International Knowledge Transfer in Photovoltaic Market Diffusion: Mexico Case Study

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Abstract

During the past two decades solar photovoltaics (PV) has been one of the fastest growing energy technologies with global growth rates at 30-40%/yr. Early markets such as the United States, Germany and Japan have been instrumental in building up a comprehensive body of knowledge and institutions related to PV deployment. This "deployment knowledge" includes various aspects, such as technical codes and standards, local regulations and permit procedures, quality management, knowledge and training of installation firms, learning among utilities, municipalities, banks and insurance companies, as well as knowledge related to business models. This study performed a two-part literature review, first, identification of industry knowledge in order to compile the main elements of deployment knowledge, and second, to investigate established literature on how this knowledge is transferred from lead markets to emerging markets. The chosen case was Mexico, due to its strong growth potential and connectivity with existing markets. The first task was to conduct a network analysis in order to provide a cursory map of major domestic and international actors. From there the goal was to then uncover linkages and characteristics of their relationships, as related to knowledge transfer. Research organizations, trade-shows, collaborative projects and transnational corporations were found to be the main contributors in the Mexican case.

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Acronyms

Clean Development Mechanism	CDM
National Energy Control Center	CENACE
Federal Electricity Commission	CFE
National Commission for Energy Efficiency	CONUEE
Energy Regulatory Commission	CRE
Greenhouse Gases	GHG
International Energy Agency	IEA
International Renewable Energy Agency	IRENA
National Renewable Energy Laboratory	NREL
Photovoltaic	PV
Ministry of Environment and Natural Resources	SEMARNAT
Energy Ministry of Mexico	SENER
Technological Innovation System	TIS
United Nations Framework Convention on Climate Change	UNFCCC

1 Introduction

Over the last 30 years the photovoltaics (PV) industry has experienced rapid growth in lead markets such as the United States, Japan, and Germany (Timilsina, Kurdgelashvili, & Narbel, 2012). During this period, legislative bodies, manufacturers, installers and utilities have developed instrumental knowledge in the successful deployment of this rapid growth energy technology (Solangi, Islam, Saidur, Rahim, & Fayaz, 2011). This "deployment knowledge" includes various elements, such as technical codes and standards, local regulations and permit procedures, quality management, knowledge and training of installation firms, learning among utilities, municipalities, banks and insurance companies, as well as knowledge related to business models (Timilsina et al., 2012). Economic and institutional conditions for solar PV continue to improve globally, resulting in a demand for expansion into new markets and countries (Zheng & Kammen, 2014).

This deployment knowledge takes many years to develop, yet the pressing issue of global climate change remains looming, so international collaboration would immensely propagate the spread of this technology into follower markets, or emerging markets for PV deployment (Zheng & Kammen, 2014). However, despite this transfer of knowledge sounding sensible and simple in theory, the opposite remains true in practice (Blohmke, 2014). While it might make sense for public bodies such as municipalities or utilities to share knowledge with follower market actors, it is not necessarily in the best interest of companies or banks to "give away" their hard-won industry knowledge (Zheng & Kammen, 2014). There remain many barriers such as intellectual property rights, maintaining competitive advantage, fundamental policy differences across borders and financing structures, to name just a few (Solangi et al., 2011). There is a vast need for innovative policies, mechanisms and schemes for knowledge sharing to take place between developed solar markets and emerging nations in order to expand PV into new territories.

Designing a solution for how this knowledge transfer may occur, in a manner that benefits all parties, is certainly challenging. According to the IEA's 2010 Technology Roadmap for Solar PV, they recommend several primary actions to be taken for international deployment to be successful; however, the most important goal is to, "develop new mechanisms to support exchange of technology and deployment of best practices with developing economies," while true, it remains vague and does not provide any specificity on how it may be achieved in a practical sense (IEA, 2010). The development of these mechanisms will be the pivotal turning point for international deployment.

Given the ubiquity of developing PV markets it would best serve the purpose of this study to focus on a particular case where a technology transfer is taking place. Mexico is one of the world's most promising and expanding markets for solar PV, due to a variety of conditions ranging from economic transformation, geographical advantages, proximity to lead firms and a growing electricity demand (GTM Research/SEIA, 2015). For example, SolarCity, the United States' largest residential PV installer with 34% market share (GTM Research/SEIA, 2015), has recently made acquisitions in order to expand into Mexico (SolarCity). Mexico is an ideal region for solar deployment, yet has utilities, municipalities and legislators that are vastly underdeveloped when compared to their U.S. counterparts (Critchley, 2016; Lacey, 2016). This exploration would investigate what knowledge gaps Mexico is facing when it comes to the successful deployment of PV and how existing knowledge from the U.S., international organizations and other lead markets could be transferred and supplement those gaps.

