would facilitate the implementation of federal public policies at the local level and would also contribute to the construction of strong and well-articulated institutions.

About half of the interviewees agreed that coordination among the three levels of government is essential for the success of energy projects. Although each project has dimensions and characteristics that make it unique, much of the success in its implementation depends on effective communication among all the actors involved. In this area, the role of SENER stands out as a facilitator among state governments in order to provide the necessary information to municipal governments.

In addition to government participation, it is necessary to have a robust legal framework and clear public policies that encourage investment while taking into account the needs and desires of the population, as well as the economic vocation of the territories. Thus, it is necessary to actively involve the population not only in decision-making but also in the monitoring of project development.

In this regard, community training in energy issues allows greater involvement of the population. Likewise, it ensures the continuity of projects beyond changes of administration, which can generate delays or even halt projects of interest to the community. The example of municipal associations in Germany for the local organization of energy project management stands out.

The importance of developing technical and technological capacities that ensure an equitable distribution of the benefits of the energy transition also stands out. To this end, it is essential to strengthen the links between industry, universities, and research centers. In particular, the government has a key role in establishing strategic alliances between the private sector and academia, through the definition of the terms under which the projects will be developed.

In this regard, the energy industry can become a regional economic engine if collaboration with academia is promoted and value chains are strengthened. Thus, negotiations between government and industry must consider not only economic aspects but also the exchange of knowledge and cutting-edge technologies.

This linkage between energy projects and academia is nothing new since the study of the four ET actions analyzed throughout this document are included in the National Strategic Programs of CONAHCYT (Pronaces), which opens new opportunities for collaboration to design action plans in accordance with the needs of the communities.

For example, in the case of the retirement of fossil plants, National Research and Incidence Projects (Pronaii) could be proposed focusing on the remediation of environmental impacts in the territories where a fossil plant is planned to be retired, as well as health and quality of life diagnostics for the surrounding population. With regard to the installation of large-scale solar and onshore wind generation, a Pronaii could be promoted to foster dialogue and determine the energy needs of the communities in order to seek solutions that benefit them and, at the same time, improve the acceptance of new projects. Finally, in the case of residential DG, in addition to being included in the Pronaces energy line, it can also open opportunities for collaboration in the housing line to promote a research agenda based on meeting the thermal needs of the population, according to the different climates, in order to make efficient use of energy and have the necessary conditions for the installation of residential DG systems.

## 6.6 State-level capacity to face the challenges of the JET

The public policy recommendations presented in the previous sections require enabling conditions for their implementation and effectiveness. As was noted, many of the actions necessary for the JET in Mexico must be defined at the national level; however, their implementation falls on the institutional capacities of the states and municipalities. Thus, state heterogeneity represents an additional challenge since it implies that ET actions will not be implemented from an even starting point. It is important to note that the role of decentralized federal states continues to be less relevant than the authority and weight of SENER in the new Sheinbaum administration, especially with regard to large-scale plant projects. SENER retains the responsibility for the implementation of projects and for binding regulation.

This section analyzes the response capacity of the states according to their participation in the four ET actions that have been analyzed in the document. For each case, aspects such as the zoning established in land-use planning instruments, local economic vocation, and productive diversification strategies are studied, considering the existence of an institutional framework for state energy policy.

The objective is to show how state conditions can facilitate or limit the effectiveness of the proposed policies and to underline the need to adapt the planning instruments to different contexts. In the following paragraphs the cases of the ten states analyzed through the vulnerability index are briefly described: Coahuila, Veracruz, Guerrero, Chihuahua, Sonora, Puebla, Nuevo León, Tamaulipas, Baja California, and Sinaloa.

