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Socio-technical analysis of the electricity sector of Mexico: Its historical evolution and implications for a transition towards low-carbon development

Marco A. Jano-Ito [a,*], Douglas Crawford-Brown [a]

[a] Cambridge Centre for Climate Change Mitigation Research (4CMR), Department of Land Economy, University of Cambridge, 19 Silver St, Cambridge CB3 9EP, United Kingdom

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ABSTRACT

The electricity sector of Mexico has been found itself in continuous transitions since its beginning in the 19th century. However, the historical reform to the sector that recently took place together with new energy market configurations around the globe may pose an important challenge to transitioning towards a low-carbon sector. The work presented here was aimed at understanding in a qualitative manner the complex interactions between the main social, technical and environmental aspects that have guided the sector in the past, their influence on the current structure and its future development, through the application of the multi-level perspective (MLP) with a governance and agency perspective. Additionally the work tried to elucidate the implications of the incumbent position of the natural gas industry and the possibilities for low-carbon technologies. The conclusions remark the importance of previous sector configurations in the present structure; the important role of government in promoting low-carbon technologies together with investment by market actors; and the possible window of opportunity that the natural gas industry in Mexico may provide to low-carbon energy technologies.

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* Corresponding author. Tel.: +44 7931018098.
E-mail address: maj52@cam.ac.uk (M.A. Jano-Ito).

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1. Introduction

The increasing evidence of the negative impacts of greenhouse gas (GHG) emissions on the global climatic system and in consequence to societies, has forced developed and developing economies to look for alternative energy pathways that could lead towards a low-carbon world. As an important member of the international community, Mexico presents an interesting case study since its energy sector has been recently reformed and at the same time, has taken an active role in international climate change negotiations. Moreover, the government has incorporated climate change as an important part of its political agenda and reassured its commitment to reduce greenhouse gas (GHG) emissions, setting a 30% GHG emission reduction goal by 2020 with respect to 2000 levels and 50% by 2050 [1–2]. In accordance to this, it has also established ambitious targets for low-carbon electricity generation. Despite this, the share of low-carbon technologies in the energy mix to date has not been sufficient to meet the established goals by the Ministry of Energy (SENER) and there is still an enormous potential to be harnessed from renewable resources. The task involves the understanding of a non-linear, highly diverse and complex system, whose behaviour emerges from the individual actions of its actors together with its engineering and technical characteristics.

The research work presented here reviews the historical socio-technical transition pathways that have guided the development of the Mexican electricity sector and explores the possible low-carbon transition pathway in order to answer the following questions: How have the different structures of the sector evolved and what are their impacts in the current structure? What are the implications of the current socio-technical network in the future development of the sector with respect to its ability to meet the increasing energy demand and transitioning towards a low-carbon sector?

This work is built on the multi-level perspective (MLP), focusing on the governance structures and actors. Additionally, it analyses the incumbent role of the natural gas industry and its future impact on the electricity sector. The work presented here updates and complements the existing literature on renewable energy prospects, barriers and policy implications of reform in the electricity sector of Mexico by taking a complex systems perspective [3–5]. Section 2 briefly describes the theoretical framework that is used in this work. Section 3 applies the MLP and presents the historical evolution of the sector while Section 4 presents the current situation of the sector, focusing on the possible forces that may shape it in the future and its low-carbon development.

2. Theoretical review for understanding transitions

The study of transitions in the context of socio-technical systems has gained importance since the 1980's and the main theoretical framework that has been developed to understand their nature relies on the multi-level perspective (MLP) approach [6]. The MLP has been described before and extensively used for analysing different technological regimes; and describes transitions, as endogenous and exogenous pressured changes and internally driven changes in the cognitive framework of agents [6–12]. As its name suggests, the MLP involves three levels: the micro, meso and macro-levels. The micro-level (technological niches) represents the level where innovations emerge with an unstable socio-technical framework. At this level, there are a reduced number of actors who support these technologies and serve as their incubation room [13]. The meso-level corresponds to the socio-technical regime which is defined by the heuristic set of behavioural rules and technological aspects that form the basis of the existing stable system [11,14]. The socio-technical landscape is the macro-level which corresponds to the external environment (society's institutions, values and beliefs) that contains and influences the other levels but is not influenced by them. The MLP suggests that transition is the result of the dynamic interaction of processes between the three levels and identifies 5 main pathways for socio-technical transitions (Table 1) [6,13].

Several authors have pointed out the need to extend and incorporate governance, power and agency into the MLP [15–19]. In this setting, transitions are explained as the result of power relations between its actors who have different properties giving rise to social interactions that govern the regime [20]. In response, Foxon, Hammond and Pearson [21] and Foxon [22] defined an

Table 1
Socio-technical transition pathways.

Pathways	Characteristics
Reproduction	The dynamic stability of the regime hinders niche innovations to break through and the system reproduces itself in an incremental process through predictable trajectories.
Transformation	The socio-technical landscape exerts some pressure on the regime, but the early stage of development in niche innovations may not allow them to take advantage of this pressure and may lead the regime to a different pathway of development and innovation areas. The main actors for this pathway are represented by regime actors and outside groups who criticise the established rules and modes of operation.
De-alignment and re-alignment	Sudden and large changes in the landscape may create the existing regime structure to de-align and create a gap that could be filled by different niche innovations that compete to dominate the market and there is eventually a re-alignment of the regime when there is a winner.
Technological substitution	The socio-technical landscape exerts important pressure on the regime, and if there are innovations that have a certain degree of development, they may replace the existing technologies and regime.
Reconfiguration	Niche innovations that present solutions to localised problems in the regime may change the fundamental structure of the regime.