2 Research Design & Methods

In order to better answer the question of why knowledge transfer from lead markets to follower markets remains slow (Zheng & Kammen, 2014), this paper will focus on an active transition, the case of Mexico's solar PV market. To be able to achieve this objective, two core tasks have been identified. The first task will be to conduct a literature review on two major aspects; (1) what constitutes deployment knowledge as relevant to the chose technology- solar PV, and (2) to identify and correlate knowledge transfer channels. The second task will be to perform a preliminary network analysis of actors in the Mexican solar market.

The major elements of solar PV deployment knowledge have been tabulated by fellow researcher Lars Strupeit in a larger working paper on the subject, through a review of literature on how PV is deployed in the field. This paper is meant to augment this large body of work through investigation of literature and a case analysis. For some elements of the identified deployment knowledge, this study relied on deductive reasoning in order to describe elements that were not explicitly named in literature and expand his initial review. For the second aspect, a wide body of knowledge exists on knowledge transfer channels, more oft described as 'technology transfer.' Analytical techniques for identifying and measuring technology transfer vary greatly in their context and application, this paper aims to draw from these various sources in order to compile a framework that can then be applied to the case of emerging solar PV markets.

This network analysis will place a heavy emphasis on connections with U.S. research organizations, lead firms and projects, given geographical proximity and some clear cases. However, the analysis will also attempt to display a connectivity to other organizations both national and international. The network analysis will rely primarily on gray literature, various periodicles, energy news outlets, solar company databases, in order to map the initial nodes and relationships, as this is not a typical focus of peer-reviewed work. The objective is not to tabulate every single actor and company working on solar deployment in Mexico, but rather to display how different actor groups interact and relate to one another, as well as connectivity to international actors. Given this, some specific pivotal players will be named if they have a particular relevance or are able to display contribution to knowledge transfer, and smaller entities may be grouped into general categorizations.

2.1 Study Limitations

At this stage the network analysis was not able to utilize in-depth interviews given time constraints, but will be expanded upon during the subsequent stages of research. Stakeholder interviews will be able to give greater granularity to whether knowledge transfer actually occurred and to what degree. However, at this stage of the research the initial goal is to determine the structure of the network, and uncover patterns of connections, influence, information flow and resource exchange. Later research will also have to determine if this flow is restricted to unilateral exchange, or if there is the existence of bilateral flows as well.

A cursory review has revealed that there is minimal academic literature on the energy transition in the Mexican context specifically (Alemán-Nava et al., 2014). However, there exists many third parties and research organizations that have performed analyses on Latin American solar markets. A significant limitation is that the seminal report on this topic, GreenTech Media's *Latin American PV Playbook* is a subscription based report which was not within the budget of this study. This examination will instead utilize gray literature that draws from GTM's report, primarily authors of the PV Playbook that have written articles on GTM's news outlet that provides part of the dataset, to indirectly supplement this gap. Literature on the knowledge transfer agenda itself is somewhat limited to certain frameworks, not all of which are applicable to this study's objective, and none are geographically specific to the chosen case. This paper will instead take general recommendations and suppositions on how to encourage knowledge transfer and apply it to the Mexican context.

2.2 Research Objective:

To understand the fundamentals of knowledge transfer for photovoltaics from developed to developing nations, as can be applied Mexico's energy transition

Research Question 1: What are the main elements of solar PV deployment knowledge?

Research Question 2: How does knowledge transfer occur internationally between lead markets and emerging markets?

Research Question 3 (Nodes): Who are the primary domestic actors? What international actors are involved?

Research Question 4 (Ties): How is PV deployment knowledge transferred between these actors (nodes)?

3 Literature Review

This section will aim primarily to define what deployment knowledge is, as well as identify mechanisms or channels in which knowledge transfer occurs. The identification of deployment knowledge will be technologically-specific to the case of solar PV, while the latter utilizes literature general to clean tech, as all types of clean technology are transferred in more or less similar ways by utilizing many of the same policies, channels, institutions and frameworks. From this review, a typology will be created specific to transfer channels for solar PV, in order to provide clearer context for the subsequent network analysis. Obtained literature was found using common industry keywords and terms such as 'technology transfer', 'knowledge transfer', 'deployment knowledge', 'learning curve', 'experience curve', 'emerging market', 'solar market', as well as other synonymous variations and combinations of above. As often as possible, terms such as 'clean tech', 'solar', or 'photovoltaics' were added in order to keep literature relevant and applicable.