Coahuila is a key state for the JET, since it concentrates almost 44% of the country's coal-fired generation capacity (CFE). It stands out for a diversified economy in different regions of its territory (manufacturing industry in the southeast, agriculture and construction in La Laguna, and manufacturing in the north). However, the coal-mining region is based on extractive activities, although potential has been identified for hunting tourism, livestock, and aquaculture activities (Ministry of Economy, n.d.-b). The commitment to the energy transition is reflected in the plan to expand the highway network and connect the Desert region, recognized for its high renewable potential, as well as in the State Climate Change Program 2022–2031, which establishes various actions to reduce emissions from the energy and industrial sector (Government of Coahuila, 2022). Nevertheless, it faces structural challenges such as the lack of an updated land-use planning plan for the coal-mining region, weak institutional coordination, and limited social participation. Additionally, the overexploitation of mesquite wood and aquifer resources in mining areas, as well as the lack of alternative jobs, accentuate the vulnerabilities of the population. The absence of clear and quantifiable objectives specifically oriented toward the energy transition in the Development Plan 2023–2029 prevents drawing a defined roadmap for the development of renewable energy projects and committing local authorities to a just transition (Government of Coahuila, 2023). The Government of the State of Coahuila de Zaragoza also has the Law for Adaptation and Mitigation of the Effects of Climate Change, a 2016 baseline Inventory of Greenhouse Gas and Compound Emissions, but it does not have an Energy Agency. It should be mentioned that the Strengthening and Expansion Plan of the SEN 2025–2030 contemplates the introduction of 2 photovoltaic plants in Coahuila, on the same CFE-owned land where the coal-fired plants are located, in order to progressively replace fossil generation with renewable generation (Presidency of the Republic, n.d.).

With respect to Veracruz, which also produces electricity from fossil sources and is an oil-producing state, there is high potential to expand renewable generation, particularly solar photovoltaic, considering that more than half of its territory receives irradiation greater than 5 kWh/m² (SOLARGIS, 2025a). It has a state energy agency and has developed about twelve instruments focused on emission reduction, air quality, and solid waste management, as well as land management. However, the Development Plan 2019–2024 recognizes that there is weak linkage between the public and private sectors in energy matters, which limits the use of opportunities to advance in clean energies and energy efficiency (Veracruz Development Plan (PVD) 2019–2024, 2019). Considering that the manufacturing industry (industrial production of tubes and pipes) is the main activity, the need for a robust and reliable electric grid that can support the growth of productive activities in the state stands out (Ministry of Economy, 2025b). According to the Development Plan 2025–2030, the unregulated expansion of productive activities and the change in land use have generated significant impacts on ecosystems and natural resources (Veracruz Development Plan (PVD) 2025–2030, 2025). This situation is aggravated by the absence of ecological land-use planning programs in 81.7% of the state territory. The areas most vulnerable to extreme weather events are the low-lying areas with irregular settlements and the coastal regions, recurrently exposed to both natural and anthropogenic phenomena, including floods, droughts, frosts, and health problems derived from environmental pollution. It should be noted that the Transformation Projects contemplated in the Plan do not incorporate renewable energy infrastructure. Likewise, the National Institute of Ecology and Climate Change (INECC) only records a state climate change program from 2009 that has not been updated, and to date there is no specific regulation governing this matter at the state level.

For its part, Chihuahua stands out as one of the states with the greatest potential for the addition of solar capacity, with viability for photovoltaic generation, located in the arid region of the state (SEMARNAT, 2025). Its Energy Territorial Planning Model (MOTE) stands out, which allows for integrated planning of the state's energy development, considering areas where resource exploitation and infrastructure are viable, which has the potential to minimize environmental impact while giving greater certainty to economic development (Energy Territorial Planning Model, 2024). The state focuses on forestry and agricultural activities with a strong presence of manufacturing (Ministry of Economy, n.d.-a). In addition, it has different industrial parks and others in the planning process that could be used for the development of local value chains in clean energies. Nevertheless, climate change represents a significant threat for this state due to extreme temperatures and low water availability, which makes it necessary to implement public policies aimed at water resource management in parallel with ET strategies. The state of Chihuahua has, since 2022, a state agency for energy development. In the Development Plan 2021–2027, a specific strategy is contemplated for the implementation of the State Climate Change Program, which includes updating the State Law on the matter, as well as the preparation of mitigation and adaptation plans. Although there are municipal plans, no updated state plan on climate matters has been identified to date.

