A glimpse into smart cities: opportunities for the development of energy cooperatives for citizens and businesses in Mexico

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Abstract: Smart cities are a local development model that has found success in recent years both in the scientific literature and in local policies. Although traditionally related to the use of technologies, clean energies are a key dimension of the concept and are promoted for the development of sustainable cities and communities. Mexico has a high potential for renewable energy generation, particularly solar energy, which represents an opportunity for national development and energy security. However, Mexico's history and economic performance, strongly linked to the energy sector, make private initiative in this area highly regulated by the state. This chapter explores the opportunities offered by locally determined energy projects combined with the cooperative model as a way to reconcile interests within the Mexican energy sector. In addition, it presents how they can contribute to addressing the country's energy poverty, as well as reducing carbon emissions when promoted among industries and companies. In this way, energy cooperatives can promote the development of a democratic Mexican energy system, while diversifying the energy mix and benefiting the public, private and social sectors.

Keywords: smart cities, energy cooperatives, bottom-up initiatives, local development, sustainable development goals.

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Introduction

In the last 20 years, the concept of the smart city has taken prominence both in the scientific literature and local policies, making different authors and institutions set out specific definitions and elements in order to better understand what this implies (Albino et al., 2015, pp. 3-21). Although there is no universal definition of the smart city, three documents at the international level serve as references and place the use of technologies at the heart of the concept. These include the following: the 2030 Agenda for Sustainable Development and the New Urban Agenda Habitat III (both documents from the United Nations), as well as the ISO 37122:2019 standards establishing definitions and methodologies for a set of indicators for smart cities. In Mexico, even though there is no normative text that homogeneously defines smart cities, the National Commission for the Efficient Use of Energy (CONUEE, 2017) has considered them to be a city model that connects its inhabitants through infrastructure and the efficient use of technology.

Smart cities are indeed a trend-setting model of local development, and while the use of technology is the main element of the concept, their wide scope allows that any local project applying innovative technologies can call itself a “smart city”. However, critical literature has expressed concern about the growing role of the technological private sector in the development of smart city projects, as the marketing objectives and return on the capital of enterprises may indeed conflict with the general interest and efficient management of public resources and services, originally conceived to serve society unselfishly (Grossi & Pianezzi, 2017, pp. 79-85). In response, some authors propose developing projects with a bottom-up dimension, which implies first identifying local needs and problems, and then determining projects based on locally available resources (Niaros, 2016, pp. 51-61).

A literature review shows that clean energies are a key dimension of the smart city concept and are considered to be a viable solution for achieving integral sustainable development. Therefore, although traditionally smart cities are related to the use of technologies, this paper focuses on the manner in which locally determined energy projects can be seen as a smart solution for the development of sustainable territories. Mexico has a high potential for the development of renewable energies including solar, wind, bioenergy, hydropower and geothermal energy (Elizondo et al., 2017, p. 15). Mexico’s solar energy potential is particularly relevant as it has one of the top five solar irradiation levels in the world, with a daily average of 5.5 kWh/m2 and a potential to cover up to 45% of demand (García Bello, 2019). The implementation of smart city projects, with regard to the production of renewable energies, represents an opportunity for energy transition in Mexico (IRENA, 2015) and could help to meet Sustainable Development Goal (SDG) 7 on the access to affordable, reliable, sustainable and modern energy for all, as well as SDG 11 on the creation of sustainable cities and communities.

Moreover, it is considered that the cooperative model can contribute to the sustainability of local energy projects, as it is a form of social organization motivated by the common interests of its members. In Mexico, they are defined as a “form of organisation made up of natural persons based on common interests and the principles of solidarity, self-help and mutual assistance, with the purpose of satisfying individual and collective needs through the performance of economic activities of production, distribution and consumption of goods and services” (General Law on Cooperative Societies, Article 2). In such considerations, cooperatives are seen, on the one hand, as entities that favour the democratic management of energy production and consumption according to the community’s energy needs; and on the other hand, as entities that can contribute to bringing energy to marginal areas where investment may be costly for governments or unattractive for businesses (COPAC, n.d.).

This chapter focuses on how locally determined energy projects, combined with the cooperative model, can be seen as a smart solution from a bottom-up perspective for Mexico’s national development and energy security. It starts by briefly setting Mexico’s energy industry context and the country’s commitments on climate change; then, it addresses the issue of energy poverty in Mexico and the challenges for the industry and business sector as leaders of energy consumption in the country; and finally, it states a conclusion that comprises recommendations and suggestions for future research, in light of Mexico's climate commitments and the new government’s energy strategy (2018-2024).