3.1 Deployment Knowledge

As aforementioned, deployment knowledge covers a wide range of aspects and competencies as relevant to solar PV development. This paper will not focus on the transferrance of technical and R&D knowledge related to the manufacturing of PV hardware, as there already exists a large body of knowledge on this topic and there is not as large a need for further research (De la Tour et al. 2011). Also, given the nature of technical knowledge, replicability is often easier to accomplish from one market to another through mechanisms such as licensing or training. Instead, this study will focus on 'soft' aspects, as opposed to hardware, such as business models and partnerships, financial markets and institutions, pilot projects and manufacturing clusters, social prerequisites and conditions, and regulatory regimes; as there is a greater knowledge gap on how these components can be transferred from one market to another, complimenting the goals of the subsequent network analysis. For the sake of cogency and completeness, technical deployment knowledge has still been identified at this stage, but will be mostly excluded from the Mexican case analysis. The below table was compiled through review of a diverse set of articles, both academic and industry gray literature, related to PV deployment, and used deductive reasoning in order to tabulate the knowledge sources seen below so they may be presented in a succinct format.

Codified Knowledge	Technical	Legal & Policy	Knowledge & Skills	Business & Financial Acumen
climate data, solar insolation mapping	orientation of the module pane and assessment of potential shading effects	support schemes for market creation	skills for operation and maintenance	customer acquisition strategies
knowledge and information for building owners	technical configuration of PV system components	technology standards related to PV hardware components	competence and learning among financers	business model design
patents	attachment or integration into the building shell	rules related to the grid connection	competence and learning among insurers	marketing strategies
	integration into the electricity grid	rules related to building law	installation and quality management standards	financial support structures
		tax laws, such as income tax, trade tax and value-added tax	managerial techniques and procedures	

Table 1. Deployment Knowledge summary (Strupeit, 2016)

3.2 Knowledge Transfer Mechanisms

Literature on innovation in developing and emerging economies has three main strands that cover the role of transnational framing of technology (Gosens, Lu, & Coenen, 2015). Gosens et al.'s focus is to use this literature for the development of the Technological Innovation System (TIS) framework, which is a popular academic tool for the study of innovation in clean-tech. Work on TIS usually does not include an international technology transfer dimension, and Gosens et al. underarching objective was to fulfill this gap and add it to the TIS framework. Due to this framing, Gosens et al.'s work is the seminal paper of this study, given its clarity and direct applicability, and will be used as the primary framework for categorizing knowledge transfer flows to then be used in the network analysis case of Mexico's solar PV market. Gosens et al. drew upon three literary strands in order to compile transnational TIS actor networks and institutions. The three strands are as follows; the first surrounds the innovative activity in emergying economies, or how well countries are able to incorporate foreign technology into the national system i.e. 'absorptive capacity'. The second is on international technology transfer, which focuses on institutions and the role of government related to transnational linkages. Lastly is literature on Global Production Networks, which is centered on the innovative capacity at the level of the firm. These schools of thought were used to frame both the categorization of deployment knowledge in the preceding section 3.1, as well as to formulate Gosens et al.'s identified international transfer channels, which are summarized below.

Transfer Mechanism/Channel	Keyword Description
International scientific cooperation	scientific publications, patents or R&D projects
Global mobility of skilled personnel	human capital: international university exchanges or transnational hiring of individuals
Transnational corporations	foreign direct investment, subsidiary firms, join ventures with domestic partners, or lastly relocation decisions of manufacturing, R&D activities or skilled personnel
Global production networks	technical and managerial knowledge transfer on the production process
Global equipment markets and market competition	complimentary products, component manufacturing
Global technology markets	licensing, patents, manufacturing designs
Private and institutional financiers	Global Environmental Facility (GEF), World Bank, IMF and Regional Development Banks, pairing project financing with technical assistance
Global industry platforms and environmental groups	organizational networks for knowledge exchange
World Trade Organization & TRIPS	reduction of trade barriers and non-discrimination
International environmental regimes	global sustainable development, international project cooperation
Institutional transfer programs	bilateral aid, Clean Development Mechanism
Technological standards and certification	performance conformity, product safety, processes, interoperability