The state of Puebla has high potential for the development of renewable energies at the state level, including solar, wind, and distributed generation. According to the State Climate Change Strategy 2021–2030, solar potential is particularly favored. More than 50% of the territory presents radiation above 6000 $Wh/m^2/day$, and some areas in the south of the state reach up to 7000 $Wh/m^2/day$ (Mexico Climate Initiative, 2021). According to the State Energy Agency (2020), the municipalities with the greatest photovoltaic potential include: Acatzingo, Chalchicomula de Sesma, Chignahuapan, Izúcar de Matamoros, Libres, Quimixtlán, Tecamachalco, Tehuacán, Tepeaca, and Tepexi de Rodríguez (Government of the State of Puebla, 2021). Puebla is the second-largest automotive producer in the country, after Aguascalientes, and has a consolidated economic infrastructure, with 18 industrial and technological parks, a road network of more than 10,000 km, and an international airport (Ministry of Economy, 2025b). This strategic connectivity positions it as a key hub for economic activity in central and southeastern Mexico. In terms of energy governance, the state has an Energy Efficiency and Transition Strategy, a Secretariat of Environment, Sustainable Development, and Land-Use Planning, as well as a State Energy Agency. To foster the sustainable use of renewable resources, Puebla has developed an Energy Territorial Planning Model that identifies land suitable for energy development, excluding those with environmental restrictions. Nevertheless, 80% of the state's territory is vulnerable to hydrometeorological phenomena such as cyclones, hurricanes, and tropical storms, which poses significant challenges for resilient energy planning (Government of the State of Puebla, 2021).

Sonora has a solid institutional and regulatory framework at the regional level, further supported by strategic guidelines of national scope, which creates particularly favorable conditions to advance in the energy transition. Nevertheless, the dimension of social justice in these processes is still not guaranteed, which poses challenges in terms of territorial equity, inclusive access to energy benefits, and effective community participation. With an installed capacity of 1,695 MW (CRE, 2023), Sonora is the state with the greatest solar generation in the country and also has high potential for the development of distributed generation. Its economy is diversified, with sectors such as mining (gold, copper, among others), agriculture, manufacturing, and commerce standing out, which positions it as a key actor in primary and secondary production at the national level. The state has adopted an industrial policy articulated in the "Sonora Plan for Sustainable Energies," whose objective is to drive the transition toward a low-carbon economy, strengthening the development of renewable energies and promoting a sustainable society (SEMARNAT, 2024). One of its strategic axes is Human Talent, which seeks to incorporate engineers, mainly local ones, into the new industries through advanced technical training, decent jobs, and participation in economic development. The state regulatory framework on renewable energies establishes the possibility of delimiting specific zones for the installation of energy infrastructure (solar plants, wind farms) and ensuring the compatibility of these uses with territorial planning. In this sense, the state land-use planning strategy contemplates the characterization of the territory according to its natural potential—such as solar radiation in desert areas or wind in coastal and mountainous areas—as well as the integration of sustainable development criteria, in line with environmental protection and the rational use of land (Government of the State of Sonora, 2018). Finally, the State Development Plan 2021–2027 explicitly incorporates the principles of the 2030 Agenda, reinforcing the state's commitment to the global sustainability goals (Government of the State of Sonora, 2021).

The state of Guerrero has an economy based on tourism, commerce, and agricultural activity. According to the State Development Plan 2022–2027, Guerrero holds a prominent position in national production of crops such as coconut, hibiscus, mango, sesame, and melon, among others (Government of the State of Guerrero, 2022). Nevertheless, the state shows high sensitivity to the impacts of climate change. It is recurrently affected by extreme events such as hurricanes, floods, droughts, heat waves, and cold waves. The case of Hurricane Otis in Acapulco (2023) clearly illustrates these risks. According to scenarios from the National Ecology Institute (INE), Guerrero is classified with high climate vulnerability and will face medium pressure on water resources by 2025. Likewise, a rise in sea level is expected that will directly impact the coastal areas.

In terms of institutional capacities, Guerrero has a State Energy Commission and Climate Change Law Number 845 (2015), which contemplates the incorporation of land-use planning and urban development criteria aligned with climate risks and adaptation actions. However, to date no specific state plan for energy transition has been identified, despite the existing regulatory framework, nor a state agency dedicated to energy. It should be noted that the Transformation Projects included in the Development Plan do not make reference to renewable energy infrastructure. The Land-Use Planning Plan for Urban Development of the State of Guerrero (POTDUEG) identifies areas with potential for renewable energies, particularly solar and wind. The areas with high solar radiation in Tierra Caliente and Costa Grande stand out, as well as the Central and Northern regions with significant wind potential. Although the POTDUEG does not include detailed energy mapping, it can indirectly influence the location of projects through land-use guidelines. In addition, it incorporates evaluation indicators that could facilitate the resolution of key problems, including those related to renewable energies. According to the National Climate Change Vulnerability Atlas, the municipalities with the greatest vulnerability of human settlements to floods are Mochitlán, Juan R. Escudero, Chilapa de Álvarez, Quechultenango, and Benito Juárez (INECC, 2022). In terms of forage production under water stress, the most affected are General Canuto A. Neri, Pungarabato, Arcelia, Pilcaya, Atenango del Río, Buenavista de Cuéllar, and Juan R. Escudero. No specific state plan has been identified, despite the existence of a dedicated law.