Context of the Mexican energy industry

It is a matter of historical fact that in the 1930s, after a long labor dispute of *"El Aguila" and others in the economic conflict with the Union of Oil Workers of the Mexican Republic* (1938), the Supreme Court of Mexico ruled in favor of the workers of foreign oil companies, culminating in the expropriation and further nationalization of the oil industry (PJF, 1999). This made the energy sector largely linked to the economic performance of Mexico for the next 80 years (Colmenares, 2008, p. 53) and, for instance, between 2007 and 2013, oil revenue represented from 31 to 38% of fiscal income and from 7.4 to 8.7% of the national GDP (Oswald, 2017, p. 155). The energy industry is a sensitive issue in Mexican politics and the participation of the private sector in this area is highly regulated by the State (Climate Transparency, 2019, p. 9).

Yet, within the last decade, Mexico has entered a period of important structural reforms that break with this long-standing tradition of a hard state monopoly on energy matters. This includes the General Climate Change Law (LGCC) of 2012; the Energy Reform of 2013; the Electricity Industry Law (LIE) of 2014; and the Energy Transition Law (LTE) of 2015. Within this framework, energy policy remains the sole responsibility of the State, but the door is open for the government to enter into contracts with individuals to participate in activities related to the electricity industry (Mexican Constitution, Article 27). This represents an opportunity to promote locally determined renewable energy projects as local governments, citizens and enterprises may participate directly in the generation, trade, transmission and distribution of electricity (CEMDA, 2017, p. 19). Moreover, the cooperative model can play a significant role in the promotion of such types of projects as it is recognized by the Mexican Constitution (Article 25) as a form of social organization for the production, distribution and consumption of socially necessary goods and services.

In that sense, and considering the solar potential that Mexico has, a strategy based on the development of photovoltaic energy could bring great benefits both for the government and particulars, thanks to the development of the cooperative model in the country. Indeed, the Ministry of Energy of Mexico (SENER, 2017) estimates that the installation of solar panels, for distributed energy generation, for 1% of the total generation capacity of the country, could represent public annual savings of around MX 1.5 billion, plus 680 million liters of unused water, and 1.3 million tons of carbon dioxide (MtCO2e) not emitted. In addition, it is considered that US$20 trillion in cooperative assets can produce around US$3 trillion of annual income (Grace et al., 2014, pp. 1-2). Mexico can then take advantage of the benefits offered by this model, while diversifying its energy matrix with clean energies and increasing a culture of cooperativism in all its types, regions and social backgrounds throughout the country.

Mexico's state of play and commitments to climate change and clean energy by 2050

Mexico is one of the signatory countries of the 2015 Paris agreement (COP21) and on this basis, the country is committing itself to reduce substantially its greenhouse gas (GHG) emissions to limit the increase in global average surface temperature to below 2°C above pre-industrial levels (Bruckner et al., 2014, p. 569). In 2013, Mexico ranked 11th in the world in terms of GHG emissions, which means equivalent emissions of 489 MtCO2e, representing 1.4% of global emissions (Rodríguez, 2017, pp. 182-191). The LGCC (Second transitional article) mandates to reduce the country's emissions by 30% by 2020 and 50% by 2050, in comparison with 2000; the National Congress has also set limits in the use of fossil fuels for electricity generation of 65% by 2024, 60% by 2035 and 50% by 2050. The Ministry of Energy of Mexico has integrated these objectives into the national development policies of the electricity sector, yet without precise quantitative targets, due to the absence of technical and economic studies on the large-scale integration of different types of clean and renewable energies (Vidal-Amaro et al., 2015, pp. 80-96).

The latest National Inventory of GHG emissions of Mexico (2018) states that the country emitted 683 MtCO2e in 2015 of which 64% corresponded to fossil fuel consumption; 10% from livestock production systems; 8% from industrial processes; 7% related to waste management; 6% from fugitive emissions from oil, gas and mining extraction; and 5% generated by agricultural activities. Conversely, 148 MtCO2e were absorbed by vegetation, mainly forests and jungles; the balance between emissions and removals for 2015 was then 535 MtCO2e, while in 1990 these were 445 MtCO2e. This means that between 1990 and

2015, Mexico's emissions increased by 54%, with an annual growth rate (AER) of 1.7%, but also AER from 2010 to 2015 decreased to 0.8% (INECC and SEMARNAT, 2015).