Table 2. Summary of transnational dimensions of clean-tech under Technological Innovation System framework (Gosens et al., 2015)

Gosens et al.'s work is by no means exhaustive as related to the transfer of deployment knowledge of solar PV, and not all of the identified mechanisms are directly applicable. This is merely meant to be used as a starting point given the study's comprehensiveness. For example, other studies focus on typical innovation capacity measures like number of registered patents or patent citations and R&D investment (Verdolini & Galeotti, 2011). Another widely-used, accessible and accepted metric is the influence of scientific literature (Hassan & Haddawy, 2015). While these are both established methods due to data accessibility and quantitative measurability, neither fully encapsulate the full image of knowledge transfer (Nemet, 2006). Focusing solely on imperfect representations such as patent citations neglects factors such as "learning by doing," which generally increases productivity and diffusion (Verdolini & Galeotti, 2011). Established literature generally categorizes 'technology transfer' into three classes; capital goods, know-how and skills for operation and maintentance, and skills and knowledge for further development (Blohmke, 2014). Other analyses focus on specific initiatives designed for technology transfer, most commonly the Clean Development Mechanism, as was performed by Lema & Lema, 2016.

There are many factors that affect the effectiveness of knowledge transfer, such as geographical proximity, which heavily contributes to the diffusion process, as there is a higher probability of learning the shorter the distance between entities (Verdolini & Galeotti, 2011). Linguistic similarities, trade block relations, and parallels in the technological space also ease the flow between countries (Verdolini & Galeotti, 2011). Technological complexity of PV, mainly of the solar cells, is a context-specific influencer on knowledge transfer, as the intricateness, continual improvement and prerequisite for highly skilled specialists represent a significant barrier (Blohmke, 2014). However, once there is an emergence of a dominant design (product architecture and core systems), innovation becomes focused on sub-systems and components (Huenteler, Schmidt, Ossenbrink, & Hoffmann, 2015). In this instance, sub-systems and components of PV modules are often interrelated to deployment knowledge (e.g. brackets, mounting systems, inverters, grid ties etc.). The manufacture of complimentary components represents an opportunity for spillover between industrialized countries and renewable energy technology adopting countries (Blohmke, 2014).

4 Network Analysis

4.1 Background – Mexican Energy Policy and Economy

Mexico is a highly prominent player in the growing solar PV industry, with one of the most accessible growth markets in the world, ranked No.1 for distributed generation in Latin America, and is one of the few countries in the world that has reached grid parity without subsidies (James, 2015; GTM Research/SEIA, 2015; Chavez, 2015; Montgomery, 2013). The country contains an abundance of diverse renewable energy resources, has a growing demand for power in all sectors, is macroeconomically stable, all while retaining historically high electricity prices, making it one of the most attractive markets for investment (Chavez, 2015). To date, Mexico has relied heavily on oil production as the largest share of national tax revenue, and only in 2012 did natural gas pass petroleum as the primary provider for fossil fuel electricity generation, with electricity generation from all fossil fuel resources comprising 78% of capacity in 2014 (EIA, 2015; Aléman-Nava et al. 2014). This heavy national dependence on the oil industry could be a contributor to why solar deployment hasn't occurred as rapidly as projected (IRENA, 2015). However, as of August 2014, Mexican President Enrique Peña Nieto enacted a massive reform of the country's energy laws and policy, with the most notable change being the partial deregulation of Federal Electricity Commission (CFE), the state-owned monopoly national regulator and distributor of electricity (Laursen, 2014). Under the new laws private companies will be able to bid for access to the grid and compete for clients as opposed to being required to sell all power directly to the utility. CFE hopes that the increased level of competition will lead to lower energy prices.

4.2 Mapping of Network Actors

In order to better answer Research Questions 3 and 4, this studied aimed to provide a basic network map of actors in Mexico's solar industry. This was conducted primarily through an online review of media sources to understand who the main players are. In some cases specific companies were selected to be representative to their group categorizations, given their prominence in the market or news, as well as their potential to be facilitators in deployment knowledge transfer. The objective at this stage was not to highlight every single organization, producer or installer in the industry but rather give a representative overview of how knowledge flows through the system. An investigation was launched into ENF's international solar company database, however the granularity was almost too high in order to make useful suppositions for the discussion, but was rather used as a supplementary guide (ENF Ltd.) Below the network map are descriptions of some of the key actors and organizations and their role in the Mexican solar market and industry.