Nuevo León has a strongly industrial and manufacturing economy, with a growing network of industrial and technological parks linked to the phenomenon of nearshoring (Ministry of Economy, 2025a). Thus, the state represents 7.9% of the national total, ranking only behind Mexico City and the State of Mexico in 2023 (INEGI, 2023). Despite this economic dynamism, the energy transition in the business sector is still limited: only 13% of companies have adopted photovoltaic energy systems, which shows a wide margin of opportunity to move toward cleaner and more sustainable sources (El Economista, n.d.). In regulatory terms, the Law on Human Settlements, Land-Use Planning, and Urban Development for the State of Nuevo León—enacted in 2017 and reformed in May 2025—establishes the State Program of Land-Use Planning and Urban Development (PEOTDU-NL). This instrument defines land uses, land reserves, citizen participation mechanisms, and intergovernmental coordination frameworks. Nevertheless, the absence of clear zoning specifically oriented toward the development of renewable energy infrastructure persists. Since 2023, the state has had a Renewable Energy Agency, which represents a significant institutional advancement. In addition, the Nuevo León Development Plan 2022–2027 includes a specific section on climate change and challenges associated with the energy matrix, highlighting the implementation of a Decarbonization Pathway toward 2050 and the promotion of mitigation actions aligned with the state's sustainability commitments (Congress of the State of Nuevo León, 2017, 2023, 2024).

The regulatory framework of the state of Tamaulipas in terms of energy transition is distinguished by the existence of multiple legal instruments that articulate climate, energy, and territorial objectives. The Climate Change Law establishes concrete emission reduction goals and promotes the use of renewable energies, energy efficiency, and sustainable mobility (Congress of the State of Tamaulipas, 2021). For its part, the State Climate Change Program 2015–2030 contemplates lines of action oriented toward mitigation, as well as economic incentives for low-emission technologies. Additionally, the Law for the Promotion and Sustainable Use of Energy introduces tax incentives aimed at sustainable energy projects (Congress of the State of Tamaulipas, 2015). In the territorial sphere, the Ecological Land-Use Planning Programs, established by mandate of the climate legislation, coordinate land use, risk management, mobility, and urban development in coherence with sustainability objectives. Nevertheless, despite the validity of these frameworks, uncertainty persists regarding the effective integration of priority energy projects into territorial planning instruments, both at the municipal and regional levels, which poses a risk of institutional and operational misalignment.

Solar radiation in Baja California is highly favorable, due to the high geographical exposure of the territory (SEMARNAT, 2025). Nevertheless, the Development Plan 2022–2027 presents an imprecise formulation in energy matters, with a limited focus on microgrids and a general mention of renewable energies, without technical specifications or quantifiable goals. Similarly, the Environmental Protection Plan 2022–2027 maintains a vague formulation regarding the concrete objectives of implementation (Government of the State of Baja California, 2022). The state also faces structural challenges in energy supply. Baja California is not interconnected with the National Electric System, which limits its capacity to balance energy supply and demand in critical situations. This disconnection increases its vulnerability to variations in local generation and limits the efficient incorporation of large-scale renewable sources. Infrastructure constraints and limitations in access to diversified energy sources have historically generated episodes of energy insufficiency, affecting both productive sectors and the population. At the regulatory level, the state has a series of instruments—among them the Climate Change Law, the POEBC 2014, urban planning and development laws, and state climate change plans—that offer a formal framework to integrate the energy transition into territorial planning. However, the lack of specific zoning for renewable energy projects, still incipient technical deployment, and limited interinstitutional articulation restrict the operational impact of said framework.