In such a context, Elizondo et al. (2017, p. 19) project that by 2050, industry and transportation are likely to lead Mexican energy consumption, accounting for around 80% of demand; buildings (heating, cooling and cooking) will account for 15-20%; and the remaining 3-7% will be related to lighting. While it is estimated that half of the energy generated in 2050 will come from fossil fuels (oil and gas), it is also considered that there are good opportunities for Mexico to rely primarily on clean energy for electricity supply (mostly renewable energies) essential for heating and tackling energy poverty in the country (Elizondo et al., 2017, p. 24). Furthermore, considering that the industrial sector is the absolute leader in terms of energy demand, the government's energy strategy should consider not only the development of clean energy, but also promote energy efficiency and coordinate actions with local and transport authorities in order to comprehensively address GHG reduction, whereas mitigation measures could be shared between agricultural waste management and forestry (Elizondo et al., 2017, p. 24).

The challenge of inequality: Tackling energy poverty through locally determined energy projects

Although there is no harmonized definition of energy poverty in Mexico, García-Ochoa and Graizbord (2016, pp. 289-337) consider that this concept encompasses the lack of access to energy, the insufficient supply and the lack of economic capacity of households to meet all energy needs. In this regard, Mexico has 12.4 million households living in energy poverty (43.4% of the total), of which 7.8 million reside in urban areas (27.5%) and 4.5 million in rural environments (16%); additionally, energy poverty in Mexico increases as one moves from the urban to the rural, although in absolute terms, urban energy poverty is almost double that seen in rural areas (García-Ochoa, 2014, p. 19). Locally determined energy projects could represent a smart alternative to address Mexico's energy backlog and the cooperative model can effectively support the implementation of local energy projects (ILO, 2013).

Local-scale projects also represent an area of opportunity as evidence shows that large energy infrastructures may come into conflict with local populations, who are affected by the implementation of major projects. This is the case, for instance, of socio-environmental conflicts related to the construction of hydroelectric plants in the States of Veracruz and Puebla (Casas Mendoza & Carbajal, 2017, pp. 70-93), as well as wind power plants in the states of Oaxaca and Yucatan (Zárate Toledo & Fraga, 2016, pp. 65-95). Considering such issues are particularly important in terms of investment risks since the cancellation of projects has represented losses of approximately MX 3 billion pesos (CEMDA, 2017, p. 33). Mexico's solar potential represents in those terms an opportunity to meet the energy needs of the poorest, as photovoltaic energy production can satisfy the demand for shorter lead times and reduce potential socio-environmental conflicts linked to other types of renewable energies (Vergara et al., 2016, p. 21).

According to the International Energy Agency (IEA), 70% of electricity access can be affordably met by renewable energy; for 65% of non-electrified households, the cheapest way could be through mini-grids and in 45% of households through off-grid technology (OECD/IEA, 2011 in ILO, 2013, p. IX). In this context, local and regional governments in Mexico could promote mini-grids and off-grid based solutions to address the country's energy backlog and basing projects on the cooperative model could help overcome the lack of institutions, policies, enterprises and human capacity that is characteristic of the most marginalized territories (ILO, 2013). Subnational governments can also take advantage of the distributed generation scheme, regulated by Electric Industry Law (Article 3 XXIII), as it promotes the capacity of local communities to propose, design, implement and operate their own technology (Dafermos et al., 2015, pp. 459-460).

In this respect, the Mexican legal framework provides that producers generating less than 0.5 MW are considered as "exempt generators", meaning that they do not require permission for energy production and may also participate in the Wholesale Electricity Market (WEM) through the representation of a Qualified Service Provider (LIE, Article 3 XXV). The distributed generation model in Mexico can thus enable micro-generators to meet their energy needs while facilitating the sale of surpluses in a simpler and faster manner than higher capacity sources (White & Case, 2014, p. 3). Furthermore, this type of project can activate the mechanisms considered by the Ministries of Finance and Welfare to provide clean energy to rural communities and marginalized urban areas at the lowest cost (LIE, Article 116). Projects could also benefit from the "sustainable energy financing" mechanism, considered by the Energy Transition Law (Article 55), to replace energy-inefficient equipment and devices, make improvements to buildings and install economically viable equipment to enable households to use renewable energy sources to meet their energy needs.