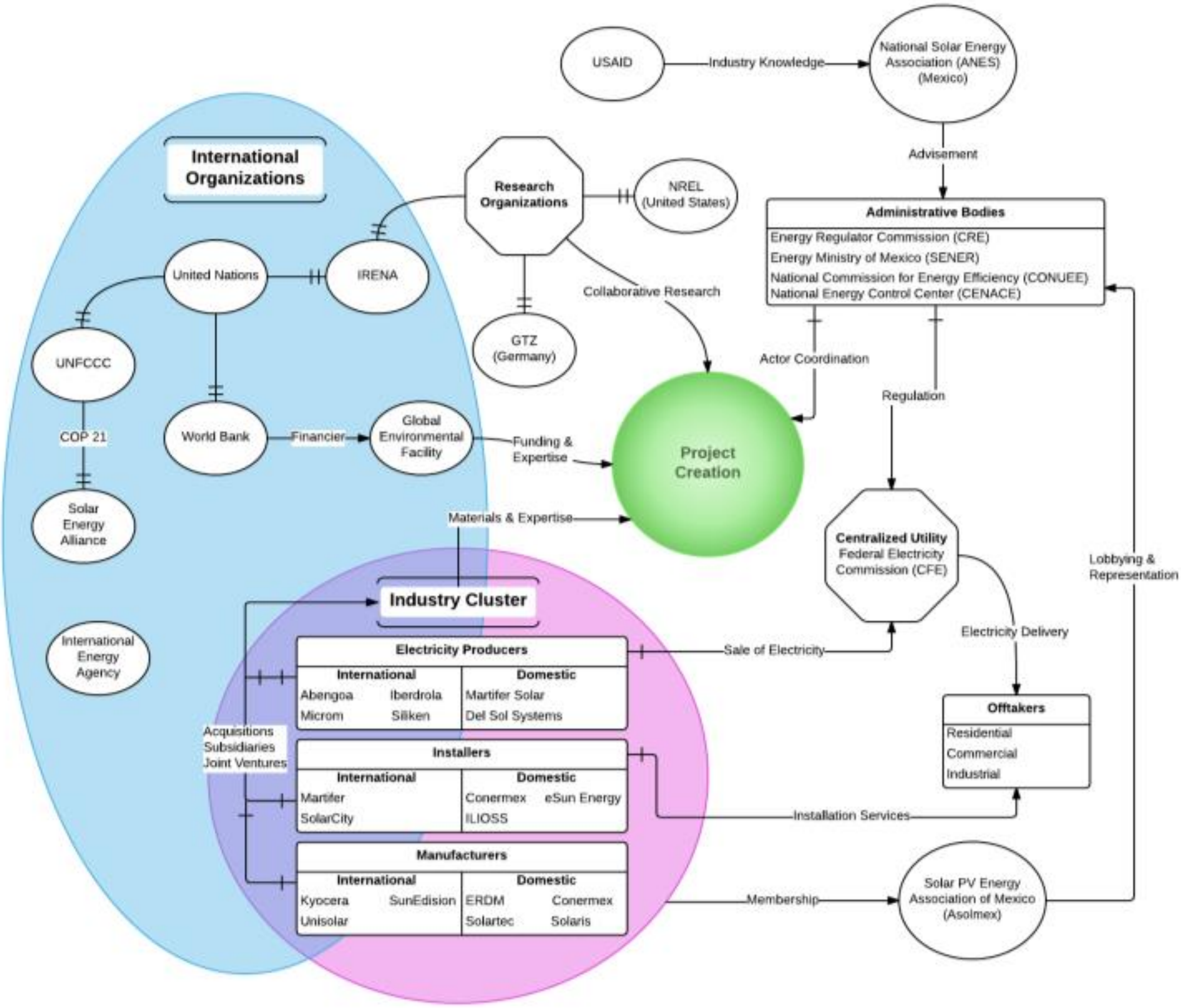

Figure 1. Network analysis of key domestic and international actors in the Mexico solar industry

Mexico employs a monopolized electricity market, with a single centralized utility, the Federal Electricity Commission (CFE). The CFE is the focal point for all power contracts, purchasing all power from electricity producers and installers and selling it to offtakers in the residential, commercial and industrial sectors.