Sinaloa constitutes a strategic hub for agricultural and agri-food production in Mexico, with intensive activity in vegetables, fruits, cereals, livestock, and fishing. The state's climatic and environmental conditions favor high rural productivity and a consolidated development of its agri-food industry nearshoring (Ministry of Economy, 2025a). In energy matters, Sinaloa has highly favorable solar potential, still underutilized, particularly in public and private urban infrastructure. The state has begun to promote some innovative initiatives—such as green methanol projects and renewable energy training programs—but its territorial and climate planning instruments remain, to a large extent, at a declarative level and lack specific zoning that promotes distributed generation, especially on urban rooftops. Added to this is weak institutional structuring to lead the energy transition at the local scale.

For an ambitious distributed solar energy program to become operational in Sinaloa, it would be necessary to: (i) update the State Climate Change Action Plan (PEACC) with clear goals and an updated energy scenario; (ii) incorporate into land-use planning a detailed mapping that identifies priority urban areas for the installation of solar panels on public and private rooftops; (iii) create a solid technical entity responsible for coordinating energy, climate change, and land-use planning policies; and (iv) launch specific incentives programs—financial, technical, and fiscal—aimed at promoting distributed generation.

It is noteworthy that, in 2025, Sinaloa became the first state in the country to develop a State Climate Action Plan specific to the fishing and aquaculture sectors, which constitutes a significant sectoral advance (Congress of the State of Sinaloa, 2025). However, the state's water infrastructure is particularly vulnerable to water stress associated with drought, a phenomenon that recurrently affects most of the state's territory. This critical water condition underscores the urgency of integrated energy and climate strategies, especially in regions highly dependent on natural resources.

# 7 Conclusions

This study presents a comprehensive vision of the vulnerabilities associated with four ET actions in Mexico: the retirement of fossil plants, the addition of large-scale solar photovoltaic and onshore wind capacity, and the promotion of residential distributed generation. Based on a literature review on the impacts of implementing these ET actions, the construction of state socioeconomic vulnerability indices, and interviews with experts on these actions, specific and cross-cutting public policy recommendations were identified for ET actions that have the potential to mitigate these vulnerabilities.

1. Strengthening governance and strategic planning, with an emphasis on intergovernmental coordination and the inclusion of local actors in project design.
2. Mitigation of socioeconomic impacts and protection of vulnerable communities, through just transition mechanisms, compensation funds, and labor reconversion programs.
3. Promotion of distributed generation, particularly in marginalized areas, as a mechanism for energy democratization and reduction of energy poverty.
4. Development of capacities and technology transfer, promoting technical education programs, job training, and alliances with academic institutions and innovation centers.
5. Mitigation of environmental impacts, ensuring comprehensive project evaluation and ecological compensation mechanisms in sensitive territories.
6. Mitigation of gender impacts, incorporating the gender perspective into energy policies and promoting the participation of women in all links of the energy value chain.

The interviews revealed an enormous challenge: the need for dialogue and effective coordination among the different levels of government, as well as among the various secretariats and institutions of the Federal Government. In addition to participatory and inclusive dialogue with all the groups that make up the communities in order to carry out the effective implementation of the projects addressing the country's energy, social, and environmental needs.

Additionally, it is necessary to consider the heterogeneity that exists not only among the federal entities, but also in the municipalities and localities that compose them. The "one size fits all" approach is not the right one. Knowing the social and geographic characteristics of the territories is crucial to offer projects that generate an impact not only on their energy demand, but also on the reduction of already existing inequalities.

In this sense, the state vulnerability index showed that the implementation of an action in different states implies different levels of vulnerability. In particular, when considering more industrialized northern states compared to the south, whose economy is based on primary activities. Furthermore, although states may appear to be at the same level, it is possible that they are heterogeneous in terms of the scores in the dimensions of exposure, sensitivity, and adaptive capacity. Thus, knowing the detail of these dimensions makes it possible to identify the strengths and weaknesses of the states when designing public policies to mitigate vulnerabilities.

Generation potential is not only important for project planning. It is also necessary to consider the marginal impact that an additional project would have in the region, as well as the existence of prior conflicts in order to listen to the population and respect their decisions regarding the installation of new projects. Additionally, it is necessary to identify economic activities that can be developed in the region, beyond energy, in order to pave the way for the implementation of new activities and reduce dependence on others that have been carried out for generations; for example, mining.

Finally, the distribution of benefits is key among all members of the community in order to make them part of the projects. It is not only about economic benefits and small infrastructure works; it is necessary to offer benefits that allow communities to experience real long-term growth—for example, the development of local human capital through linkages with academic institutions and developers.

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Agence française
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