In summary, Mexico's energy poverty could be tackled by all three levels of government by promoting cooperative photovoltaic energy projects. In fact, electricity access can be affordably met by renewable energy and the cooperative model presents a series of competitive advantages based on a democratic control that allows better decision-making in the production, supply, distribution and consumption of electricity (ILO, 2013). Likewise, this type of project can contribute to bringing energy to marginal areas where investment can be costly for governments or unattractive for businesses (COPAC, n.d.). From this perspective, local and regional governments, in partnership with the national government, could promote community energy systems to effectively address the energy backlog in the country, particularly in marginalized urban and rural areas, while empowering people and increasing local knowledge for sustainable energy generation (Walker & Simcock, 2012, p. 194).

Reconciling interests: The benefits of the cooperative model for industry and business

Although energy production is relatively easy for "exempt generators", they do not always meet the needs of industries and businesses (leaders in energy consumption by 2050) that have to resort to medium-scale production (0.5 to 10 MW); yet the installed production capacity of small, medium and large photovoltaic arrays in recent years shows a significant growth trend that represents an opportunity for cooperativism within the Mexican industrial and business sector (DGRV, 2018, p. 122). Mexican legislation considers producers of more than 0.5MW as "qualified generators", therefore subject to the regulations of the WEM (LIE, Article 3 XLVII). Plants between 0.5 and 2 MW are particularly affected by this legal framework as the installation process is more complex and the investment less profitable; however, it is considered that industries and businesses can benefit from the cooperative model by implementing an investment system that allows the installation of larger capacity generators under a collective measurement scheme for energy production and consumption (DGRV, 2018, p. 120).

In fact, Mexican law considers a model of isolated supply for the generation or import of electric energy to satisfy one's own needs (LIE, Article 22). The Energy Regulatory Commission of Mexico (CRE, 2017) has reinforced this criterion and provided that a group of persons that have similar commercial and financial interests can be considered a "group of economic interest" in order to meet personal energy needs. This concept is in line with Mexican jurisprudence on administrative matters, which considers that a "group of economic interest" can coordinate its activities to achieve a certain common objective (Thesis I.4o.A. J/66. *Group of economic interest. Its concept and elements that make it up in terms of economic competition.* Volume XXVIII, November 2008, p. 1244). As such, this could be seen as an opportunity for industries and businesses as it allows synchronizing their activities in order to achieve a common goal and generate more than 500kW without carrying out all the formalities for participating in the WEM (DGRV, 2018, p. 124).

Notwithstanding, it is worth noting that financing mechanisms, especially for power plants of more than 0.5MW and less than 2MW, still need to be strengthened as this is the sector with the lowest return on investment (DGRV, 2018, p. 129). Commercial banking is developing financial mechanisms to meet the needs of the different groups in the distributed generation, although, it continues to face certain obstacles including price uncertainty that increases investment risk, and loans that do not give a grace period over the construction phase necessary to increase their attractiveness (DGRV, 2018, p. 129). Consequentially, the leadership of the State in the promotion, funding and integration of the concepts of ownership, design, effective participation and representation, with regard to energy production, is a necessary condition for the successful deployment of medium-scale generation plants in Mexico (Climate Transparency, 2019, pp. 6, 9).

LTE provides for financial and investment instruments and establishes that the resources for the energy transition must come from the Federal Expenditure Budget, financial instruments available for public works and services, as well as from private contributions (LTE, Article 43). Funds are intended to attract and guide public and private financial resources, national or international, to support programs and projects that help to diversify and enrich the energy matrix (LTE, Article 48). In this context, clean energy certificates (CELs) created by the Law for the Use of Renewable Energies and Energy Transition Financing (2008) can be seen as a promising mechanism, as CELs are issued by the CRE and certify the production of a certain amount of electricity as coming from clean sources (LIE, Article 3 VIII).