The Energy Regulatory Commission (CRE) is responsible for the drafting of all laws, regulation and energy policy. In 2008 they passed the National Law for the Use of Energy from Renewable Sources and Financing the Energy Transition, along with the Law for Sustainable Use of Energy (Mundo-Hernández et al. 2014). The two laws highlight the importance of transitioning away from Mexico's historical dependence on fossiul fuels towards renewable sources and clean tech.

Mexico also has an energy ministry (SENER), which is responsible for providing energy services while ensuring that CFE acts in an energy efficient and environmentally-reponsible way. The are also meant to provide quality management and ensure the the electricity systems functions reliably and productively, and promotes innovation in the energy sector.

The national energy control center (CENACE) is geared more towards technical issues and regulating the power grid itself, setting interconnection standards, monitoring electricity flows and power plants, and overseeing the transmission and distribution networks (CENACE website).

Mexico is also home to Asolmex, a solar power association of professionals and businesses, brings together operators, suppliers, investors, and developers of solar PV, in order to represent them to the above regulatory bodies (Asolmex website). Organizations such as Mexico's solar energy association (ANES) and the solar power association Asolmex lobby for private firms and ensure that the Energy Regulatory Commission, national energy control center, and even the energy ministry act as watchdogs to curb the CFE's monopoly (Tippett, 2014).

4.3 Knowledge Transfer

Channels and mechanisms for the transfer of knowledge manifest in many different forms. To date, most literature and international policy mechanisms have focused on how technology can be transferred from one market to another, leading to schemes such as the Clean Development Mechanism (CDM) which is a well-known structure for enabling transferrance from industrialized to developing nations (Lema & Lema, 2016). However, this paper looked to expand this scope and look at how non-technical knowledge can be moved across borders in order to induce technological uptake and diffusion. Therefore, I define *knowledge transfer*, as related to clean-tech and in this case solar photovoltaics specifically, as, "channels, mechanisms, or institutions that promote or allow for knowledge related to the implementation or diffusion of technology to be transferred and shared from one nation or market into another."

In an attempt to further condense the varying techniques of analyizing technology/knowledge transfer from the Literature Review, especially Gosens et al.'s comprehensive approach, apply it to the solar PV context, all while connecting it back to the defined deployment knowledge in *Table 1*, possible channels of international deployment knowledge transfer have been identified below. This list is by no means comprehensive and should be complimented by further investigation and refinement.

Information	Organizations	Initiatives	Other
Software for planning	Internationally operating banks	International research projects on PV deployment	Mobility of skilled personnel
Books	Internationally operating producers of PV hardware	International initiatives for education and vocational training of staff at installation firms	Online resources & databases
Trade journals	International solar associations	Networks, meetings, trade fairs, and other events	Global trade policy
Knowledge embodied in technology (PV hardware) that is traded internationally	Internationally operating installation firms	Collaborative pilot projects, joint ventures	
Patents, manufacturing designs	National solar associations as knowledge brokers and national focal points	International standard setting and certifications	
Module component outsourcing	Global sustainable development organizations		

Table 3. Solar PV knowledge transfer channels and mechanisms (Strupeit, 2016, Gosens et al. 2015)

4.4 Network Relationships

In this section examples of linkages between the defined actors will be discussed, which will then be connected back to the categorized deployment knowledge from section 3, and knowledge transfer channels from section 4.3. The objective here is to display real examples of knowledge transfer under the created framework of channels and mechanisms.

The clearest example of knowledge transfer is the collaborative project between Mexico's main energy and environmental authorities, CFE, CONUEE, SENER and SEMARNAT, with the Deutsche Gesellschaft für Technische Zusammenarbeit GmbH (translated; German Technical Cooperation, German Federal Ministry for Economic Cooperation and Development), henceforth referred to as GTZ (Mundo-Hernández, De Celis Alonso, Hernández-Álvarez, & De Celis-Carrillo, 2014). The collaboration project, called "Sustainable Energy in Mexico", began in 2009 and completed in 2013 with a stated objective to improve the conditions for the uptake of energy efficiency and renewable energy resources (GTZ website). The program had three focal activities; to establish a legal and regulatory framework, design and implement promotion and dissemination programmes, and create training services and raise awareness. GTZ has claimed that they have achieved results in creating a knowledge and interaction platform, technical quality specifications for PV systems, improved monitoring, certifications for specialists, and a committee for solar professional training.