According to the Mexican Institute for Competitiveness (IMCO), the proper regulation of CELs can help diversify the energy mix – which had an 80% share of fossil fuels in 2015 (SENER, 2016, p. 30), while fostering a CEL's exchange market in line with the objectives of clean energy production of Mexico (IMCO, 2014, in Moreno Sánchez, 2017, p. 28). In this sense, CELs could encourage the purchase of surplus energy from medium-sized cooperative producers, thus promoting investments in energy generation, while mitigating vulnerability to supply interruptions and reducing market volatility (IPCC, 2011, p. 20). Cooperatives can then generate their own clean energy and consider a long-term repayment plan to cover the initial investment (DGRV, 2018, p. 128) through the sale of surplus energy to a trading service provider or supplier (LIE, Article 23).

While from a business perspective the objective is to make projects profitable at a low cost per kWh by competing with the prices established by the WEM, medium-scale cooperatives can offer other types of benefits to their members. This includes a reduced technology price thanks to the economies of scale, savings in electricity consumption compared with high tariffs, collective awareness raised by actively participating in the generation of clean energy and the possibility of selling the surplus generated to the distributed generation network (DGRV, 2018). In addition, they can collaterally favor access to affordable clean energy, encourage the creation of local jobs, contribute to improved performance of the national energy grid and, in general, promote economic sustainability (ILO, 2013, p. 29) and energy security for the poorest communities, industries and businesses.

Conclusions

The smart city concept has developed in recent years as a way of providing solutions to local problems through the use of technology. Although the concept is broad and its scope diverse, the implementation of clean energy projects is shown to be a central axis of the smart city concept and can contribute to promoting sustainable development and reducing carbon emissions. In the case of Mexico, history and national economic performance are strongly linked to the energy sector, which makes the participation of the private sector in this area highly regulated by the State. Furthermore, although in recent years the Mexican energy sector has been opened to various types of investments, in particular by States, municipalities and the private sector, in practice, energy policy remains a matter of federal competence, which means that there is a degree of centralization in this area that significantly affects the development of smart energy projects at the local scale.

The cooperative model can help reconcile interests within the Mexican energy sector, thus contributing to the development of local projects, the promotion of investment, and diversification of the energy mix in favor of energy security and the creation of a democratic national energy system. Indeed, cooperatives are shown to be important contributors to the development of smart local energy projects, favoring democratic management of energy production and consumption according to the energy needs of a community, while bringing positive benefits to the State, business and society at large. In addition, based on the cooperative model, the development of locally determined smart energy projects can help address two main issues related to the energy sector in Mexico such as the country's energy backlog and poverty, and the reduction of carbon emissions from the industrial and business sectors as leaders of energy consumption by 2050.

In this way, the government could promote mini-grids and off-grid solutions to address the country's energy backlog, while overcoming the lack of institutions, policies, enterprises and human capacity of most marginalized areas. Micro-generators can then meet their energy needs and sell their surplus energy production under the country's distributed generation scheme. Moreover, projects can take advantage of the policies and strategies considered by the Ministries of Finance and Welfare, as well as of the "sustainable energy financing" mechanism considered by the Energy Transition Law, to provide clean energy to rural communities and relegated urban areas at the lowest cost. Finally, they can allow better decision-making in the production, supply and distribution of electricity, while empowering communities and increasing local knowledge for sustainable energy generation.

In the same manner, the government can encourage cooperativism among industries and businesses as "groups of economic interest" in order to produce their own energy needs and promote energy efficiency in this sector. The expected benefits can be translated into a reduction in the price of technology through economies of scale, savings in electricity consumption compared with high tariffs, collective awareness raised by actively participating in the generation of clean energy and the possibility of selling the energy surplus to the distributed generation network. In this context, CELs could be seen as a tool to promote a market for the purchase and sale of clean energy, enabling medium-scale cooperatives to meet their energy needs, while considering a repayment plan to cover the initial investment through the sale of energy surplus to a trading service provider or supplier. This can help increase interest in clean energy production, thereby diversifying and enriching the energy mix, mitigating vulnerability to supply disruptions, as well as reducing energy market volatility.

Finally, yet importantly, although the Mexican government (2019-2024) has stressed the importance of the development of smaller-scale and locally determined renewable energy projects, major State investments have been focused, until today, on increasing the exploitation of hydrocarbons and the renovation of the national hydroelectric system. Detailed monitoring of these plans is suggested for further research and their examination, in light of climate change commitments, is relevant to the assessment of Mexico's energy transition. Similarly, the development of cooperatives as a form of social entrepreneurship, empowerment and active participation of Mexican society in energy transition is also suggested as a topic of interest for future research.

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