In addition, NREL, the United States research authority for renewable energy, designed a Renewable Electricity Grid Integration Roadmap for Mexico. The advisory study included a diverse set of recommendations varying from grid interconnection, demand management, portfolio development, and operational best practices. One of NREL's key goals was to help establish a market for clean energy certificates, which is now a component of the ongoing energy reform started in 2014, and is a strong and clear indicator that knowledge is being transferred to Mexican authorities (NREL, 2015; Chavez, 2015).

A similar case exists with IRENA, which is an "intergovernmental organization that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international cooperation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy" (IRENA, 2015). IRENA created an independent Renewable Energy Roadmap for 2030 in coordination with SENER, CRE, CFE, as well as other industry leaders such as SunEdison and the Global Institute for Sustainability. Climate data on insolation provided by IRENA and other international agencies identify the ideal regions within Mexico for siting PV, and according the growth of large scale developments in the northern and central states, project developers seem to be acknowledging this public information provided by international actors (Lacey, 2016).

ANES has also jump started an initiative to provide national market statistics, with the support of the United States Agency for International Development (USAID). The two entities have jointly constructed a survey to be sent to installers and manufacturers all across Mexico (Epp, 2014).

As displayed by these four cases, research organizations seem to be principle agents for facilitating knowledge transfer and coordinating international and domestic actors. Research organizations often host nternational events, which are also a prime channel for knowledge to take place, and Mexico City just recently hosted Green Tech Media's Solar Summit, where industry leaders from all sectors from around the globe take part in discussions and exchange information (Critchley, 2015). Mexico was also a recent host of SolarPlaza, a private company focused on organizing international high-level conferences and exploratory trade missions in both established and emerging markets across the globe (SolarPlaza). The 2015 event in Mexico City brought a variety of interntional actors into Mexico's domain, global finance giants such as Deutsche Bank, national solar companies like Canadian Solar, and solar specialists like Exosun, integrating with local energy associations, VC funders and installers.

Solar PV is a mass-produced good, meaning it has a relatively simple product architecture but requires large scale production processes. PV technology encountered many product innovations early in its innovation life-cycle, but is now facing a surge of process innovations, especially in cell production (Huenteler et al., 2015). The manufacture of solar cells and modules represent a significant opportunity for Mexico, as lead firms often seek to our-source labor intensive production, and emerging economies such as Mexico are often advantageous in this regard with access to low cost labor (Gosens et al. 2015). Some of the most easily identifiable knowledge transfer channels are business partnerships, acquisitions, and projects, due to their announcement across media sources. For example, BP Solar entered a partnership with Jabil for panel assembly and manufacture, who also manufactures panels for SunPower (Sustainble Business, 2010). SunEdison has partnered with Foxconn to also make the move into manufacturing in Mexico (SolarReviews, 2013). Other international firms such as Kyocera and Unisolar already have production sites in Mexico, and there are a variety of domestic players like Solartech, ERDM and Conermex as well (Mundo-Hernández et al. 2014; ENF Ltd.). However, Kyocera and Unisolar's production is for export market only, and Mexico does not have a clear industrial cluster for PV (such as Silicon Valley for IT), so the level of knowledge transferrance is uncertain (Critchley, 2016). Yet a favorable environment exists, the mere movement and concentration of international firms into the country is nearly self-evident, and as previously defined if mobility of employees occurs between companies, skills and knowledge will most likely follow. While manufacturing is not directly related to the deployment or diffusion of solar PV systems in Mexico itself, the proximity of manufacturing firms has been shown to increase the likelihood in the uptake of technology, as the connection between manufacturing R&D activity and market demand creates a positive feedback loop (Zheng & Kammen, 2014). Beyond manfacture other industry movements have begun to occur, as SolarCity recently acquired ILIOSS, a local installer, beginning a move into Mexico's commercial and industrial markets (SolarCity website).

A massive improvement in global policy came with the signing of the Cancun Agreements under the UNFCCC, in Mexico itself in 2010. The agreements establish a new institutional technology transfer architecture under the Technology Mechanism, which will facilitate the development and transfer of climate mitigation technology at all stages of the technology cycle, from R&D to demonstration, deployment, diffusion and transfer. This new Technology Mechanism goes beyond the Clean Development Mechanism framework, which focuses on hardware import, and has been viewed as a "climate first" approach, meaning that the goal is rapid reduction of GHG emissions, whereas the Technology Mechanism is a bottom-up approach focused on sustainable development and technology transfer (Blohmke, 2014). Global sustainable development organizations oft play a large role in the transfer of deployment knowledge of technology by facilitating projects (financing, removing regulatory barriers, etc.) and organizing and coordinating actors.

5 Discussion

Despite being a cursory analysis, one can see several trends begin to emerge on knowledge transfer from the chosen case study. Research organizations seem to hold a central role in the dissemination of deployment knowledge. This is likely due in part to their nature as information flagships for the industry and they benefit from their ability to partner and share information. Part of their underlying objectives and vision is to spread the uptake of renewable energy sources and technologies, further propogating their ability to maneuver and spread deployment knowledge. From the uncovered examples, they seem to achieve this through several mechanisms. The most common is through research reports, which can either be put forth of their own accord, or through contracting by a local entity calling for the analysis as was the case with NREL. This is often distributed as public information, in order to have it reach as many relevant parties as possible. A similar but separate mechanism is official advisement service, as between GTZ and the Mexican energy authorities. The final mechanism is trade shows and international events, which provide an informal setting for domestic and international actors to meet and exchange knowledge.

Private arena actors also seem to be the other key mover of knowledge. As described in the Gosens et al. study, transnational corporations transfer knowledge in a myriad of ways, foreign direct investment, subsidiary firms, joint ventures with domestic partners, and relocation decisions of manufacturing, R&D activities or skilled personnel. In Mexico we saw indication of all of these, Martifer, an international firm, with a solar division with a presence in Mexico, acquisition of a local installer by SolarCity, SunEdison relocating manufacturing, and a plethora of joint development projects. As people are one of the key retainers of industry knowledge, their mobility amongst the industry is likely to have one of the largest effects on knowledge transfer.

The final example was centered around global initiatives, specifically the Clean Development Mechanism and the new Technology Mechanism under the UNFCCC. As described before the CDM was not particularly focused on facilitating knowledge transfer, but several studies have investigated its ability to do so (Lema and Lema, 2016). However, it seems that with the development of the Technology Mechanism at the Cancun Agreements, this is becoming more of a priority among global sustainable development organizations, as it embeds capacities into emerging renewable energy markets which will propogate and enable further sustainable development.

Further research could focus on particular aspects of the study. First would be to either further hone the aspects of solar PV deployment knowledge or the channels and mechanisms for knowledge transfer. Analysis techniques for knowledge transfer vary in number even greater than the channels and mechanisms it employs, however it is clear that a focus on the transnational element is still seriously lacking in existing literature. The typology created by this study is fairly comprehensive, however its structure could be improved to better represent the concept. The three main avenues chosen; Information, Organizations and Initiatives are clear, however the typology needs to be improved in order to remove the Other category. The second area of future research would be to collect qualitative data from the identified domestic stakeholders in order to investigate if deployment knowledge was transferred and how they came to receive. This would give increased support to some of the preliminary suppositions made from the chosen examples and give real insight into how knowledge is transferred in practice, and to what degree of success.

6 Conclusion

The main elements of solar PV deployment knowledge are likely the most easily identifiable portion of this study. Deployment knowledge encapsulates technical aspects, regulation, standards, and industry learning across many stakeholder groups. This study focused on particular types of deployment knowledge given data availability and the stated objective to focus on 'soft' aspects, however the evolvement of deployment knowledge is bound to change as institutions and stakeholders continue to learn. Knowledge transfer mechanisms are harder to identify and correlate, and extensive research is required to validate their varying degrees of success.

International knowledge transfer seems to be centered around organizations that are focused on facilitating it, but transnational corporations have a huge role to play here as well.

Given the structure of Mexico energy market, key domestic stakeholders were easy to identify, as there is only a singular utility, as well as a minimal amount of federal agencies that oversee its function. International stakeholders and domestic firms were more difficult to identify given their extent. By focusing on key firms and prominent players this issue was somewhat mitigated. This also gave insight into who may be contributing to the transfer of knowledge. The Mexican solar PV market is certainly expanding and is poised to continue growing, as evident from the number and diversity of firms moving into the region. From this initial investigation into the Mexican solar industry, research organizations and projects, trade fairs, collaborative projects and transnational corporations seem to be the main facilitators and contributors to the transfer of knowledge. From a global community perspective there also seems to be movement towards a focus on the importance of knowledge transfer into developing nations/emerging markets, as evidenced by the Cancun Agreements and the newly created Technology Mechanism.

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